DRAFT PLAN
AND
ENVIRONMENTAL ASSESSMENT

for

Mosquito Control
for
Bandon Marsh National Wildlife Refuge

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Glossary of Terms and Abbreviations, Acronyms, and Initialisms

Action Threshold. Mosquito population levels that trigger integrated pest management (IPM) actions to manipulate mosquito populations.

Adulticide. Killing adult mosquitoes or a pesticide that kills adult mosquitoes.

Arbovirus. Arthropod-borne virus. A viral disease carried and transmitted by mosquitoes or other arthropods.

Biological Diversity. The variety of life and its processes, including the variety of living organisms, the genetic differences among them, and communities and ecosystems in which they occur. (See 601 FW 3 for more information on biological diversity.)

Biological Integrity. Biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic conditions, including the natural biological processes that shape genomes, organisms, and communities. (See 601 FW 3 for more information on biological integrity.)

Biorationals. Third-generation pesticides that are environmentally sound and closely resemble or are identical to chemicals produced in nature such as by bacteria and viruses.

BMPs. Best management practices

Bti. *Bacillus thuringiensis israelensis* is a bacterial toxin that is a variant of the common soil bacterium *Bacillus thuringiensis*. *Bti* has insecticidal activity against mosquitoes, black flies, and certain species of midge.

CCP. Comprehensive Conservation Plan

CCPH. Coos County Public Health

CD. Compatibility determination

CDC. Centers for Disease Control and Prevention

CEQ. Council on Environmental Quality

Competence (mosquito). The relative ability of a mosquito species to carry and transmit virus.

CWA. Clean Water Act (33 U.S.C. 1251-1387)

Environmental Assessment (EA). A concise public document, prepared in compliance with the National Environmental Policy Act, that briefly discusses the purpose and need for an action, alternatives to such action, and provides sufficient evidence and analysis of impacts to determine whether to prepare an environmental impact statement or finding of no significant impact (40 CFR 1508.9).

EBV. Epstein-Barr virus

EEC. Estimated environmental concentration

Environmental Health. Composition, structure, and functioning of soil, water, air, and other abiotic features comparable with historic conditions, including the natural abiotic processes that shape the environment. (See 601 FW 3.)

Enzootic. A relatively consistent prevalence of disease in animals. The term is comparable to endemic, but refers to animals.

EO. Executive order

EPA. Environmental Protection Agency

Epizootic. An outbreak of disease affecting many animals of one kind at the same time; also, the disease itself.

ES. Ecological Services Program

ESA. Endangered Species Act (16 U.S.C. 1531-1544)

Finding of No Significant Impact (FONSI). A document prepared in compliance with the National Environmental Policy Act, supported by an environmental assessment, that briefly presents why a federal action will have no significant effect on the human environment and for which an environmental impact statement, therefore, will not be prepared (40 CFR 1508.13).

Health Threat. An adverse impact to the health of human, wildlife, or domestic animal populations from mosquito-borne disease identified and documented by federal, state, and/or local public health authorities. Health threats are locally derived and are based on the presence of endemic or enzootic mosquito-borne diseases, including the historical incidence of disease, and the presence and abundance of vector mosquitoes. Health threat levels are based on current monitoring or vectors and mosquito-borne pathogens. We refer to “adverse impact” in terms of non-disease health impacts to humans from mosquito bites (see Section 1.3.1).

Integrated Marsh Management (IMM). IMM involves a holistic approach to mosquito control and wetlands management utilizing a variety of applied management techniques to achieve multiple site-specific goals. IMM takes into consideration the many aspects of wetland management, including mosquito control, vegetation management, wildlife habitat enhancement, hydrologic modification, and wetland restoration.

Integrated Pest Management (IPM). A sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks.

Larvicide. Killing mosquito larvae, or a pesticide that kills mosquito larvae.

MAD. Mosquito Abatement District

Methoprene. Synonymous with S-methoprene in this report. A synthetic insect juvenile growth hormone that interferes with insect development, resulting in death.

Monitoring (mosquito). Activities associated with collecting quantitative data to determine mosquito species composition and to estimate relative changes in mosquito population sizes over time.

Mosquito management. Any activity designed to inhibit or reduce populations of mosquitoes in the family Culicidae. It includes physical, biological, cultural, and chemical means of population control directed against any life stage of mosquitoes.

Mosquito-borne disease. An illness produced by a pathogen that mosquitoes transmit to humans and other vertebrates. The major mosquito-borne pathogens presently known to occur in the United States that are capable of producing human illness are the viruses causing eastern equine encephalitis, western equine encephalitis, St. Louis encephalitis, West Nile encephalitis/fever, LaCrosse encephalitis, and dengue, as well as the protozoans causing malaria.

NEPA. National Environmental Policy Act (42 U.S.C. 4321-4347)

NOAA Fisheries. National Oceanic and Atmospheric Administration – Fisheries.

Non-target Organisms. Species or communities other than those designated for population control.

NPDES. National Pollutant Discharge Elimination System established by Section 402 of the Clean Water Act.

NWRC. National Wildlife Refuge Complex

NWRS. National Wildlife Refuge System.

ODEQ. Oregon Department of Environmental Quality

OSU. Oregon State University

ppt. Parts per thousand

ppb. Parts per billion

Preferred Alternative. This is the alternative determined (by the decision maker) to best: achieve a refuge's purpose(s), vision, and goals; contributes to the Refuge System mission; addresses the significant issues; and is consistent with principles of sound fish and wildlife management.

Public Health Authority. A federal, state, and/or local agency that has health experts with training and expertise in mosquitoes and mosquito-borne diseases and that has the official capacity to identify human health threats or adverse impact and determine health emergencies.

PUP. Pesticide Use Proposal.

PUR. Pesticide Use Report.

Refuge-Based Mosquitoes. Mosquitoes that are produced within, or occur on, a refuge.

Refuge System. National Wildlife Refuge System

Reservoir Host. A species in which a pathogen is maintained over time. Reservoir hosts are capable of transferring the pathogen to a vector.

RQ. Risk quotient

SBG. Single brood granule

Service. United States Fish and Wildlife Service

Service-Authorized Agent. A contractor, cooperating agency, cooperating association, refuge support group, volunteer, or other party working on refuge on behalf of the Service to help achieve refuge the purpose(s) or NWRS mission.

S-methoprene. Synonymous with methoprene in this report. A synthetic insect juvenile growth hormone that interferes with insect development, resulting in death.

SUP. Special use permit

Surveillance (mosquito-borne disease). Activities associated with detecting pathogens causing mosquito-borne diseases, such as testing adult mosquitoes for pathogens or testing reservoir hosts for pathogens or antibodies.

USFWS. United States Fish and Wildlife Service

Vector. An organism, such as an insect or tick, that is capable of acquiring and transmitting a disease-causing agent, or pathogen, from one vertebrate host to another, or the act of transmitting a pathogen in such a manner.

WNV. West Nile Virus.

Chapter 1. Purpose and Need for Preferred Alternative

1.1 Introduction

In 2011, the U. S. Fish and Wildlife Service (USFWS or Service), a team of cooperators, and experts in the field of Oregon tidal marsh ecology and restoration completed a 420-acre tidal marsh restoration project on the Ni-les'tun Unit of Bandon Marsh National Wildlife Refuge (NWR or Refuge). The restoration project involved, in part, the alteration of 11 miles of shallow drainage ditches by discing, filling 4 miles of larger ditches, and construction of 5 miles of new sinuous tidal channels (Figure 1-1). A large portion of the perimeter dike was lowered and three water control structures were removed adjacent to the Coquille River to allow for full tidal flow across the historic and newly restored tidal marsh. After construction, depressions that hold water during low tides remained in many of the shallow ditches that were disced, along some large ditches where the fill settled, and along tracks left by heavy equipment. Monthly high tides fill many of the depressions and retain water long enough to permit salt marsh mosquitoes (*Aedes dorsalis*) time to complete their development before drying or the next tidal flushing. This created ideal breeding conditions for the salt marsh mosquito and has resulted in unprecedented, and what the Service considers unnatural, mosquito production on the Refuge.

In summer 2012, refuge staff noted an increase in mosquito numbers within the newly restored salt marsh habitat and received several telephone calls and one letter describing increased mosquito numbers from landowners directly across the river from the Ni-les'tun Unit. In the fall of 2012, refuge staff began coordinating with Coos County Public Health (CCPH) concerning the complaints of increased mosquito numbers. Mosquito Abatement Districts (MAD), also known as Vector Control Districts, are the public entities that conduct mosquito monitoring, surveillance, and control activities across the country on public and private lands, including on National Wildlife Refuges where special use permits (SUP) have been issued for these activities. Coos County does not have a MAD. Refuge staff began detailing funding needs for Service-led inventory and monitoring of mosquitoes.

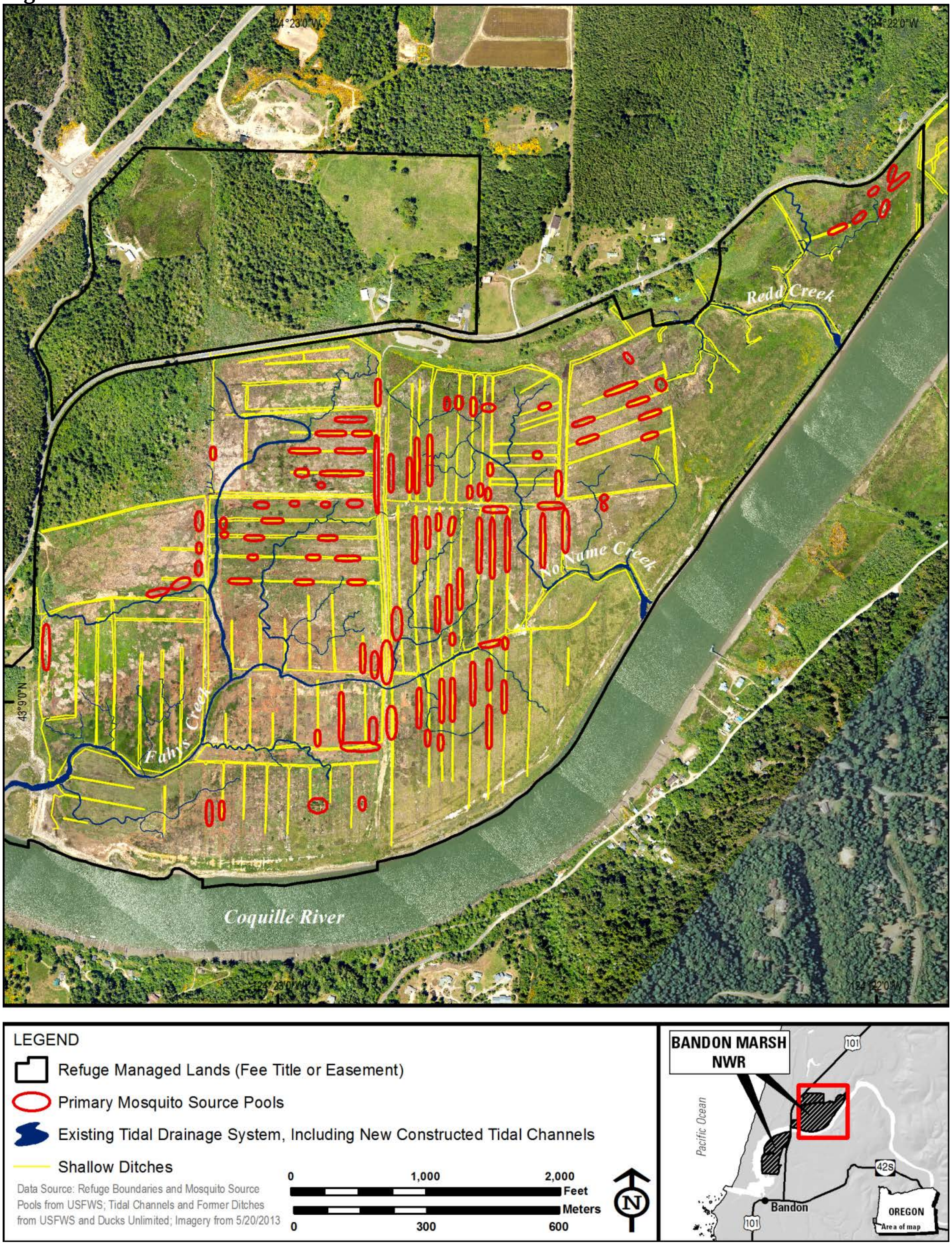
During the winter of 2012–2013, refuge staff began discussions regarding mosquito inventory and monitoring needs on the Refuge with the Oregon Mosquito and Vector Control Association and private vector control managers. Discussions continued with CCPH concerning inventory and monitoring needs on refuge lands. In the spring of 2013, refuge staff coordinated with the Centers for Disease Control and Prevention, Oregon State Health Department, U.S. Geological Survey, and mosquito research organizations, but failed to locate outside funding for inventory and monitoring of mosquitoes. Instead, the Service established a volunteer agreement with Oregon State University's Entomology Department to begin inventory and monitoring of mosquitoes on the Refuge.

Beginning in June 2013, the local mosquito population grew tremendously, reaching levels unprecedented in recent decades according to local residents. On June 27, 2013, refuge staff and Oregon State University (OSU) began biweekly monitoring of mosquito larvae and adult abundance and species identification on the Bandon Marsh and Ni-les'tun Units of the Refuge (Figure 1-2). The monitoring and species identification were coordinated with the Multnomah County Health Department and Benton County Health Services due to the lack of a Mosquito Abatement/Vector Control District in Coos County. The mosquito species identified by the Multnomah County Health Department and refuge staff at the Refuge in 2013 were *Aedes dorsalis*, *Aedes sticticus*, *Aedes* *cinereus*, *Culiseta particeps*, and *Culex tarsalis*. Of the five species of mosquitoes present, about 90% of the mosquitoes sampled were the "summer salt marsh mosquito" (*Aedes dorsalis*), making this species the target of management. Shallow pools of water filled by the highest tides of each month were found to be providing breeding habitat for salt marsh mosquitoes at extremely high levels. Late July mosquito sampling following the monthly high tide series found larvae in great abundance in nearly every pool on the Ni-les'tun Unit south of North Bank Lane. The larvae sampling at this time indicated that another major fly-off of salt marsh mosquito adults was forthcoming. Adult trapping data confirmed that large numbers of adult females were using the restored tidal marsh as a breeding site and dispersing to adjacent habitats on the Refuge and nearby private lands.

Beginning in June and continuing through August, Service offices in Bandon, Newport, and Portland received numerous complaints via phone, email, letter, and in-person from local citizens. Most of the complaints came from residents within a 1.25-mile radius of the Refuge, but some were business owners and/or residents from more distant areas. Citizens complained of not being able to go outside for most of each month during this period without being overwhelmed by large numbers of aggressively biting mosquitoes. The Service also received reports of local residents, including children, as well as some domestic animals, needing medical attention due to allergic reactions to numerous bites.

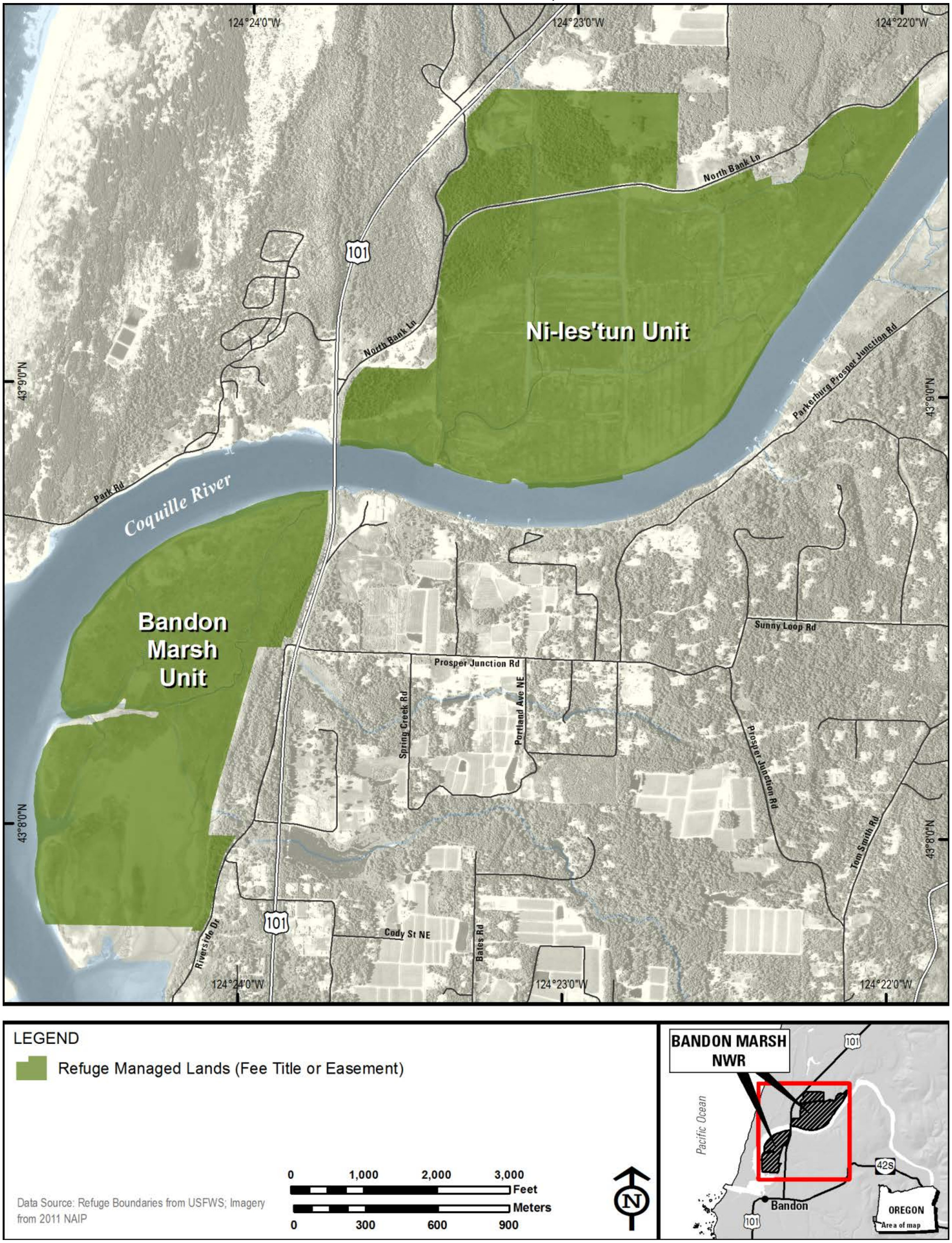
On August 19, 2013, the City of Bandon passed Resolution 13-21 (City of Bandon 2013), demanding action for immediate and effective mosquito abatement to protect public health, safety, and welfare of residents and visitors to Bandon. On August 22, 2013, CCPH issued a Health Advisory for excessive mosquito numbers. On August 26, 2013, in concurrence with the National Wildlife Refuge System Administration Act of 1966 as amended (668dd[k] Emergency power), the Project Leader for the Oregon Coast National Wildlife Refuge Complex (NWRC) made an Emergency Declaration due to the deleterious effects to the public from the excessive mosquito production on the Ni-les'tun Unit of the Refuge . Following the Emergency Declaration, a SUP was issued to CCPH allowing the use of specific pesticides on the Refuge for mosquito control. Following a public meeting and consultation with mosquito control experts, CCPH released a Draft "Proposal for Mosquito Control on the Bandon Marsh Refuge and Surrounding Area" to inform the public and obtain approval from the Coos County Board of Commissioners to implement the plan (Coos County Public Health 2013). Ultimately, CCPH selected the larvicide S-methoprene (trade name MetaLarv S-PT) to apply to a designated area of the Ni-les'tun Unit tidal marsh to prevent larval mosquitoes present on the Refuge from maturing into adults. S-methoprene (synonymous with methoprene in this document) interferes with the larval insect's maturation stages, preventing the insect from transforming into the adult stage, thereby precluding additional flying and biting mosquitoes (Henrick 2007). The aerial application of the larvicide was conducted on September 12, 2013 over 292 acres of the Refuge at the rate of four pounds per acre by a contractor hired by CCPH (Figure 1-3). The Service cooperated with the county for this treatment to reduce the mosquito population on the Refuge.

Figure 1-1. Aerial view of the Ni-les'tun Unit of Bandon Marsh NWR.



The back sides of maps are blank to improve readability.

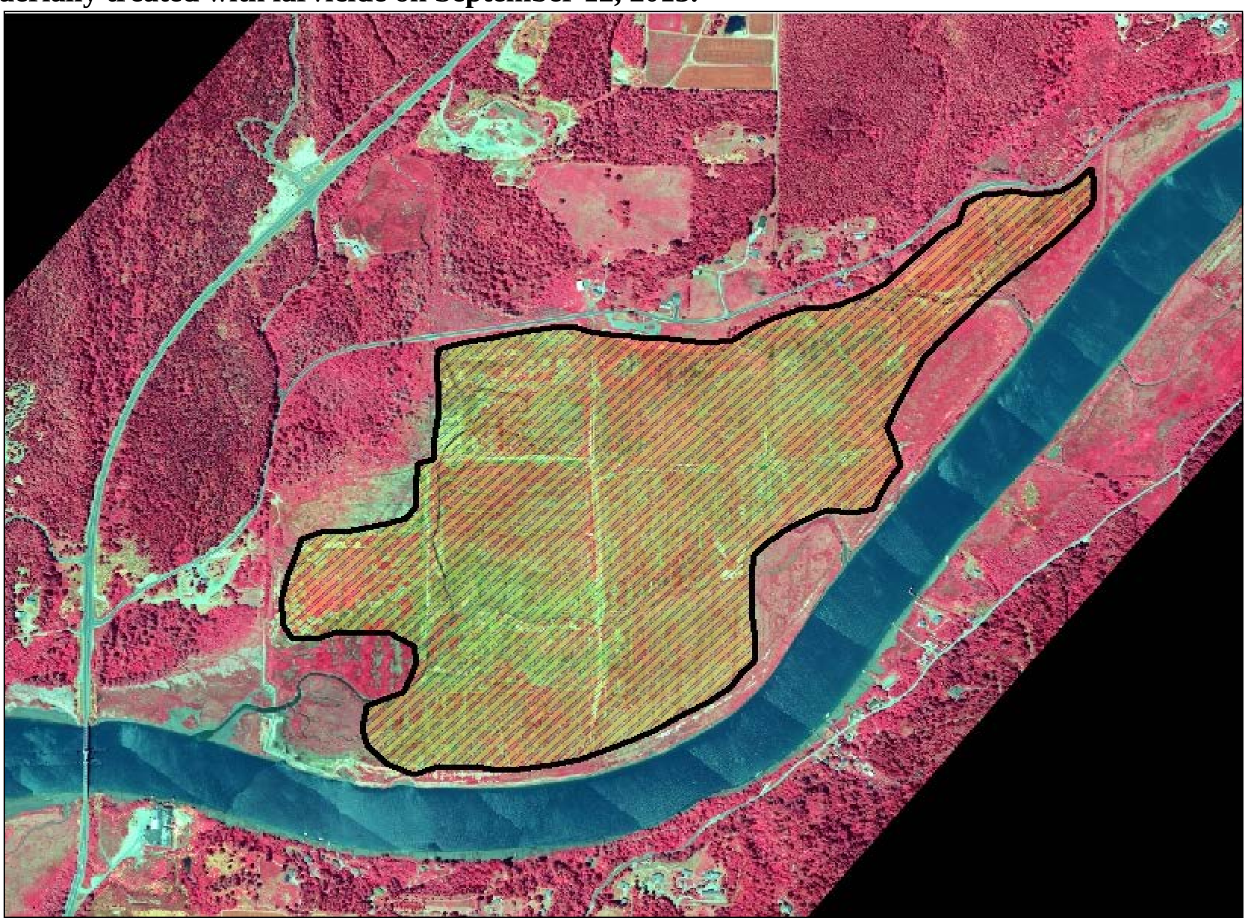
Figure 1-2. Map of Bandon Marsh National Wildlife Refuge.
The tidal marsh restoration occurred on the Ni-les'tun Unit, south of North Bank Lane.



The back sides of maps are blank to improve readability.

In the fall, female mosquitoes produce overwintering (diapause) eggs that do not hatch until favorable conditions occur the following spring. A primary objective of the larvicide treatment was to reduce the number of newly hatched adults available to lay the diapause eggs, with the intended result of fewer mosquitoes hatching the following spring. However, mosquito experts contend that there is still a large bank of viable eggs on the Refuge and mosquito populations are likely to remain high indefinitely unless they are actively managed. Acknowledging that this situation is largely an unintentional result of marsh restoration activities, the Service committed to collaborating with public health officials to solve the problem of inflated mosquito populations on the Refuge, and has developed a comprehensive Integrated Marsh Management (IMM) approach, which is outlined in this draft Plan and Environmental Assessment (Plan/EA) and a separate draft marsh management Supplemental Environmental Assessment (Supplemental EA) (USFWS 2014) being developed concurrently. The IMM approach focuses on a long-term solution of modifying the restoration site hydrology to eliminate most of the mosquito breeding pools that were inadvertently created. However, the ground work needed to accomplish that will not be completed in time to prevent expected large fly-offs in 2014, as anticipated. To manage mosquito numbers until plans to eliminate breeding habitat are implemented and begin to be effective, it will be necessary to use larvicides to prevent mosquitoes from developing past their aquatic life stages as they hatch from breeding pools on the Refuge. This Plan/EA describes the Service's options and projected environmental impacts for application of larvicide to manage mosquito numbers.

Figure 1-3. The 292-acre portion of the Ni-les'tun Unit of Bandon Marsh NWR that was aerially treated with larvicide on September 12, 2013.



1.2 Refuge Location and Site Description

Bandon Marsh NWR consists of the 307-acre Bandon Marsh Unit and the 582-acre Ni-les'tun Unit (Figure 1-2). The total approved Refuge boundary includes 1,000 acres. The Bandon Marsh Unit was established in 1983 and is located near the mouth of the Coquille River with approximately 25% of the Unit within the city limits of Bandon. The Ni-les'tun Unit was established in 2000 and is located on the east side of U.S. Highway 101 on the north bank of the Coquille River. The primary purpose for establishing the Bandon Marsh Unit was to protect the physical and biological integrity of the tidal salt marsh, and to conserve the last substantial tract of salt marsh in the Coquille River estuary (USFWS 1981). The Ni-les'tun Unit was established to protect and restore intertidal marsh, freshwater marsh, and riparian areas to provide a diversity of habitats for migratory birds including waterfowl, shorebirds, wading birds, and songbirds, and to restore intertidal marsh habitat for anadromous fish, such as Chinook (*Oncorhynchus tshawytscha*) and chum (*Oncorhynchus keta*) salmon, steelhead (*Oncorhynchus mykiss*), coastal cutthroat trout (*Oncorhynchus clarki clarki*), and the threatened coho salmon (*Oncorhynchus kisutch*) (USFWS 2013a).

In Oregon, the Coquille River estuary has suffered the largest percentage loss of tidal wetlands, with a reduction of 94% of the historical total acreage (Good 2000). The loss of tidal wetlands, through agricultural dike construction and subsequent draining, has been identified as a major factor contributing to the decline of fishery resources and overall estuarine productivity throughout coastal Oregon. The completion of a restoration project at the Ni-les'tun Unit in summer 2011 resulted in a 400-acre net increase in tidal wetland habitat in the lower Coquille River estuary and an additional 4.3 percent within the state.

1.3 Preferred Alternative

The Refuge proposes to implement an IMM approach that consists, in part, of a phased approach to mosquito larvicide application described herein, and is consistent with the principles of Integrated Pest Management (IPM). The approach includes ongoing coordination with CCPH and incorporates appropriate Service policy related to how the Service addresses mosquito issues on National Wildlife Refuges. Guiding policies include: Comprehensive Conservation Planning Process (602 FW 3), Step-Down Management Planning Policy (602 FW 4), Biological Integrity, Diversity, and Environmental Health (601 FW 3), Integrated Pest Management (569 FW 1), Appropriate Refuge Uses (603 FW 1), and Compatible Uses (603 FW 2). The IMM approach focuses on a long-term strategy of eliminating the majority of the salt marsh mosquito breeding habitat by modifying the site hydrology so that the breeding pools cannot retain water long enough for the mosquitoes to complete their development into adults. An assessment of the environmental consequences of alternatives for accomplishing this habitat modification appear in a separate Draft Supplemental Environmental Assessment for the Ni-les'tun Unit of the Bandon Marsh National Wildlife Refuge Restoration Project (USFWS 2014) being developed concurrently with this Plan/EA. The Preferred Alternative considered in this Plan/EA includes the application of select larvicides to mosquito breeding sites on the Refuge and associated mosquito monitoring activities. The Preferred Alternative in this Plan/EA and the proposed habitat modifications detailed in the draft Supplemental EA incorporate the range of IPM principles (569 FW 1) and would collectively constitute an Integrated Marsh Management approach.

1.3.1 Purpose and Need

1.3.1.1 Purpose

The purpose of the proposed mosquito control is to ensure that management activities on the Refuge do not result in a human health threat or adverse impact (e.g., non-disease human health impact, Health Advisory) from mosquitoes. The proposed action is to implement phased response larvicide application with the intent to manage mosquito numbers until plans to physically eliminate breeding habitat would be implemented and begin to be effective. Pesticide applications may be necessary for several years thereafter until the bank of viable eggs in the system is largely expended and the mosquito population subsequently drops below the threshold constituting a human health threat or adverse impact (see Section 2.2.2.2).

1.3.1.2 Need

As described in the Introduction, it has been determined that the salt marsh mosquito population on the Refuge is abnormally high, and is largely the result of recent marsh restoration activities that inadvertently created abundant mosquito breeding habitat. Mosquito experts contend that the numbers experienced in 2013 and the associated human health threat or adverse impact will likely recur if no remedial actions are taken to prevent it. Within the context of this draft Plan/EA, we use “human health threat” to refer to risks to human health due to mosquito-borne disease. We refer to “adverse impact” in terms of non-disease health impacts to humans from mosquito bites. The IMM approach previously outlined is intended as a comprehensive program to redress this problem, and the use of larvicides considered in this Plan/EA is deemed necessary to prevent large adult mosquito fly-offs from the Refuge that are likely without their use, at least until habitat modification substantially reduces the number and extent of mosquito breeding pools.

Non-Disease Health Impacts from Mosquito Bites: Mosquito bites can adversely impact health, even in the absence of any pathogenic organism. The most common nuisance mosquitoes in North America belong to the *Aedes* and *Culex* genera (McKnight 2005). About 90% of the mosquitoes sampled on the Refuge were identified as the summer salt marsh mosquito (USFWS unpublished data). Adults of this species are aggressive day biting mosquitoes that have been found capable of traveling distances of more than 30 miles (Rees and Nielsen 1947) in pursuit of a host (i.e., blood meal).

Mosquito bites cause immunologically mediated reactions (Crisp et al. 2013). Allergic reactions to mosquito bites are common, and may decrease quality of life (Peng and Simons 2004). These reactions include small local, large local, and even systemic allergic reactions. The clinical diagnosis “mosquito allergy” is reserved for large local, atypical, or systemic reactions (Peng and Simons 2007a, Simons and Peng 2003). Most of the population at any given time will have some reactivity to mosquito bites. Immediate reactions occur in 70% to 90% and delayed reactions in 55% to 65% of people subjected to mosquito bites (Peng et al. 1996, Oka and Ohtaki 1989). The incidence of self-reported large local reactions in one study was 2.5% (Arias-Cruz et al. 2006). Naturally acquired desensitization to mosquito saliva may occur during childhood or during long-term exposure to mosquitoes (Peng and Simons 2007b). Desensitization through natural exposure may take 2 to 20 years because people typically attempt to limit their exposure due to the unwanted effects of the bites (Kulthanan et al. 2010).

"Skeeter Syndrome" is a form of severe, large local reaction that can occur in otherwise healthy children within hours of a mosquito bite, can last for 3–10 days, and is characteristically hot, swollen, red, itchy, painful, and frequently accompanied by fever (Simons and Peng 1999). Systemic reactions can also follow mosquito bites in some people. These reactions include angioedema (swelling below the surface of the skin), itchy rash, nausea, vomiting, and wheezing (Arias-Cruz et al. 2006, Peng et al. 2004, Galindo et al. 1998). Anaphylactic reactions to mosquito bites, a life-threatening, whole-body type of allergic reaction, are extremely rare but have occurred (McCormack et al. 1995). Persons at increased risk for severe reactions include those with high exposure (outdoor workers) and those lacking acquired immunity, such as young children and immigrants (Peng and Simons 2007a, Simons and Peng 1999, McCormack et al. 1995). Others at higher risk for severe reactions are those with primary or acquired immunodeficiencies, such as human immunodeficiency virus, and Epstein-Barr virus (EBV)-associated diseases (Asada 2007, Asada et al. 2003, Smith et al. 1993, Diven et al. 1988). EBV is one of the most common viruses in humans.

Human Health Threat: Mosquitoes can be vectors of disease to both humans and wildlife and in some cases can cause death. Arthropod-borne viruses (termed "arboviruses") are viruses that are maintained in nature through biological transmission between susceptible vertebrate hosts by blood-feeding arthropods (mosquitoes, sand flies, ceratopogonids "no-see-ums", and ticks). Vertebrates can become infected when an infected arthropod bites them to take a blood meal (CDC 2010). Recently, the arbovirus labeled West Nile virus (WNV) has been of particular concern across the United States and in Oregon (see Section 3.3.4). With the swift westward advance of WNV across the United States, concern by the public and the Service over mosquito management and disease prevention has intensified. As a result, Service personnel across the National Wildlife Refuge System (Refuge System) have undertaken a number of actions, including: stepping-up coordination and communication with mosquito experts in MADs, universities, and elsewhere; increasing communication with public health officials; participating in mosquito management seminars and workshops; initiating mosquito management-oriented research on refuges; and conducting restoration that benefits natural resources and reduces the need for mosquito management.

West Nile Virus: In the United States, WNV is transmitted by infected mosquitoes, primarily members of the *Culex* and *Aedes* species, although 64 mosquito species have been identified in WNV positive mosquito pools in the United States since 1999 (CDC 2010). There are 10 Oregon species of mosquito that are known vectors of arboviruses. All 10 species have been shown to be capable of infection with WNV and able to transmit the disease at some level (Goddard et al. 2002). *Culex tarsalis* is considered one of the most efficient laboratory vectors of WNV tested from North America and is abundant in Oregon and much of western North America, where it is also involved in the maintenance and amplification of western equine encephalomyelitis virus and Saint Louis encephalitis virus (Goddard et al. 2002). *Culex tarsalis* larvae are typically found in irrigation ditches, ponds, and storm sewers, and other areas that usually contain abundant organic material. Of the 10 mosquito species studied by Goddard et al. 2002, *Culex tarsalis* showed the greatest potential to amplify and maintain WNV in Oregon. Mosquito species identified on the Refuge in 2013 were *Culex tarsalis, Aedes dorsalis, Aedes sticticus, Aedes cinereus,* and *Culiseta particeps* (USFWS unpublished data). Four of the five species identified on the Refuge in 2013 were *Aedes* or *Culex*. The Oregon Health Authority has tracked WNV cases in the state since 2001, and reports one human case in Coos County in 2012 (DeBess 2013). It is unknown whether WNV positive wildlife or mosquitoes occur in the county, because no specimens have been tested.

1.3.2 Historical Perspective of Need

Historical documents concerning mosquitoes and mosquito-borne diseases in Oregon focus on the presence of malaria and large nuisance populations of mosquitoes affecting the first immigrants and settlers. The most severe mosquito disease and pest outbreaks of the 1800s occurred in the Columbia River region and Willamette Valley of Oregon (Kohn 2008). In the mid-1920s, mosquito control focused around problem areas of the Columbia and Willamette Rivers adjacent to the City of Portland (USDA 1972). The early efforts of mosquito control involved the assistance of OSU's Entomology Department in the development of one of Oregon's early mosquito control programs. The program included the collection of information concerning the biology and breeding sites of important species of the area, and the release of imported mosquitofish (*Gambusia affinis*) for control purposes. These early studies emphasized the lack of knowledge of the biology and control of mosquitoes in the western U.S. In 1930, the U.S. Department of Agriculture was asked to initiate a research program with appropriated Congressional funds. In the early 1930s, with information on biology and breeding sites, an effort to control mosquitoes with a large-scale brush clearing program was started in Multnomah, Columbia, and Tillamook counties in Oregon. In 1940, a state legislative act enabled the organization of mosquito abatement districts in Oregon. This law was amended in 1959 to allow counties in Oregon to organize MADs under their provisions. Mosquito control in the Portland area has been occurring since 1933 and major mosquito vector control organizations within Oregon totaled 15 by the mid-1960s. In 2012, there were 12 vector control districts and one county health department performing mosquito surveillance in Oregon (DeBess 2013).

Today, MADs and public health departments within the state of Oregon and Pacific Northwest employ an IPM approach to mosquito control that emphasizes permanent solutions, such as wetland restoration, mechanical control of water levels or exchange, and may include the use of biorationals (third-generation larvicides that are environmentally sound and closely resemble or are identical to chemicals produced in nature, such as bacteria and viruses) and synthetic chemical larvicides (NWMVCA 2014).

The history and continued presence of disease-carrying mosquito populations within the state of Oregon continues to cause concern among the MADs and local health departments. A positive mosquito pool for WNV was first detected in 2004 when a suite of equine, avian, and human cases of WNV were documented (DeBess 2013). From 2004 through 2012, 153 human cases of WNV were diagnosed in Oregon. In 2012, the one and only Coos County case of human WNV infection was detected in the Bandon area. Further information on WNV from 2004 to 2012 is available for counties in Oregon and is provided in Appendix G. Western equine encephalitis and St. Louis encephalitis viruses, both of which can be transmitted by mosquitoes, are the primary types of encephalitis found in California residents, but were not detected in Oregon in 2013 (USGS 2013).

1.3.3 Historical Mosquito Production Areas of the Refuge

No systematic attempt to measure mosquito populations on the Refuge occurred before June 2013, when the unusually high numbers of mosquitoes became problematic to local residents. Anecdotal information from local residents and Service staff since the Refuge was established clearly confirms past periodic outbreaks of mosquitoes, but those infestations seem to have been largely confined to the wetland areas.

On Bandon Marsh NWR, only the recently restored Ni-les'tun Unit of the Refuge produced higher than average mosquito populations during spring through early fall seasons in 2013 (Figure 1-1). The Ni-les'tun Unit is characterized as a recovering tidal marsh fringed with a freshwater wetland. Characteristics of elevated mosquito production areas include shallow depressions and swales within the marsh plain (5–7 feet North American Vertical Datum 1988 [NAVD88]) that hold water for extended periods following high tides and precipitation, and eventually dry out (a requirement of the salt marsh mosquito life cycle) before they are refilled by high tides. Marsh depressions with these topographic and hydrological characteristics make ideal breeding sites for salt marsh mosquitoes. Over time, natural processes of sedimentation and channel development would fill and drain these depressions, but that could take years to decades to occur on its own. Evidence that these depressions are not features of naturally developed tidal marshes is amply demonstrated by the lack of such features in the Bandon Marsh Unit, and other natural tidal marshes in the region.

1.3.4 How the Preferred Alternative Would Be Accomplished

The Preferred Alternative provides a phased approach for surveillance, monitoring and control of mosquitoes on the Refuge in a manner consistent with the IMM approach, Service policies, and Coos County public health and safety guidelines. The Refuge has made an initial determination that the proposed mosquito management actions are appropriate and compatible with the Refuge purposes (see Section 1.5.1.4). A draft Appropriate Use Finding and Compatibility Determination for mosquito management activities is included in Appendix A.

Each year refuge staff would work with CCPH to develop the SUP (see Section 1.5.1.10) that would cover the surveillance, monitoring, and control activities allowed on the Refuge that year. Coordination and implementation with CCPH would include any county entity, such as a MAD that may be developed in the future, that would act as the primary cooperator for mosquito management. An annual meeting between the Refuge and Coos County health managers would ensure that permits are current, communication is continuous, and concerns related to mosquito populations and other biological resources of the Refuge are addressed. It is vital to the mission agreed to by our respective agencies that a positive and productive working relationship is maintained. Pesticide use proposals (PUPs) and pesticide use reports would be prepared annually by the Refuge with data support from CCPH. In addition, prior to issuing the SUP, the Service would review the Endangered Species Act Section 7 consultation, cultural resource compliance, and this Plan/EA to determine if any additional documentation would be necessary.

1.3.5 Objectives of the Preferred Alternative

- Protect the public from mosquito-related active or potential health and safety threats.
- Protect migratory birds, and other wildlife and their habitats from inordinate risk of mosquito-borne diseases.
- Allow Refuge mission-compatible surveillance of mosquito populations on the Refuge.
- Development of a refuge-based phased response within an IMM approach. Where mosquito control is needed, use the most effective means that pose the lowest risk to wildlife and associated habitats.
- Identify priority areas for enhancement or restoration to reduce the need for mosquito management and improve habitat for native fish, wildlife, and plants.

1.4 Issues and Concerns

1.4.1 Public Participation

Public participation will be solicited through public review of this draft Plan/EA. This document will be sent to CCPH; regional MADs; experts in the field of mosquito biology and control; neighboring land management agencies; federal, state, county and local conservation agencies; Tribes; and other concerned organizations and individuals for comment. Comments will be incorporated into the final document as appropriate. The final Plan/EA will be posted on the Refuge web site (www.fws.gov/oregoncoast) and a copy will be provided to anyone upon request.

1.4.2 Issues Related to the Preferred Alternative

Specific issues associated with mosquito population management on the Refuge include:

- Understanding how refuge-based mosquito populations may contribute to a mosquito-related health threat or adverse impact to surrounding human developments.
- Effects of mosquito population monitoring and control activities on migratory birds, endangered species, and other fish and wildlife and associated habitats.
- Inter- and intra- agency communication regarding mosquito management activities.
- Planning and implementation of wetland enhancement and restoration projects that reduce the persistence of above-normal mosquito populations.
- Reliable, consistent management of the mosquito program by CCPH and the Service.

1.5 Summary of the Laws, Regulations and Policies Governing the Preferred Alternative

Activities of the Service are governed by Acts of Congress and the Executive Branch; therefore, the Preferred Alternative must comply with legislative acts, executive orders, laws and regulations. The Service has a number of policies that describe how the Service addresses mosquito issues on National Wildlife Refuges.

1.5.1 Legislative Acts, Laws, Policies and Regulations

1.5.1.1 Endangered Species Act (ESA) of 1973, as amended

The Endangered Species Act (ESA; 16 U.S.C.1531–1544) provides for the identification, protection, and recovery of species approaching extinction. One of the means used to protect such species is found in Section 7 of the ESA. This section requires federal agencies to consult with the Service's Ecological Services (ES) Program or the U.S. Department of Commerce's National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries) whenever an action is proposed which may affect a threatened or endangered species or its critical habitat. Consultation with NOAA Fisheries is for listed marine species, including anadromous fish, most marine mammals, and sea turtles.

All mosquito management activities conducted on the Refuge will be in compliance with the ESA. The Refuge will determine whether Section 7 consultation is required for specific wetland restoration or enhancement projects.

1.5.1.2 National Wildlife Refuge System Administration Act of 1966, as amended

The most important federal statute guiding management of refuges is the National Wildlife Refuge System Administration Act of 1966, as amended (Refuge Administration Act; 16 U.S.C. 668dd–668ee). This law was significantly amended in 1997 with passage of the National Wildlife Refuge System Improvement Act of 1997 (Refuge Improvement Act). This amendment provides the Refuge System with the following statutory mission statement: “The mission of the System is to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.” The law makes clear that the Refuge System is to be managed first and foremost for wildlife conservation. It also requires that six wildlife-dependent public uses be given priority consideration in refuge planning and management over all other general public uses. In essence, the law establishes a management hierarchy by declaring that refuges are to be managed first for wildlife, second for priority public uses, and last for other general public uses (which would include mosquito control). Several substantive and procedural requirements associated with compatibility determinations form a major feature of the law. This is because all public uses must first be determined compatible with the purpose(s) of the refuge and the Refuge System mission before they are allowed on a refuge. The law also requires monitoring of the status and trends of refuge fish, wildlife, and plants; as well as maintenance of the Refuge System’s biological integrity, diversity, and environmental health.

1.5.1.3 Biological Integrity, Diversity, and Environmental Health Policy

National guidance has been developed to implement some of the key provisions of the 1997 amendments to the Refuge Administration Act. This includes the Biological Integrity, Diversity, and Environmental Health policy (601 FW 3). Consistent with the refuge purpose(s), this policy provides for maintenance and restoration of healthy, functioning biological communities composed of native species and habitats comparable with historic conditions. The policy favors refuge management which restores or mimics natural ecosystem processes or functions. The policy reaffirms the use of IPM strategies that incorporate the most effective combination of mechanical, chemical, biological, and cultural control and discourages the removal of native species, although it acknowledges that this action may at times be necessary and appropriate. Relevant to a planning process, a key to proper implementation of this policy is evaluating how a Preferred Alternative would affect achievement of the refuge purpose(s).

If a public health agency has advised a refuge manager of a documented public health risk or threat or adverse impact due to mosquitoes on a refuge, BIDEH guides the refuge manager’s review of the public health agency’s (or their authorized, designated representative) proposed alternatives for mosquito management. A refuge manager considers the refuge mission and the biological integrity, diversity, and environmental health of the refuge, and works with the public health agency/district to select a mosquito management treatment alternative that achieves the necessary reduction of risk to human health threat or adverse impact while maintaining the refuge purpose(s) and minimizing adverse effects to biological integrity, diversity, and environmental health.

1.5.1.4 Appropriate Refuge Uses Policy

The Appropriate Refuge Uses policy (603 FW 1) directs refuge managers to determine if new or existing uses are appropriate refuge uses. In general, appropriate uses are those which contribute to the public's understanding and appreciation of the refuge's natural or cultural resources, or are beneficial to the refuge's natural or cultural resources, can be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality compatible, wildlife dependent recreation into the future, and are manageable within available budget and staff in the future within existing resources (see 603 FW 1 for an explanation of all the factors considered in making an appropriate use determination). If a new use is not appropriate, the refuge manager can deny the use without determining compatibility. If a use is determined to be appropriate, then a compatibility determination must be developed to determine whether the use can be allowed.

1.5.1.5 Compatibility Policy

The Service's Compatible Use policy (603 FW 2) and the associated regulations (50 CFR §26.41) provide guidelines and direct refuge managers to ensure that a new or existing activity (e.g., mosquito management method) will not interfere with or detract from the fulfillment of refuge purpose(s) and the mission of the Refuge System, and that any use considered compatible is periodically reviewed, and complies with all applicable laws, policies, and regulations. The Compatibility policy (603 FW 2.10C) also provides additional guidance on how to implement the Refuge Administration Act, 668dd (k) Emergency power.

If a health department, MAD, or other non-Refuge System entity is proposing to conduct mosquito control or mosquito management activities on a refuge, this would qualify as a "refuge use" and the compatibility regulations and policy would require that a compatibility determination be developed. This determination would be for the purpose of determining whether, based on the refuge project leader's sound professional judgment, the proposed mosquito management activities would materially interfere with or detract from the refuge purpose(s) or the Refuge System mission. The determination would need to be made in writing and would have to allow an opportunity for public comment.

The Compatibility policy also states that a use must be determined not compatible if the Service has insufficient information to determine it compatible. In addition, if the Services has insufficient management resources (e.g., funds, staff, facilities, and equipment) to ensure that a use would occur in a compatible manner, and then the use is not compatible. Finally, the Compatibility policy states that a use would not be compatible if it would conflict with maintenance of refuge biological integrity, diversity, and environmental health. A refuge mosquito management program needs to be carefully planned and implemented to ensure that this last policy requirement is not violated. Appendix A includes a copy of the Appropriate Use Finding and Compatibility Determination for mosquito management at the Refuge. The public will have 30 days to review these drafts along with the Plan/EA.

1.5.1.6 National Environmental Policy Act

The National Environmental Policy Act of 1969, as amended (NEPA; 42 U.S.C. 4321-4347) is another important federal statute that would be triggered by a proposed refuge mosquito management program. NEPA's requirements are primarily procedural in nature. Among other things, NEPA requires that federal agencies "Utilize a systematic, interdisciplinary approach…in planning and decision-making…" and "...ensure that presently unquantified environmental amenities and values... [are]...given appropriate consideration in decision-making along with economic and technical considerations...." Prior to making a decision to undertake a Preferred Alternative, agencies are to consider a range of reasonable alternatives and the effects of their implementation. The Service has prepared this draft Plan/EA in compliance with NEPA. Following public review of the Plan/EA, the Service will make a decision whether or not to sign a finding of no significant impact (FONSI).

1.5.1.7 Federal Water Pollution Control Act, as amended in the Clean Water Act of 1977

The Clean Water Act (CWA; 33 U.S.C. 1251–1387) provides for the restoration and maintenance of the Nation's water quality. One provision of the Act, Section 402, applies to point source discharges of pollutants into waters of the United States. It established the National Pollutant Discharge Elimination System (NPDES). A recent court decision held that NPDES permits were required for the discharge of pesticides into waters of the U.S., even if the pesticides were applied consistent with label requirements legally established under the Federal Insecticide, Fungicide, and Rodenticide Act (Headwaters, Inc. v. Talent Irrigation District, 9th Cir. 2001, 243 F.3d 526). The U.S. Environmental Protection Agency (EPA) since issued memoranda commenting on the court decision and stating that enforcement of the decision was not a high priority. States are variously interpreting this court order and EPA's response (NPDES Permits). Some states (including California and Washington in the Pacific Region) have adopted statewide general NPDES permits covering application of pesticides to water, including for mosquito control purposes. Refuges are encouraged to add stipulations to compatibility determinations and associated SUPs for mosquito control requiring MADs or other permittees to satisfy all relevant legal requirements for conduct of their work, including water quality permits, and training and certification requirements for any pesticide applicators.

Section 404 of the Clean Water Act regulates the placement of fill or the dredging of wetlands under the jurisdiction of the U.S. Army Corps of Engineers or the EPA.

1.5.1.8 National Historic Preservation Act of 1966, as amended

Section 106 of the National Historic Preservation Act requires federal agencies to consider how their actions could affect historic properties. Compliance with Section 106 will be completed between the Service and the Oregon State Historic Preservation Officer as ground disturbing activities are identified.

1.5.1.9 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended

This law regulates all activities related to pesticides, including development, registration and classification, production, storage and transport and applications. Section 18, as amended, provides for exemption of state or federal agencies from all requirements in cases where the Governor or head of that agency requests and secures such an exemption. This constitutes declaration of official emergency conditions (such as an imminent human health hazard).

1.5.1.10 Integrated Pest Management Policies

The Department of Interior policy for use of pesticides (517 DM 1.2.A) is to "use pesticides only after full consideration of alternatives - based on competent analysis of environmental effects, safety, specificity, effectiveness, and costs. The full range of alternatives including chemical, biological, and physical methods, and no action will be considered. When it is determined that a pesticide must be used in order to meet important management goals, the least hazardous material that will meet such goals will be chosen."

The Department of Interior IPM policy (517 DM 1.3 C) allows for management of pests, defined as any living organism that may interfere with the site-specific purposes, operations, or management objectives, or that jeopardizes human health and safety. Further, 517 DM 1.4 and 1.5 direct that the departmental bureaus will (1) manage pests using IPM principles such that risks from both the pests and the associated pest management activities are reduced; (2) accomplish pest management through cost-effective means that pose the least risk to humans, natural and cultural resources, and the environment; (3) incorporate all applicable federal authorities when addressing pest issues.

Pursuant to this policy, the Service has considered all alternatives for accomplishing the purpose of the Preferred Alternative. Physical alteration of habitat, which the Service intends to do concurrently, is considered the most effective method of controlling mosquitoes in the long term and is described in a separate document under development concurrently with this assessment (USFWS 2014). The Preferred Alternative herein provides the option to use larvicides that have been chosen because they are the least toxic and most effective tools available. The intent is to only use them as necessary to control mosquitoes that are produced on the Refuge until the habitat modification becomes effective at controlling mosquitoes without the use of pesticides.

The Service's IPM policy (569 FW 1) follows the Departmental policy. Under 569 FW 1.3 and 1.6, the Service manages pests that interfere with site management goals and objectives; when human health or safety is jeopardized; when there is a threat to wildlife health; and when action thresholds for the pest are exceeded. The Service receives no appropriated funds for mosquito management activities. Unless mosquito populations interfere with site management goals and objectives, or jeopardize human health or safety, Department and Service policies authorize refuge managers to allow native mosquito populations to exist unimpeded. When a public health district or agency identifies to the Service that there is a threat or adverse impact to human health from mosquitoes on a refuge, as documented by local, current mosquito monitoring data, refuge managers are authorized to allow mosquito management actions on the refuge as long as the activities are in full accordance with Service regulations, policies, and permitting procedures. Under the IPM policy, the National IPM Coordinator works with the Regional IPM Coordinators and other technical advisors to inform employees about mosquito management techniques and products.

Section 569 FW 1.4 directs managers to use the most effective IPM method or combination of methods that pose the lowest risk to fish, wildlife, and their habitats. Section 569 FW 1.7 also directs managers to choose pest management methods by considering human health, environmental integrity, effectiveness, and cost. Refuge managers evaluate the mosquito treatment options using this guidance.

1.5.1.11 Pesticide Use Proposals

Both the Department of the Interior and the Service have policies which address management of pests and application of pesticides on national wildlife refuges. These policies can be found at 517 DM 1 and 569 FW 1. The policies are based on IPM principles and allow use of pesticides only after evaluation of a range of alternatives (including physical and cultural methods, biological controls, and no action); and full consideration of safety, environmental effects, efficacy, specificity, and costs. The Department of Interior policy for use of pesticides (517 DM 1.2.A) is to "use pesticides only after full consideration of alternatives - based on competent analysis of environmental effects, safety, specificity, effectiveness, and costs. The full range of alternatives including chemical, biological, and physical methods, and no action will be considered. When it is determined that a pesticide must be used in order to meet important management goals, the least hazardous material that will meet such goals will be chosen."

In order to provide assistance with refuge pest management programs and evaluate proposed pesticide applications, policy requires refuge project leaders to develop and submit PUPs for approval. This requirement includes pesticides that MADs or other permittees propose for use as part of a refuge mosquito management program. Depending on the pesticide proposed for use and the proposed application method(s), approval of PUPs may reside with the refuge project leader, Regional Office, or Headquarters Office. A PUP would be prepared each year for pesticides that are used on the refuge.

1.5.1.12 Special Use Permits

Long-standing Refuge System policy addressing Administration of Specialized Uses (5 RM 17) guides issuance of SUPs for economic uses, special events, access to closed areas, and other privileged uses. Controlling mosquitoes on a refuge by a MAD or other party is a specialized use and requires issuance of a SUP. Requests by MADs or other non-NWRS parties to control mosquitoes on a refuge trigger requirements to comply with several, potentially all, of the laws and policies briefly discussed above. According to the Refuge Administration Act, such a request for mosquito control would be considered a general public use and subject to compatibility, which is the lowest of the three tiers in the Refuge System management hierarchy. Implementation of the Preferred Alternative includes developing a SUP each year. In addition, prior to issuing the SUP, the Service will review the Section 7 consultation, cultural resource compliance, and this Plan/EA to determine if any additional documentation will be necessary.

1.5.1.13 Comprehensive Conservation Planning and Step-Down Management Planning Policy

The Service's Comprehensive Conservation Planning (CCP) policy (602 FW 3) describes the process we use to establish long-range guidance and management direction to achieve refuge purposes and fulfill the refuge mission. Comprehensive Conservation Plans may include, but are not limited to, refuge-specific IPM plans, invasive species management plans, or mosquito management plans, as appropriate. The Service's Step-Down Management Planning Policy (602 FW 4) allows for step-down management plans, such as IPM plans and/or mosquito management plans, that may be prepared when necessary to provide strategies and implementation for meeting goals and objectives identified in a CCP; all are subject to NEPA compliance documentation.

The Bandon Marsh National Wildlife Refuge Comprehensive Conservation Plan specifically includes integrated pest management principles (USFWS 2013a, Appendix G Integrated Pest Management). Along with a more detailed discussion of IPM techniques, the CCP describes the selective use of pesticides for pest management on refuge lands, where necessary. Throughout the life of the CCP, most proposed pesticide uses on refuge lands will be evaluated for potential effects to refuge biological resources and environmental quality. This draft plan and Environmental Assessment for Mosquito Control are in compliance with the Service's Step-Down Management Planning Policy and serve to fulfill the need for additional management strategies and CCP implementation specific to mosquito management.

1.5.2 Executive Orders (EO)

1.5.2.1 Protection of Wetlands (EO 11990)

This order directs federal agencies to minimize the destruction, loss or degradation of wetlands and preserve and enhance the natural beneficial value of wetlands in the conduct of the agency.

1.5.2.2 Floodplain Management (EO 11988)

This requires federal agencies to avoid construction or management activities that would adversely affect floodplains. It directs agencies to restore and preserve the natural and beneficial values served by floodplains when carrying out their responsibilities, minimize the effect of floods on human safety, and reduce the risk of flood loss.

1.5.2.3 Protection and Enhancement of the Cultural Environment (EO 11593)

This Executive Order directs agencies to inventory historic, archeological, and paleontological properties for inclusion on the National Register of Historic Places. Archeological sites may be in existence on the Refuge. Any actions that include disturbing the ground will be reviewed by a qualified archaeologist for archeological significance prior to approvals.

1.5.2.4 Intergovernmental Review of Federal Programs (EO 12372)

A Notice of Availability for this Plan/EA will be sent to local, county and city governments, regional and state agencies, other federal agencies, Tribes and interested parties.

1.5.3 USFWS and Refuge Missions and Policies

1.5.3.1 The U.S. Fish and Wildlife Service Mission

The mission of the Service is:

> "...to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people." (1 RM 4.3)

The mission of the Service, set forth in National Policy Issuance 99-01, is:

> "working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people."

1.5.3.2 The National Wildlife Refuge System Mission

The mission of the Refuge System is:

> "To preserve a national network of lands and waters for the conservation and management of the fish, wildlife and plants of the United States for the benefit of present and future generations." (EO 12996)

The Administration Act, as amended by the Improvement Act, states:

> "The mission of the System is to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant

resources and their habitats within the United States for the benefit of present and future generations of Americans."

1.5.3.3The Goals of the National Wildlife Refuge System

The goals of the National Wildlife Refuge system are:

- Conserve a diversity of fish, wildlife, and plants and their habitats, including species that are endangered or threatened with becoming endangered.
- Develop and maintain a network of habitats for migratory birds, anadromous and inter-jurisdictional fish, and marine mammal populations that is strategically distributed and carefully managed to meet important life history needs of these species across their ranges.
- Conserve those ecosystems, plant communities, wetlands of national or international significance, and landscapes and seascapes that are unique, rare, declining, or under-represented in existing protection efforts.
- Provide and enhance opportunities to participate in compatible wildlife-dependent recreation (hunting, fishing, wildlife observation and photography, and environmental education and interpretation).
- Foster understanding and instill appreciation of the diversity and interconnectedness of fish, wildlife, and plants and their habitats. (601 FW 1)

1.5.3.4 Bandon Marsh National Wildlife Refuge Purposes

The purposes of the Bandon Marsh National Wildlife Refuge are:

- "For the preservation and enhancement of the highly significant wildlife habitat … for the protection of migratory waterfowl, numerous species of shorebirds and fish … and to provide opportunity for wildlife-oriented recreation and nature study on the marsh" [95 Stat. 1709, dated Dec. 29, 1981] and Public Law 97-137 – Dec. 29, 1981 and H.R. 2241 March 2, 1981.
- "for the development, advancement, management, conservation, and protection of fish and wildlife resources" [16 U.S.C. 742f (a)(4)]; "for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to the terms of any restrictive or affirmative covenant, or condition of servitude" [16 U.S.C. 742f (b)(1) (Fish and Wildlife Act of 1956)].
- "particular value in carrying out the national migratory bird management program" [16 U.S.C. 667b (An Act Authorizing the Transfer of Certain Real Property for Wildlife)].

1.6 Decision to be Made

The Service must decide whether implementing the Preferred Alternative would have a significant impact to the human environment. If the Service concludes that the Preferred Alternative does not have a significant impact to the human environment then a FONSI would be signed and implementation would begin immediately.

Chapter 2. Alternatives Including the Preferred Alternative

2.1 The Process Used to Develop the Alternatives

Alternatives were developed to meet the purpose and need using guidance from several pertinent information sources, as previously reviewed. In October 2013, the Refuge hosted a two-day technical meeting of mosquito management experts with the goal of developing the most effective and environmentally sound means to manage mosquitoes on the Refuge, including consideration of the relative merit of all options available. The attending technical advisory group included mosquito ecology experts, a CCPH representative, representatives of several MADs, marsh ecologists, fish biologists, regulatory experts, and Service staff with mosquito management experience. The information provided by the technical advisory group was instrumental in the formulation of the alternatives. This information included mosquito ecology relevant to the species identified on the Refuge, history of mosquito populations and their management, cultural tolerances for mosquitoes, past and current historical human health threats, monitoring techniques, physical manipulation techniques to reduce mosquito breeding sites, treatment thresholds, and disease surveillance.

2.2 Description of Alternatives, Including the Preferred Alternative and No Action

2.2.1 Factors Common to all Alternatives

Actions that are common to all alternatives are described below and are not repeated in each alternative description.

2.2.1.1 General Permits

The Refuge, in cooperation with CCPH, must obtain all clearance and permits required for state and federal endangered species compliance before allowing mosquito management activities in endangered species habitat on the Refuge. Other general permits may also be required such as an NPDES permit, depending on the scope of the action proposed each year.

2.2.1.2 Special Use Permits

CCPH must obtain an annual refuge SUP if they would be conducting mosquito management activities on the Refuge. A SUP would be issued, renewed, and/or revised annually and would document all uses on the Refuge and provide clear guidance for activities on the Refuge. To ensure that mosquito management activities are compatible with the refuge purposes, permitted activities described herein meet the stipulations listed in the Compatibility Determination (Appendix A).

2.2.1.3 Supplemental NEPA Documentation

Each of the alternatives described below may require supplemental NEPA documentation depending on whether the scope of the action proposed each year changes significantly from that proposed here.

2.2.1.4 Education and Outreach

Where appropriate, the Service would collaborate with non-government agencies, public health authorities, agriculture departments, and vector control agencies to conduct education and outreach activities aimed at protecting human and wildlife health from threats associated with mosquitoes. The Service would provide access to information materials about mosquito-associated threats to our visitors and employees (e.g., via refuge office, websites, and news media). The Service would prepare an instructional package for employees on personal protection measures to minimize their exposure to mosquito-related health threats or adverse impact.

2.2.1.5 Integrated Marsh Management Approach.

If approved, the habitat modification actions in the draft Supplemental EA (USFWS 2014) would be implemented regardless of the alternative chosen for mosquito control in this Plan/EA. Habitat modification to drain the artificial mosquito breeding sites would be occurring concurrently with mosquito monitoring and application of larvicides for control. The Preferred Alternative in this Plan/EA and the proposed habitat modifications detailed in the draft Supplemental EA incorporate the range of IPM principles (569 FW 1) and would collectively constitute an IMM approach. IMM involves a holistic approach to mosquito control and wetlands management utilizing a variety of applied management techniques to achieve multiple site-specific goals. IMM takes into consideration the many aspects of wetland management, including mosquito control, vegetation management, wildlife habitat enhancement, hydrologic modification, and wetland restoration (Rochlin et al. 2012).

2.2.1.6 Mosquito Population Monitoring

Fundamental to IMM is monitoring of the conditions that indicate management needs and success; therefore, monitoring the status of mosquito populations on the Refuge would continue under all alternatives described in this Plan/EA, including the No Action Alternative. The Service would allow monitoring and surveillance of larval and adult mosquito populations on the Refuge by CCPH under a SUP. To avoid harm to wildlife or habitats, access to traps and sampling stations must meet the requirements found in the project Compatibility Determination (Appendix A) and may be restricted.

Mosquito population monitoring involves collecting quantitative data to determine mosquito species composition and to estimate relative changes in mosquito populations over time. The objectives of mosquito population monitoring are to:

1. Establish baseline data on species and abundance;
2. Map breeding and/or harboring habitats; and
3. Estimate relative changes in population sizes for making IPM decisions to reduce mosquito populations when necessary.

Mosquito-borne disease surveillance may be conducted by CCPH at its discretion to detect whether pathogens causing mosquito-borne diseases are present, by testing adult mosquitoes for pathogens or testing reservoir hosts for pathogens or antibodies. This information may be necessary to determine public health risks associated with mosquito-borne pathogens on or near the Refuge.

Monitoring of immature (larval and pupal) mosquitoes on the Refuge would be conducted by CCPH. CCPH and refuge staff would develop and maintain a list and map of known mosquito breeding sites on the Refuge and field technicians would visit them during likely periods of mosquito production. The timing and frequency of monitoring would be based on a number of factors including history of mosquito production, tidal cycles, precipitation levels, and available resources. Mosquito populations would be sampled using established protocols developed by CCPH in conjunction with the Refuge. Samples would be examined in the field or laboratory by the CCPH to determine the abundance, species, and life-stage of mosquitoes. This information would be compared to database records and established thresholds and would be used as a tool for treatment decisions.

Although larval mosquito control is preferred, it may not be possible to identify all larval sources. Therefore, adult mosquito monitoring would be used to supplement immature monitoring data, and potentially locate additional mosquito source pools. Adult mosquitoes would be sampled using standardized trapping techniques (i.e., New Jersey light traps, carbon dioxide-baited traps and oviposition traps). Mosquitoes collected using these methods would be counted and identified to species by field technicians, with help from outside experts when needed. Information on adult mosquito abundance from traps would be augmented by tracking mosquito complaints from local residents. Analysis of requests for mosquito control allows CCPH staff to gauge the success of control efforts and locate additional sources of mosquito development. The CCPH would conduct public outreach programs and encourage local residents to contact them to report infestations.

2.2.1.7 Access

Access for the purposes of mosquito management (e.g., monitoring and control) would be limited in areas known to support threatened coho salmon. The following access limitations apply:

- All personnel entering the wetlands would be trained by refuge staff to avoid disturbance to endangered, threatened or other sensitive species of the Refuge.
- Motorized vehicle access would only be used when no other practical means of conducting mosquito management is available.

These access limitations would limit direct and indirect (e.g., habitat) negative effects on sensitive species to comply with the project Compatibility Determination (Appendix A). Access within sensitive areas would be identified by the refuge manager in coordination with CCPH and designated in the annual SUP.

2.2.1.8 Annual Meeting/Training

All alternatives require that an annual meeting be held to discuss mosquito activities for the past year and any proposed wetland and mosquito management changes or issues for the upcoming season. The following is a list of topics that should be covered:

Service:	Staff introduction/changes
	Pest management policy changes
	Summary of current wetland restoration and management program
	Proposed enhancement or restoration projects
	Current wildlife populations & status
	Techniques to minimize disturbance to wildlife
CCPH:	Staff introduction/changes
	Mosquito policy changes
	Summary of mosquito production areas
	Summary of mosquito management activities
	Updated PUPs and labels
	Proposed changes to mosquito management program

Current mosquito and disease information
Results of relevant mosquito research projects
Proposed mosquito reduction projects
Current mosquito production areas

2.2.2 Alternative A: Phased Response Larvicide Application Plan (Preferred Alternative)

As described in Section 1.3, the Preferred Alternative to use larvicides as part of a phased response plan would be closely coordinated with the mosquito habitat reduction plan that addresses the root cause of the over-production of mosquitoes on the Refuge, which is described in a separate draft Supplemental EA (USFWS 2014). The use of larvicides is included in the IMM approach because the Service recognizes that, without them, there is a high likelihood that mosquito production would be problematic in the spring and summer of 2014 before the marsh restoration would be accomplished. Even after the restoration, although the Service fully expects a drastic reduction in the capacity of the Refuge to produce mosquitoes, there may be a need to apply larvicides to control mosquitoes at a lower intensity in future years. The Service considers the procedures described in this phased response larvicide application plan as necessary to manage potential health threats or adverse impacts to humans associated with mosquitoes produced on the Refuge in the near and long term, and to be consistent with an IPM approach.

Application of larvicides would be approved based on the phased approach outlined below. The principal goal of a phased approach to mosquito management is to minimize effects on Refuge resources while addressing legitimate human health concerns and impacts to fish and wildlife, and complying with Service regulations and policy. The adoption of this phased response approach would result in a consistent mosquito management program that adheres to Service policies. Because occurrences of arboviruses and other human health issues resulting from mosquitoes are unpredictable, the phased approach, which uses current conditions to determine what management actions would be implemented, permits appropriate flexibility.

Implementation of this alternative is dependent upon communication and cooperation with CCPH. Although CCPH would have the lead for monitoring, disease surveillance, and larvicides applications, the evaluation of monitoring data and approval for each management action would be the responsibility of the Refuge. This oversight and responsibility is necessary to ensure that the conditions for refuge compatibility are met and the program is implemented as planned to avoid or minimize impacts on refuge resources.

Table 2-1 provides abbreviated descriptions of conditions and responses associated with each of the mosquito management phases, and is followed by more detailed phase descriptions. This approach focuses on the implementation of a phased response mosquito management program to protect the public from mosquito-related health threats or adverse impact. The specific timing and number of monitoring and treatment activities would depend on resources, weather, and results of monitoring as they become available, and therefore cannot be specified in this planning document.

Mosquito monitoring conducted by CCPH would be the fundamental activity of mosquito management on the Refuge. Monitoring is required to determine mosquito species, relative abundance of adults and larval stages, locations of infestations, and timing of control efforts for maximum effectiveness. Although the CCPH would be monitoring mosquito populations and setting decision trigger thresholds, all mosquito management decisions would be made in consultation with the Refuge.

The foundation for the following plan is a series of IPM options that are intended to minimize effects of mosquito management to refuge resources while protecting human health. The Service's intention for the first two years is to control mosquito populations until such time that the proposed habitat manipulation actions detailed in the draft Supplemental EA (USFWS 2014) would be implemented and become effective at minimizing mosquito breeding habitat. The first phase (Table 2-1) requires the Refuge to use non-pesticide approaches (e.g., reduction of mosquito breeding habitat, adjustments in habitat management) to reduce mosquitoes with little or no negative effect to refuge resources. The last two phases allow the use of specific pesticides (i.e., three types of larvicides) to address threats to human and wildlife health. Treatment with larvicides would be directed at specific locations where there are high concentrations of larvae, as discovered through intensive monitoring. Ground-based application of larvicides is the preferred method, but the option of aerial application is retained in case ground application becomes unfeasible or ineffective. In all phases below, the proposed habitat manipulation, as addressed in the draft Supplemental EA (USFWS 2014), would be ongoing.

Table 2-1. Phased response mosquito management guidelines for Bandon Marsh NWR.

Phase	Condition	Response
1	A human health threat or adverse impact[1] has not been identified and mosquito abundance is below the pre-determined thresholds on the Refuge, as documented by monitoring.	Conduct monitoring on the Refuge and areas surrounding the Refuge to inform management actions on the Refuge. Remove/manage artificial breeding sites such as gutters, tanks, or similar containers. Inform refuge staff and visitors of personal protective measures to prevent or reduce the risk of mosquito bites.
2	Either of the following has occurred: (1) Public health authorities declare a potential human health threat or adverse impact (e.g., Health Advisory) posed by mosquitoes occurring on the Refuge; or (2) The pre-determined abundance thresholds[2] have been documented on the Refuge as determined by standardized monitoring.	Response as in phase 1, plus: allow site-specific application of early-stage larvicides (*Bti*, methoprene) in infested areas as determined by monitoring.
3	The requirements for Phase 2 have been met and either of the following has occurred: (1) the pre-determined (by CCPH) threshold for late instar and pupal-stage mosquitoes has been reached; or (2) monitoring demonstrates that a pre-determined, large area of the Refuge is producing mosquitoes.	Response as in phase 2, plus: if appropriate, increase the intensity and frequency of early-stage larvicide application, and consider aerial application; allow site-specific use of late-stage larvicide (CocoBear™) in infested areas identified through monitoring to be beyond control with early-stage larvicides. Increase monitoring frequency.

[1]An existing or potential human health threat or adverse impact from mosquito-borne disease or non-disease adverse health impacts identified and documented by federal, state, and/or local public health authorities. Health threats are locally derived and are based on the presence or potential of endemic or enzootic mosquito-borne diseases, including the historical incidence of disease, and the presence and abundance of mosquitoes, which can adversely impact health even in the absence of any pathogenic

organism via immunologically mediated reactions to mosquito bites. [2]Human health threshold (e.g., numbers per dip) is determined by CCPH by considering several factors (Table 2-2).

2.2.2.1 Phased Approach to Mosquito Larvicide Application

Phase 1: In Phase 1, a mosquito-based human health threat or adverse impact has not been identified and mosquito abundance is below the pre-determined thresholds on the Refuge, as documented by monitoring. Public health authorities and the Refuge would collectively institute a proactive prevention and management program for mosquitoes. Artificial mosquito breeding habitat, such as clogged gutters, open containers, and other equipment or objects that pool water where mosquitoes may breed, would be eliminated throughout the Refuge. Refuge staff and visitors would be informed of personal protective measures to prevent or reduce the risk of mosquito bites, such as wearing mosquito repellant or loose-fitting clothing. Monitoring would determine mosquito species presence and abundance on refuge lands and identify potential or documented vectors of mosquito-borne diseases that represent a potential human health threat.

Phase 2: Phase 2 is triggered when either (1) public health authorities declare a human health threat or adverse impact (e.g., Health Advisory) posed by mosquitoes occurring on the Refuge; or (2) the pre-determined abundance thresholds have been documented on the Refuge during the monitoring. This would indicate that non-larvicide attempts to reduce mosquito populations have not been successful (or in 2014, habitat reduction had not yet been implemented or had time to have the intended effect). Under Phase 2, application of larvicides that target the early mosquito development stages (i.e., first to fourth instars) would be applied. On-refuge treatment locations would be based on surveys that identify areas that are being used for breeding.

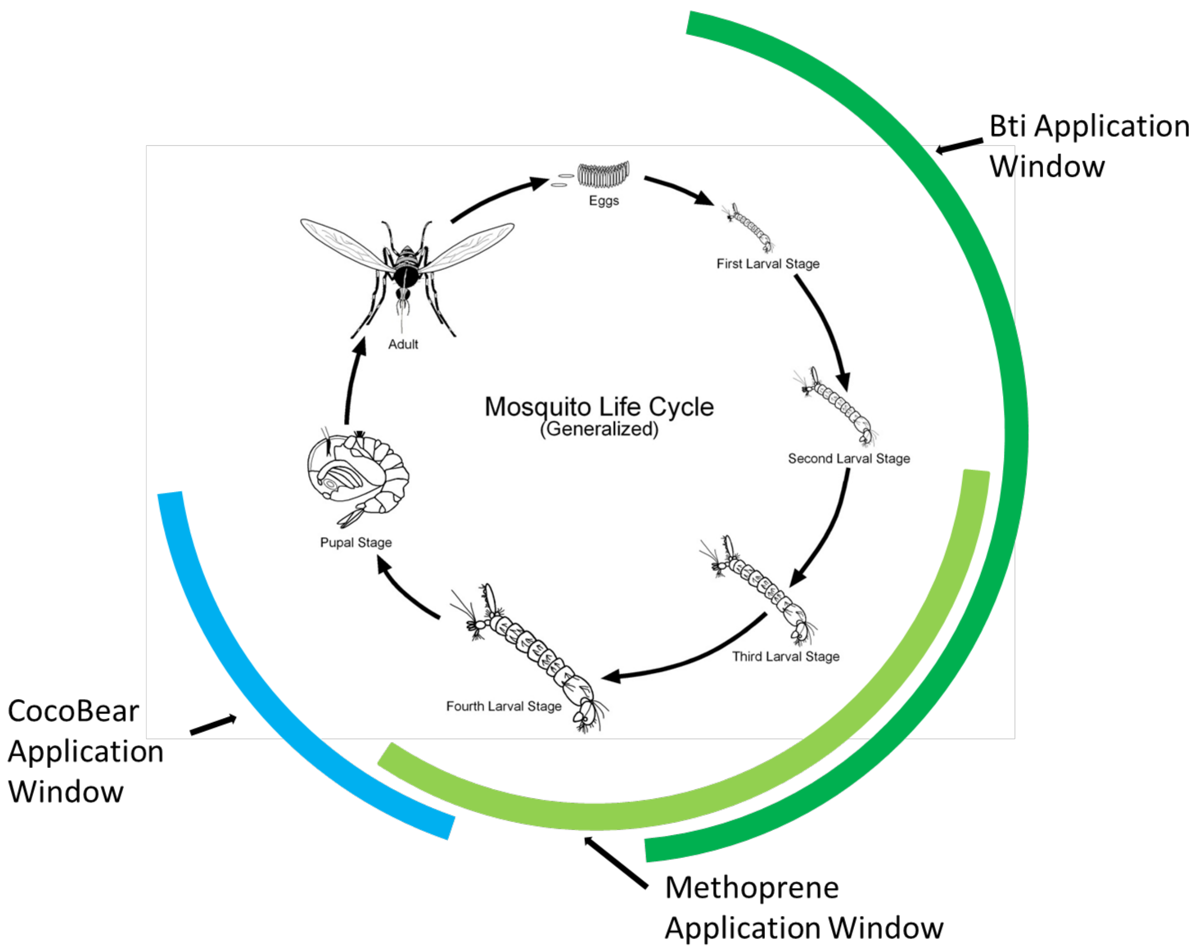
The larvicides selected for application are the biorationals *Bacillus thuringiensis israelensis* (*Bti*) and methoprene because of proven efficacy and limited environmental effects. Application of *Bti*, in either its single dose or time-release (longer acting) formulation, is the preferred larvicide because of its minimal non-target effects (see Section 2.2.1.6 and Appendix C). The synthetic larvicide methoprene is a broader spectrum larvicide and therefore less preferred, but would be used if necessary due to the restrictive conditions needed for *Bti* to be effective (see Section 2.2.1.6, and Figure 2-1). When applying methoprene, ground-based application of single dose (non-persistent) methoprene formulations is preferred, as that would result in the least amount of larvicide with the least degree of persistence to be targeted only where needed.

Prior to Mosquito Habitat Reduction: The documented abundance of adult mosquitoes present on the Refuge late in the 2013 season makes it likely that a substantial reservoir of diapause eggs are poised to hatch in spring 2014. Prior to when the proposed 2014 marsh restoration (detailed in a separate draft Supplemental EA [USFWS 2014]) would begin to be effective in naturally reducing the mosquito population (i.e., 1 to 2 years), CCPH may decide to pre-treat with a time-release (effective up to 40 days) formulation of *Bti* before larvae are detected to maintain control and reduce the likelihood of needing to use methoprene or CocoBear™ later (see below).

Phase 3: Phase 3 is triggered when either (1) the pre-determined (by CCPH) threshold for late instar and pupal-stage mosquitoes has been reached; or (2) monitoring demonstrates that a pre-determined, large area of the Refuge is producing mosquitoes. Either of these scenarios indicates that monitoring had failed to detect the mosquitoes soon enough for effective early-stage larvicide treatment, or that unforeseen and extenuating circumstances made it impossible to execute a ground application in a timely manner. In this phase, application of early-stage larvicides would include ground or aerial application of time-release formulations of methoprene in breeding sites still dominated by early instar larvae.

Bti and methoprene are only effective on mosquitoes during larval instar stages (up to the fourth) and do not control pupae. Therefore, Phase 3 also includes the use of a 10% mineral oil larvicide (trade name CocoBear™; mfr. Clarke) that is effective at killing both larvae and pupae (see Section 4.2.1). Because CocoBear™ can negatively affect all aquatic invertebrates that require air, its application would be ground-based and spatially limited to pools less than ¼-acre in size that are known to be infested with late instar larvae or pupae (Figure 2-1) beyond pre-determined threshold levels (determined through monitoring).

Figure 2-1. Illustration of when during the life cycle of salt marsh mosquitoes application of the three larvicides that could be applied under the phased plan would be effective.
Mosquito life cycle diagram courtesy of Purdue Extension Service (http://extension.entm.purdue.edu/publichealth/resources.html).



2.2.2.2 Mosquito Threshold Treatment Levels

Action thresholds are mosquito population levels and/or levels of disease activity that, once reached, indicate an increased health risk and trigger additional response. In general, the level of threat or adverse impact to human health can be expected to be relatively static, changing only when monitoring data indicate significant changes in mosquito populations and/or disease activity. When monitoring data indicate an increasing risk to human and/or wildlife health, health threat/adverse impact levels may be increased. State/local public health authorities and vector control agencies would establish numerical (i.e., number of mosquitoes per sample) action thresholds based on current conditions.

Mosquito abundance action thresholds represent mosquito population levels that may require intervention measures or more intense surveillance. It is important to consider the limitations of such numerical action thresholds, especially in the context of minimizing disease transmission. Thresholds are developed considering many factors which include, but are not limited to, those listed in Table 2-2. Unfortunately, very few scientifically-determined estimates of mosquito abundance have been defined as threshold values for any mosquito species in the context of limiting disease transmission. Vector control agencies usually develop threshold values for their own immediate use based on years of experience. However useful such values are for limiting human annoyance from biting mosquitoes, these values often cannot be practically validated with respect to being accurate thresholds of disease transmission. Thus, in the absence of scientifically-determined threshold data, there would necessarily be some subjectivity in establishing numeric thresholds for mosquito abundance. Public health authorities and vector control agencies can use the factors identified in Table 2-2 as a guide in establishing numeric thresholds. Also note that numerical thresholds can be raised or lowered depending upon current conditions (e.g., environmental conditions, abundance of mosquito predators, presence of pathogens; see Table 2-2).

Thresholds would be species specific (or species-group specific) for larval, pupal, and adult mosquito vectors and reflect the potential significance of a particular species or group of species to a particular health threat or adverse impact. For example, mosquito vector species known to be important in the transmission cycle of a disease may have a lower action threshold than species with lesser transmission roles. Likewise, mosquito species known to cause non-disease health impacts to humans when in abundance may have lower action thresholds. Intervention measures would only be implemented when current mosquito population estimates, as determined by current mosquito monitoring data, meet or exceed action thresholds. Treatment thresholds for the Refuge would be determined by CCPH in consultation with the Service, as discussed above.

Table 2-2. Factors considered in establishing treatment thresholds for use of pesticides to control mosquitoes.

Factor	Description	Consideration
Mosquito species	Mosquito species vary in the following: ability to carry and transmit disease; flight distances; propensity to bite; feeding preference (birds, mammals, humans); seasonality; and type of breeding habitat (see Mosquito Biology, Appendix D).	These factors will be considered when establishing adult and larval thresholds along with spatial distribution by age. Often the species and biology of the mosquito will be more important in developing thresholds than their relative abundance.

Factor	Description	Consideration
Proximity to human populations	The distance from potential mosquito habitat on the Refuge to population centers (human numbers and density).	The potential to produce large numbers of mosquitoes in close proximity to population centers may result in less tolerance or lower thresholds for implementation of mosquito control on the Refuge.
Seasonality and weather patterns	Seasonal changes in prevailing wind patterns, precipitation, and temperatures.	Prevailing wind patterns that carry mosquitoes from refuge environments to population centers may require lower thresholds. Inclement weather conditions may prevent mosquitoes from moving off-refuge resulting in higher thresholds.
Cultural mosquito tolerance	The tolerance of different populations within proximity of the Refuge varies.	The Refuge lies within a rural area adjacent to a more urban area that exhibits lower thresholds (relative to other areas of the country) and a general intolerance to mosquitoes. Number of mosquito complaints is a factor.
Adults harbored, but not produced, on-refuge	Refuge may provide resting areas for adult mosquitoes produced in the surrounding landscape.	Threshold for mosquito management on the Refuge should be high with an emphasis for treatment of mosquito breeding habitat off -refuge.
Spatial extent of mosquito breeding habitat on and off the Refuge	The relative availability of mosquito habitat within the landscape that includes the Refuge. Until marsh restoration is complete, refuge habitat is extensive. Post-restoration breeding habitat would be substantially less.	If the Refuge is a primary breeding area for mosquitoes that likely affect human health (pre-restoration), thresholds may be lower. If refuge mosquito habitats are insignificant in the context of the landscape (post-restoration), thresholds may be higher.
Tidal cycles	The tides rise and fall twice daily in areas within the tidal zone. Spring tides bring higher than normal tide levels and result in increased flooding of the marsh plain, resulting in more breeding habitat.	Much of the land base of the Refuge lies within the tidal zone where spring tides can flood the marsh plain. Depressions that are filled by spring tides only may retain water during the lower tides and create mosquito habitat. Restoration would reduce these depressions.
Natural predator populations	Balanced predator-prey populations may limit mosquito production.	If refuge vertebrate and invertebrate prey populations are adequate to control mosquitoes, threshold for treatment should be higher.

Factor	Description	Consideration
Water quality	Water quality influences mosquito productivity.	High organic content in water may increase mosquito productivity, lower natural predator abundance, and may require lower thresholds.
History of mosquito borne diseases in area	Recent history indicates low disease incidence, but that could change.	Thresholds in areas with a history of mosquito-borne disease(s) are lower.

2.2.2.3 Pesticide Approval Process

As a result of its statutory authority under the Migratory Bird Treaty Act, the ESA, and Service policy, the Service is required to consider whether use of specific pesticides would harm trust species. Approval for use of a specific pesticide is based on a review of its history of adverse effects on non-target species and persistence in the environment, in a formal process initiated by preparation of a PUP.

The Refuge would prepare PUPs on an annual basis (in coordination with CCPH) for Service approval. The PUPs would include the larvicides discussed within this Plan/EA, or other larvicides manufactured in the future that offer greater efficacy and less non-target impacts (see Section 2.2.2.4). At the end of each calendar year, annual pesticide use reports would be prepared by the Refuge in coordination with CCPH, regardless of whether any larvicide was applied that year. To assist the Refuge in tracking mosquito management activities, CCPH would prepare an annual quantitative summary of refuge mosquito monitoring and surveillance results, control activities on the Refuge (e.g., larvicides applied, amount of larvicides applied, locations of application, method of application), and regional disease surveillance. The report would be accompanied by maps showing specific areas where management activities occurred. All surveillance and control activities would be spatially referenced based on GPS coordinates recorded by field technicians. Comparisons of mosquito management activities and results within and among years would be made and analyzed to permit evaluation of the efficacy of all management efforts, and the need for modification of the management approach.

2.2.2.4 Mosquito Control Pesticides

Mosquito control pesticides can be categorized into two groups: larvicides and adulticides. Modern adulticides are generally applied as fogs or atomized liquid sprays that are toxic to mosquitoes and other insects upon direct contact. Due to unavoidable non-target effects and the difficulty of treating highly mobile adult mosquitoes without large scale (i.e., beyond the refuge boundaries) application, adulticides would only be considered under a documented mosquito-borne disease outbreak that could not be controlled otherwise. The Service would respond to a mosquito-borne disease outbreak on refuge lands through its Disease Contingency Plan (USFWS 2007).

The use of larvicides would be approved subject to the appropriate level of review via the PUP process (see previous section), as articulated by the USFWS' Western Regions (1, 2, 6, 8) Pesticide Uses Granted Field Station Level Approval and the USFWS Headquarters Guidance for Pesticide Use Proposals (USFWS 2013b). Data from various sources (e.g., scientific literature, professional applicators) would be used to identify whether new preferred chemicals exist, as they become available. New control products would be considered for use on the Refuge based on their efficacy and environmental effects compared to those products identified in this Plan/EA.

The list of larvicide products proposed for use in the Preferred Alternative was developed after careful consideration of the choices available for least toxic, effective pesticides. A preliminary list of products provided by mosquito control experts was subjected to intensive scrutiny by Service toxicologists, who reviewed primary peer reviewed literature and EPA documents that characterize each larvicide formulation's mode of action, toxicity to salt marsh mosquitoes in estuaries, non-target effects, and environmental fate. The resulting list includes various formulations of the larvicidal bacteria *Bacillus thuringiensis israelensis* (*Bti*), and the synthetic insect growth regulator methoprene, which are both early-stage larvicides (i.e., effective on early larval stages of the mosquitoes). The list also includes another larvicide, CocoBear™, which is an oil film product effective on all mosquito larval and pupal stages, but would only be used if early-stage larvicides cannot be used, and is therefore referred to herein as a late-stage larvicide. A more detailed description of how these larvicides work and their environmental effects is in Chapter 4. The complete toxicology review of these products, including a screening-level ecological risk assessment of each product, and recommendations for application methods to minimize environmental risk, is in Appendix C.

Bti Products Considered for Use: We considered the *Bti*-based products in the following table (Table 2-3) for use at Bandon Marsh NWR. These choices were based on recommendations from several mosquito control experts familiar with the species of salt marsh mosquito and the environmental conditions within areas of the Refuge requiring treatment; their inclusion does not represent Service endorsement. Based on our evaluation of the literature (see Section 4.2.1), all *Bti* formulations considered (Table 2-3) were deemed appropriate for use at the Refuge.

Table 2-3. *Bti* products considered for use, with active content and application rates from product labels.

Product Name	EPA Registration Number	Active Ingredient (%)	Application Interval (days)	Application Rate (Lower)	Application Rate (Upper)	Application Rate (Max)
Solid and Granular Formulations				*(lbs product per acre)*		
Fourstar Bti CRG™	85685-4	10	40	7.5	10	20
Teknar G™	73049-403	1.7	7–14	2.5	10	20
Teknar CG™	73049-403	1.7	7–14	2.5	10	20
VectoBac GS™	73049-10	2.8	7–14	2.5	10	20
VectoBac GR™	73049-486	2.8	7–14	2.5	10	20
Vectobac G™	73049-10	2.8	7–14	2.5	10	20
AquaBac 200G™	62637-3	2.86	7–14	2.5	10	20
AquaBac 400G™	62637-1	5.71	7–14	5	8	8
Liquid Formulations				*(oz. product per acre)*		
Teknar SC™	73049-435	5.6	Not listed	4	32	32
Aquabac XT™	62637-1	8	Not listed	4	32	32
VectoBac 12AS™	73049-38	11.61	Not listed	4	32	32

Methoprene Products considered for use: We considered the methoprene-based products in the following table (Table 2-4) for use at Bandon Marsh NWR. As with *Bti*, these choices were based on recommendations from several mosquito control experts familiar with the species of mosquito (*Aedes dorsalis*) and the environmental conditions of areas requiring treatment at the Refuge.

CocoBear™. CocoBear™ is a 10% mineral oil product used for control of immature mosquitoes. It is considered an effective control agent that acts on the larval and pupal stage of mosquitoes to prevent adult mosquito emergence. This surface oil is effective against all immature stages by acting as a suffocant. It also disrupts the surface tension of water and prevents female mosquitoes from landing to lay eggs. For the purposes of this plan, CocoBear™ is referred to as a late-stage larvicide, only to be used on a small scale (i.e., pools less than ¼ acre in size) in situations where early-stage larvicides (i.e., *Bti*, methoprene) have not been, or would not be effective.

Table 1-4. Methoprene products considered for use, with label application rates.

Product Name	EPA Registration Number	S-methoprene (%)	Minimum Labeled Rate	Maximum Labeled Rate	"Polluted" Labeled Rate Polluted	Persistence (days, from label)
Solid and granular formulations			*(pounds per acre)*			
Altosid SBG™	2724-421	0.2	5	10	20	5–10 days
Altosid XR-G™	2724-427	1.5	5	10	20	several floodings
MetaLarv S-PT™	87276-7-53883	4.25	2.5	5	10	up to 42 days
Altosid Pellets™	2724-448	4.25	2.5	5	10	up to 30 days
Liquid formulations			*(ounces per acre)*			
Altosid Liquid Larvicide™	2724-392	5	3	4	Not Listed	Not Listed, reapply when control of mosquitoes stops
Altosid Liquid Larvicide Concentrate™	2724-446	20	0.75	1	Not Listed	Not Listed, reapply when control of mosquitoes stops

2.2.3 Alternative B: Mosquito Control without Synthetic Larvicides

Mosquito populations would be managed primarily through habitat modification where possible. Under this alternative, use of synthetic chemical larvicides (e.g. methoprene, CocoBear™) would not be permitted to reduce mosquito populations on the Refuge. *Bti* would be allowed to control larval mosquito populations. Mosquito populations would still need to exceed pre-determined (by CCPH) threshold levels prior to application of *Bti* larvicides. The only exception would be in 2014, when CCPH may decide to pre-treat with a time-release formulation of *Bti* before larvae are detected to maintain control (see Section 2.2.2.1). Improving tidal circulation or other alterations of the environmental features that contribute to production would be considered as preferred treatments. The Refuge and public health managers would work cooperatively to plan and permit proposed changes that do not significantly detract from or interfere with the purposes for the Refuge. If habitat modifications were not feasible, timely, or effective at controlling the mosquito production, an appropriate formulation of *Bti* would be applied aerially or with ground-based methods.

2.2.4 Alternative C: No Mosquito Larvicide Application

Under this alternative, mosquito population control using biorational (e.g., *Bti*) or synthetic chemical (e.g. methoprene, CocoBear™) larvicides would not be permitted or conducted on refuge lands. If approved, tidal marsh restoration would proceed, per actions identified in the draft Supplemental EA (USFWS 2014), with the goal of reducing mosquito populations to below treatment threshold levels.

2.2.5 Alternatives Summary

The table below summarizes the activities that would be permitted on the Refuge under each of the mosquito management alternatives.

Table 2-5. Summary of mosquito management activities permitted under each alternative.

Alternative	Monitoring of Mosquito Populations	Pesticides Permitted for Use[1]	Reduce Breeding Habitat	Access
A	Yes	Larvicide (early and late-stage, biorational and synthetic chemical)	Yes	Limited in sensitive species habitat.
B	Yes	*Bti* only (early-stage biorational)	Yes	Same as A
C	Yes	None	Yes	Same as A

[1]L = larvicides (*Bti*, methoprene, CocoBear™)

Chapter 3. Affected Environment

3.1 Physical Environment

3.1.1 Climate

The climate at Bandon Marsh NWR is greatly influenced by the Pacific Ocean on the west and the Coast Range to the east. The Coast Range rises between 2,000 and 3,000 feet above sea level in the north and between 3,000 and 4,000 feet in the southwestern portion of the state with occasional mountain peaks rising an additional 1,000 to 1,500 feet. The southern Oregon coastal zone is characterized by wet winters, relatively dry summers, and mild temperatures throughout the year. Because of the moderating influence of the Pacific Ocean, extremely high or low temperatures are rare and the annual temperature range is lower here than in any other Oregon climate zone. Precipitation is heavier and more persistent during the winter but regular moisture occurs from rain and fog throughout the year (WRCC 2011). The area's heavy precipitation during winter results from moist air masses moving from the Pacific Ocean onto land. The lower elevations along the coast receive annual precipitation of 65 to 90 inches, which can cause flood events if abundant rainfall is consistent for several days. Occasional strong winds (50–70 miles per hour) occur along the coast, usually in advance of winter storms. Wind speeds have been recorded to exceed hurricane force and have caused substantial damage to structures and vegetation in exposed coastal locations (Taylor and Hannan 1999, Taylor 2008). Skies are usually cloudy in the winter during the frequent storms and clear to partly cloudy during summer, with localized fog along the coastline. As a result of persistent cloudiness, total solar radiation is lower along the coast than in any other region of the state.

3.1.2 Topography

The topography of the Bandon Marsh NWR is largely flat, with most areas below 11 feet NAVD88 in elevation (OLC 2010) and within the intertidal zone of the estuary. The majority of the Bandon Marsh Unit is composed of intertidal areas which range from low marsh and mudflats exposed only at low tide, to high marsh inundated only at seasonally high tides combined with high river flows. Tidal sloughs drain into the river channel to the west. A natural levee, ranging from 7.5 to 9.0 feet NAVD88, fringes along the west and north boundaries with the Coquille River.

The topography of the Ni-les'tun Unit is generally sloping from the north to the Coquille River on the south. The northeastern section of the Unit, encompassing the upland grassland, refuge headquarters, bunkhouse, shop, and Ni-les'tun overlook is located on a marine terrace. The southern extent and lowest elevations of the marine terrace are found at the Ni-les'tun overlook. Marsh plain elevation of the restored salt marsh ranges from seven feet NAVD88 at the eastern end to five feet NAVD88 at the western end. Eighty percent of the restoration site is below seven feet NAVD88 (Mean Higher High Water). The natural levee along the river ranges from nine feet NAVD88 at the east (upstream) end to six and a half feet NAVD88 at the west (downstream) end (Ducks Unlimited 2009).

3.1.3 Soils and Geology

The northeastern section of the Ni-les'tun Unit, encompassing the upland grassland, refuge headquarters, bunkhouse, shop, and Ni-les'tun overlook, is located on the Whisky Run terrace (McInelly and Kelsey 1990). This relatively thick marine terrace (10–66 feet) is made up of deposited marine and stream sediment. The marine terrace rests atop the Otter Point formation which is composed primarily of sheared sedimentary rocks with smaller amount of volcanic material (Baldwin et al. 1973a).

Excluding the areas of the Refuge on the Whisky Run marine terrace, the remainder was formed following a series of sea level rise, subsidence, and uplift events. The current location of the Coquille estuary was under tidal influence by 7,000 years ago, forming a "drowned river" estuary. Gradual uplift in the period between earthquakes may also reduce the size of the estuary, but this effect is temporary, being offset by episodic subsidence during earthquakes (Nelson 1992, Nelson et al. 1995, Witter 1999, Byram and Witter 2000, Witter et al. 2003).

Infilling of the estuary and marsh development occurs as runoff from precipitation washes sediments from slopes into streams or their floodplains. These sediments are then transported downstream to the estuary where they settle and become influenced by tides (Simenstad 1983). Most of the present-day Refuge is located on this alluvium (Baldwin et al. 1973b). Much of the coarser sediment settles out near the banks of the river, forming natural levees. The finer materials remain suspended longer and settle throughout the intertidal zone and flooded lowlands. Additionally, sediments are moved into the lower estuary from the ocean shore by tsunamis, storm surges, and dune building.

The Bandon Marsh Unit has formed relatively recently (Baldwin et al. 1973a). Prior to 1895, most of the current marsh was open water according to early maps. Since that time it has grown due to rapid sediment accretion and minor dumping of dredge spoil along its external edge. The marsh occupies the inner bend of a meander of the river, and is typically an area for deposition of fine-grained sediments.

The entire Oregon coast is a tectonically active area that experiences massive earthquakes every 240 years, on average, when the land may subside 3.3 to 6.6 feet, and then subject the coast to large tsunami waves. The last such earthquake occurred in 1700 and with each passing year the odds of the next one happening increase (Atwater et al. 2005, Goldfinger et al. 2010). Obviously, the current landscape of the lower Coquille basin will change profoundly when the next large quake occurs.

3.1.4 Hydrology and Water Quality

The Bandon Marsh Unit currently consists of tidally influenced habitats, including salt marsh and mudflats, a narrow fringe of forested wetlands and upland forest along its east (landward) boundary, and a high marsh natural levee along its west and north boundary with the Coquille River. The entirety of the Unit is within the boundary of the 100-year floodplain. The intertidal marsh ranges from low marsh and mudflats exposed only at low tide, to high marsh inundated only at seasonally high tides combined with high river flows. Two small freshwater streams draining primarily residential and agricultural areas, Spring Creek and Simpson Creek, enter the marsh from the east. However, the hydrology is dominated by the ocean tides and the tidally influenced Coquille River, which enters the marsh via a network of tidal channels.

The Ni-les'tun Unit is bounded on the south and east by the tidally influenced Coquille River. The Unit consists largely of restored tidal marsh with small acreages of forested wetlands, natural tidal marsh, and riparian corridors. Except for the higher elevation areas, the majority of the Ni-les'tun Unit lies within the boundary of the 100-year floodplain. The tidal marsh restoration project initiated in 2009 and completed in 2011 filled and removed 15 miles of interior drainage ditches and channels, constructed 5 miles of tidal channels, lowered all of the artificial river levees, and removed tide gates, and water control structures to facilitate full tidal function of the Unit. Typically, the highest tides that cover the entire marsh occur in the winter when they combine with elevated winter river flows. The National Ocean Survey tidal benchmark information for the Coquille River in Bandon for the 1983–2001 period is summarized in Table 3-1.

Table 3-1. Tidal benchmark summary for Bandon, Oregon, at the Coquille River (NOAA 2014).

Station Information	Bandon, Coquille River Sta. ID 9419750
Mean Higher High Water (MHHW) (feet)	7.09
Mean High Water (MHW) (feet)	6.37
Mean Tide Level (MTL) (feet)	3.78
Mean Sea Level (MSL) (feet)	3.75
Mean Low Water (MLW) (feet)	1.19
North American Vertical Datum 1988 (NAVD88)	0.10
Mean Lower Low Water (MLLW)	0.00

Four small stream courses run through the Ni-les'tun Unit: Fahys Creek, Redd Creek, Blue Barn Creek (flowing into Redd), and No Name Creek. Prior to restoration, three of these creeks (Fahys, Redd, and No Name) were primarily tide-gated drainage ditches that dewatered the historic tidal and forested wetlands for agricultural purposes. Restoration, completed in 2011, re-connected the mouth of Fahys Creek to the Coquille River in its historical location and replaced the ditched and tide-gated portion of Redd Creek with a new excavated channel to connect the upland watershed drainage. No Name Creek was opened to tidal exchange through the removal of a tide gate. Now, No Name Creek is a tidally driven system without a continuous creek channel entering it. The freshwater input is primarily from subsurface discharge from the north marine terrace.

Mean salinities recorded for the Coquille River estuary at the location nearest to the Bandon Marsh Unit for January–March, April–June, and July–September are 8, 22, and 31 parts per thousand (ppt), respectively. At the mouth of Fahys Creek, adjacent to the Ni-les'tun Unit, mean salinities for January–March, April–June, and July–September are 1, 14, and 30 ppt (Hamilton 1984). These salinities can be considered the maximums along the gradients occurring through the respective marshes extending to the entirely fresh inputs in the upper marshes. These measurements indicate that during winter and spring, the freshwater flow down the Coquille River and its tributaries strongly limits the intrusion of marine water. Freshwater flow, measured at North, Middle, and South forks of the Coquille, is usually lowest in August and September and highest during January (Kraeg 1979).

No waters within the Bandon Marsh NWR boundary (i.e., Fahys, Redd, Blue Barn, and No Name creeks) were listed as impaired because these waters have not been assessed under the Section 303(d) of the Clean Water Act. However, the Coquille River adjacent to the Refuge was listed as impaired in the 2002 and 2004/2006 303(d) reporting cycles. The Coquille River was also listed as impaired in Oregon's 2010 Section 303(d) List of Category 5 Water Quality Limited Waters. Many parameters and beneficial uses are impaired on the Coquille River. Significant impairments include chlorophyll a, dissolved oxygen, fecal coliform, and temperature (ODEQ 2002, ODEQ 2006, ODEQ 2011).

3.1.5 Air Quality

The Oregon Department of Environmental Quality (ODEQ) does not have any ambient air quality monitoring stations located on the Oregon Coast. The majority of ODEQ's air quality monitoring stations is located within the interior valleys between the Coast and Cascade Mountain Ranges where the majority of Oregon's population resides. The lack of ambient air quality monitoring on the Oregon Coast makes it difficult to assess baseline air quality conditions.

Bandon Marsh NWR is located within the Oregon Coast Airshed which is generally well mixed year-round due to the influence of the Pacific Ocean. Low pressure systems move through the airshed throughout the year and usually bring wind, clouds, and rain. The intensity and frequency of these low pressure systems increases during the fall through winter resulting in sometimes very rainy and windy conditions. In between these low pressure systems, high pressure systems move in, resulting in drying trends. High pressure systems generally dominate the airshed during late spring, summer, and early fall. Coastal fog due to inland heating is common during the summer months. In general, the Oregon Coast Airshed remains relatively unstable resulting in a well-mixed atmosphere with suspected good air quality.

3.2 Biological Environment

Bandon Marsh NWR provides a variety of environments, each with its own characteristic set of flora and fauna. Environments throughout the lower Coquille estuary have been altered by past and current human actions including diking, draining, dredging, and agriculture. Today, land managers are working with interested partners towards enhancement and restoration of historic wetland environments of the Coquille River. These efforts provide opportunities to enhance or expand existing habitats for the benefit of wildlife, plants, and people. An important consideration moving forward is to ensure that the Refuge's actions do not enhance or create conditions in which mosquito populations increase above levels that create a health threat to the visiting public, adjacent landowners, and local communities.

3.2.1 Environments, Vegetation, and Associated Resources

Environments of the Refuge may be grouped into three types: (1) tidally-influenced habitats (Temperate Pacific Tidal Salt and Brackish Marsh, Temperate Pacific Intertidal Mudflat, and North Pacific Intertidal Freshwater Wetland), (2) non-tidal wetland and riparian habitat (North Pacific Hardwood-Conifer Swamp and North Pacific Lowland Riparian Forest and Shrubland), and (3) upland forests (North Pacific Hypermaritime Sitka Spruce Forest) (USFWS 2013a). Vegetation type descriptions according to the International Terrestrial Ecological System Classification under development by NatureServe and its natural heritage program members (Comer et al. 2003, NatureServe 2012) are listed in parentheses above. This Plan/EA's proposed action area is composed of tidally-influenced habitats. Tidally influenced habitats are of high ecological importance and are considered essential habitat for many marine and anadromous fish, crabs and other shellfish, and migratory birds (ODFW 2006, Seliskar and Gallagher 1983).

Salt marshes and estuaries occur where freshwater rivers meet the salty waters of the ocean. This dynamic habitat is greatly influenced by twice daily tidal flooding that affects the water levels, salinity, temperature, and the amounts of sunlight penetration, which in turn relates to oxygen levels. Salt marshes provide food and nursery areas for numerous young fish, crabs, shrimp, clams, and other invertebrates when flooded. Natural (un-diked) marshes provide numerous benefits including shoreline stability against wave and wind erosion; reduced flood peaks; trapping of nutrients, sediment, and pollutants; and sequestration of carbon. As one of the most productive ecosystems on earth, tidally influenced salt marshes are highly important to fish, wildlife, and society.

The only remaining large natural salt marshes in the lower Coquille watershed are located within Bandon Marsh NWR. The Refuge contains 650 acres of salt marsh. Plant species common in Refuge salt marsh include Lyngby's sedge (*Carex lyngbyei*), seashore saltgrass (*Distichlis spicata*), pickleweed (*Salicornia virginica*), Pacific silverweed (*Argentina pacifica*), and tufted hairgrass (*Deschampsia cespitosa*). These plants are associated with unaltered estuarine tidal wetlands in Oregon (USFWS 2006). Within the Ni-les'tun Unit there is a mixture of non-native species including creeping bentgrass (*Agrostis stolonifera*), tall fescue (*Festuca arundinacea*), and reed canarygrass (*Phalaris arundinacea*) and the native plant species also found within the unaltered Bandon Marsh Unit. As the marsh adjusts to post-restoration conditions, the proportion of non-native plant species has been declining (USFWS unpublished data).

Intertidal mudflats are largely unvegetated substrates flooded and exposed by tidal action. Each type of mudflat (sand, mud, gravel or combination of these) supports slightly different plant and animal communities. Algae and diatoms are the principal plant types; vascular plants are rare or absent. Species such as native eelgrass (*Zostera marina*) are rare within the lower Coquille estuary's mudflats, but bands of widgeon grass (*Ruppia maritima*) are common along the margins of the flats and bottoms of the channels. These native intertidal grasses and algae are important habitat components of mudflats for a multitude of native fishes; smaller forms of gastropods, bivalves and crustaceans (Swayne 2004); shorebirds; and waterfowl.

3.2.2 Threatened and Endangered Species

One goal of the Refuge System is "To conserve, restore where appropriate, and enhance all species of fish, wildlife, and plants that are endangered or threatened with becoming endangered." In the policy clarifying the mission of the Refuge System, it is stated, "We protect and manage candidate and proposed species to enhance their status and help preclude the need for listing." In accordance with this policy, the Service considered all species with federal or state status. Tables 3-2 and 3-3 list federal or state endangered and threatened species that are known or have the potential to occur on the Refuge. There are no listed reptiles, amphibians, invertebrates, or plants known or likely to occur on the Refuge.

Western snowy plovers (*Charadrius nivosus nivosus*) are found on open sandy beaches along the Oregon coast. A small breeding population occurs on the beach approximately 2–3 miles south of Bandon. Because of their preference for sandy substrates on the Oregon coast they are rarely found within estuaries here. In the Coquille River estuary, there is a single record of a bird observed in the Bandon Marsh Unit of the Refuge on August 14, 2002. There have been no observations of snowy plovers on the Ni-les'tun Unit pre- or post-restoration and suitable habitat is not present. Marbled murrelets (*Brachyramphus marmoratus*) may occasionally fly over the Refuge, but they have never been documented doing so, and they are not expected to use any refuge habitats.

Table 3-2. Federal or state listed bird species with the potential to occur within the project area.

Common Name	Scientific Name	Federal Status	State Status	Current Occurrence
Marbled murrelet	*Brachyramphus marmoratus*	Threatened	Threatened	Potential flyover
Western snowy plover	*Charadrius nivosus*	Threatened	Threatened	One recorded sighting on the Bandon Marsh Unit in 2002.

Of the three listed species of fish that may occur in the lower Coquille estuary (Table 3-3), only juvenile coho salmon have been documented to use the Refuge. Surveys have found coho throughout the tidal channels of the marsh when there is sufficient water of suitable temperatures, most of the year except June through September (Silver et al. 2012). Off-channel wintering habitat provided by the Refuge is considered very important for pre-smolts and smolts to enter the ocean in prime condition (ODFW 2007).

Table 3-3. Federal or state listed fish species known or with the potential to occur within the project area or in surrounding waters (Coquille River).

Common Name	Scientific Name	Federal Status	State Status	Current Occurrence on Refuge
Oregon Coast Coho salmon	*Oncorhynchus kisutch*	Threatened		Bandon Marsh and Ni-les'tun Units/Coquille River/coastal streams
Pacific smelt (eulachon)	*Thaleichthys pacificus*	Threatened		Coquille River (suspected)
Green sturgeon	*Acipenser medirostris*	Threatened		Coquille River (suspected)

3.2.3 Key Wildlife Species Supported

Bandon Marsh NWR provides habitat for a wide range of wildlife species. These environments provide feeding, resting, or breeding habitat for both resident and migratory species. The Refuge contains the largest remaining tracts of salt marsh in the Coquille River Estuary and is considered an important migratory stop-over site along the Pacific Coast for migrating shorebirds and waterfowl. The estuarine salt marsh and tidal flats of Bandon Marsh NWR contain rich beds of algae, marine invertebrates and plant life that support wading birds, thousands of migratory waterfowl and hundreds of thousands of shorebirds, which in turn provide an important prey base for numerous raptors (i.e., birds of prey) including the recently delisted bald eagle (*Haliaeetus leucocephalus*) and the peregrine falcon (*Falco peregrinus*) (Hodder and Graybill 1984, Castelein and Lauten 2007, USFWS unpublished data). Wading birds such as great blue heron (*Ardea herodias*) and great egret (*Ardea alba*), and shorebirds such as black-bellied plover (*Pluvialis squatarola*), killdeer (*Charadrius vociferous*), least sandpiper (*Calidris minutilla*) and western sandpiper (*Calidris mauri*), dunlin (*Calidris alpina*), and long-billed (*Limnodromus scolopaceus*) and short-billed dowitcher (*Limnodromus griseus*) make extensive use of the mudflats for foraging on macro-invertebrates and in some cases biofilm (Mathot et al. 2010, Skagen and Oman 1996).

Invertebrates such as snails, shrimp, clams, worms, and crabs are locally common or abundant (Simenstad 1983). The most common and important invertebrate species occupying the Bandon Marsh NWR mudflats include Dungeness crab (*Metacarcinus magister*), softshell clams (*Mya arenaria*), ghost shrimp (*Callianassa californiensis*), mud shrimp (*Upogebia pugettensis*), and a variety of worms (Rudy and Rudy 1983, USFWS unpublished data).

3.2.3.1 Birds

Bird use of the Ni-les'tun Unit has been monitored on a regular basis along an established sampling transect from November 2009 until late August 2013 (USFWS unpublished data). Based on systematic observations made throughout this period, Table 3-4 lists the species of birds potentially present in the treatment area during the mosquito treatment season from March through September. Species listed as likely have been directly observed during this season in recent years. Those listed as unlikely could be present but are rarely seen in this season. The majority of the birds present at these times are transitory migrants, such as shorebirds and some waterfowl, and summer residents, such as other waterfowl, raptors, waders, and passerines.

Table 3-4. Birds known or likely to be present in tidal marsh habitat of the Ni-les'tun Unit (USFWS unpublished data).

Common Name	Scientific Name	Likely	Unlikely
Aleutian Canada goose	*Branta canadensis leucopareia*	X	
American coot	*Fulica americana*	X	
American crow	*Corvus brachyrhynchos*	X	
American goldfinch	*Carduelis tristis*	X	
American kestrel	*Galco sparverius*	X	
American pipit	*Anthus rubescens*	X	
American robin	*Turdus migratorius*	X	
American wigeon	*Anas americana*	X	
Bald eagle	*Haliaeetus leucocephalus*	X	
Barn swallow	*Hirundo rustica*	X	
Belted kingfisher	*Ceryle alcyon*	X	
Black phoebe	*Sayornis nigricans*	X	
Black-bellied plover	*Pluvialis squatarola*	X	
Black-capped chickadee	*Poecile atricapilla*		X
Brewer's blackbird	*Euphagus cyanocephalus*	X	
California gull	*Larus californicus*	X	
Caspian tern	*Sterna caspia*	X	
Cliff swallow	*Petrochelidon pyrrhonota*	X	
Common raven	*Corvus corax*	X	
Common yellowthroat	*Geothlypis trichas*	X	
Coopers hawk	*Accipiter cooperii*		X
Double-crested cormorant	*Phalacrocorax auritus*	X	
Dunlin	*Calidris alpina*	X	
European starling	*Sturnus vulgaris*		X

Common Name	Scientific Name	Likely	Unlikely
Gadwall	*Anas strepera*		X
Great blue heron	*Ardea herodias*	X	
Great egret	*Ardea alba*	X	
Greater white-fronted goose	*Anser albifrons*		X
Greater yellowlegs	*Tringa melanoleuca*	X	
Green-winged teal	*Anas crecca*	X	
Hooded merganser	*Lophodytes cucullatus*		X
Killdeer	*Charadrius vociferus*	X	
Lapland longspur	*Calcarius lapponicus*		X
Least sandpiper	*Calidris minutilla*	X	
Lesser yellowlegs	*Tringa flavipes*		X
Lincoln's sparrow	*Melospiza lincolnii*	X	
Long-billed dowitcher	*Limnodromus scolopaceus*	X	
Mallard	*Anas platyrhynchos*	X	
Marsh wren	*Cistothorus palustris*	X	
Merlin	*Falco columbarius*		X
Northern flicker	*Colaptes auratus*	X	
Northern harrier	*Circus cyaneus*	X	
Northern pintail	*Anas acuta*	X	
Pectoral sandpiper	*Calidris melanotos*		X
Peregrine falcon	*Falco peregrinus*	X	
Purple martin	*Progne subis*	X	
Red-shouldered hawk	*Buteo lineatus*	X	
Red-tailed hawk	*Buteo jamaicensis*	X	
Red-winged blackbird	*Agelaius phoeniceus*		X
Savannah sparrow	*Passerculus sandwichensis*	X	
Scaup sp.	*Aythya* sp.		X
Semipalmated plover	*Charadrius semipalmatus*	X	
Sharp-shinned hawk	*Accipiter striatus*		X
Short-billed dowitcher	*Limnodromus griseus*	X	
Short-eared owl	*Asio flammeus*		X
Solitary sandpiper	*Tringa solitaria*		X
Song sparrow	*Melospiza melodia*	X	
Spotted sandpiper	*Actitis macularia*	X	
Tree swallow	*Tachycineta bicolor*	X	
Turkey vulture	*Cathartes aura*	X	
Violet-green swallow	*Tachycineta thalassina*	X	
Virginia rail	*Rallus limicola*	X	
Western Canada goose	*Branta canadensis moffitti*	X	
Western gull	*Larus occidentalis*	X	

Common Name	Scientific Name	Likely	Unlikely
Western meadowlark	*Sturnella neglecta*	X	
Western snowy plover	*Charadrius nivosus nivosus*		X
Western sandpiper	*Calidris mauri*	X	
White-crowned sparrow	*Zonotrichia leucophrys*	X	
White-tailed kite	*Elanus leucurus*	X	
Wilson's snipe	*Gallinago delicata*	X	
Wood duck	*Aix sponsa*		X

3.2.3.2 Mammals

No formal survey of mammal use of the Bandon Marsh NWR has been conducted, but species that have been observed using the marsh by Refuge personnel are listed in Table 3-5. Probably the most abundant and widespread mammal is Townsend's vole (*Microtus townsendii)*, which uses the dense vegetation in the higher parts of the marsh. Raccoon (*Procyon lotor*) and mink (*Mustela vison)* are common medium-sized mammals based on the frequency with which their tracks are seen. Beaver (*Castor canadensis)*, muskrat (*Ondatra zibethicus*), and nutria (*Myocastor coypus*) are present but rarely observed, and probably occur in very low numbers, likewise for black-tailed deer (*Odocoileus hemionus columbianus*) and coyote (*Canis latrans*). Harbor seals (*Phoca vitulina*) forage within the waters that are present over the marsh/mudflats when they are inundated at high tide and in the lower Bandon Marsh Unit, they haul out on the low marsh edges to rest during the day.

Table 3-5. Mammals observed in tidal marsh habitat of Bandon Marsh NWR (USFWS unpublished data).

Common Name	Scientific Name
Black-tailed deer	*Odocoileus hemionus columbianus*
Beaver	*Castor canadensis*
Big brown bat	*Eptesicus fuscus*
Black rat	*Rattus rattus*
Brush rabbit	*Sylvilagus bachmani*
California myotis	*Myotis californicus*
Coyote	*Canis latrans*
Fog shreq	*Sorex sonomae*
Harbor seal	*Phoca vitulina*
Little brown bat	*Myotis lucifugus*
Long-eared myotis	*Myotis evotis*
Marsh shrew	*Sorex bendirii*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethicus*
Norway rat	*Rattus norvegicus*
Nutria	*Myocaster coypus*
Opossum	*Didelphis virginiana*

Common Name	**Scientific Name**
Raccoon	*Procyon lotor*
River otter	*Lontra canadensis*
Short-tailed weasel	*Mustela erminea*
Silver-haired bat	*Lasionycteris noctivagans*
Spotted skunk	*Spilogale gracilis*
Striped skunk	*Mephitis mephitis*
Townsend's mole	*Scapanus townsendii*
Townsend's vole	*Microtus townsendii*
Yuma myotis	*Myotis yumanensis*

3.2.3.3 Reptiles and Amphibians

The few representatives of these taxa are generally restricted to the forested wetland fringes of the Bandon Marsh NWR where fresh water dominates. Species observed near tidal marsh habitat are listed in Table 3-6.

Table 3-6. Reptiles and amphibians near tidal marsh habitat of Bandon Marsh NWR (USFWS unpublished data).

Common Name	**Scientific Name**
Northwestern salamander	*Ambystoma gracile*
Northwestern garter snake	*Thamnophis ordinoides*
Pacific tree frog	*Pseudacris regilla*
Red-legged frog	*Rana aurora*
Rough-skinned newt	*Taricha granulose*
Southern alligator lizard	*Elgaria multcarinata*

3.2.3.4 Fish

Fish use of waters within Bandon Marsh NWR has been monitored via regular sampling throughout the year by USFWS staff and a research cooperator as part of the restoration efficacy monitoring program that ended in late September 2013. This has included sampling along permanent streams flowing through the marsh, tidal channels, and the mainstem of the Coquille River. In general, these investigations show the return of many species and an increased use of the restored marsh channels by salmonids and other estuarine species such as surf smelt (*Hypomesus pretiosus)*, surf perch (*Cymatogaster aggregate)*, and starry flounder *(Platichthys stellatus)*. Within the Bandon Marsh NWR, juvenile coho and Chinook salmon have been observed in the tributaries and estuary waters of the lower Coquille River. No known salmon spawning habitat is within creeks on the Refuge. Surveys from 2005–2013 of Redd, No Name, and Fahys creeks in the Ni-les'tun Unit and Spring and Shipwreck creeks in the Bandon Marsh Unit documented the year-round presence of juvenile coho and Chinook salmon (Hudson et al. 2010, Silver et al. 2012, van de Wetering unpublished data).

Bandon Marsh NWR provides spawning and rearing habitat for coastal cutthroat trout. Surveys from 2005–2013 of Redd, No Name, and Fahys creeks documented the year-round presence of adult and juvenile coastal cutthroat trout (Hudson et al. 2010, USFWS unpublished data). Cutthroat trout spawning redds were observed in 2012 in the recently restored (2011) portion of Fahys Creek both on- and off- refuge (Chris Claire, ODFW, pers. comm.). In addition, spawning habitat is suspected to occur on off-refuge lands, including within Simpson, Spring, Fahys and Redd creeks.

However, very low numbers of salmonids occur within the marsh during the summer season due to seasonally warm water temperatures. Table 3-7 lists all fish species known or likely to be present in Bandon Marsh NWR.

Table 3-7. Fish known or with the potential to occur within Bandon Marsh NWR.

Common Name	Scientific Name	Known	Potential
American shad (non-native)	*Alosa sapidissima*	X	
Black bullhead (non-native)	*Ictalurus melas*	X	
Bluegill (non-native)	*Lepomis macrochirus*	X	
Brown bullhead (non-native)	*Ictalurus nebulosus*	X	
Chinook salmon	*Oncorhynchus tshawytsha*	X	
Coastal cutthroat trout	*Oncorhynchus clarki*	X	
Coho salmon	*Oncorhnchus kisutch*	X	
Common carp	*Cyprinus carpio*	X	
Eulachon	*Thaleichthys pacificus*		X
Green sturgeon	*Acipenser medirostris*		X
Largemouth bass (non-native)	*Micropterus salmodes*	X	
Mosquitofish (non-native)	*Gambusia affinis*	X	
Northern anchovy	*Engraulis mordax*	X	
Pacific staghorn sculpin	*Leptocottus armatus*	X	
Prickley sculpin	*Cottus asper*	X	
Saddleback gunnel	*Pholis ornata*	X	
Shiner surfperch	*Cymatogaster aggregate*	X	
Small mouth bass (non-native)	*Micropterus dolomieu*	X	
Starry flounder	*Platichthys stellatus*	X	
Steelhead trout	*Oncorhynchus mykiss*	X	
Surf smelt	*Hypomesus pretiosus*	X	
Threespine stickleback	*Gasterosteus aculeatus*	X	
Whitebait smelt	*Allosmerus elongatus*		X

One introduced species, the mosquitofish (*Gambusia affinis*), is a commonly used biological control for mosquitoes. Historically, mosquitofish were introduced into the Coquille River watershed. Since then, the species has spread into streams throughout the watershed including Bandon Marsh NWR. Due to this species' intolerance of saline conditions, it is restricted to more freshwater habitat of the Refuge found along the fringing forested wetland or marine terrace seepage areas.

3.2.4.5 Invertebrates

Invertebrates are considered an important component of any habitat, including tidal ecosystems. Despite their importance to ecosystems as a whole, little is known about the ecology and biology of invertebrates (excepting mosquitoes) within Bandon Marsh NWR. A detailed understanding of how terrestrial and aquatic invertebrates contribute to the success of other estuarine organisms (e.g., plants, wildlife) is lacking. However, some systematic sampling of aquatic invertebrates has occurred on the Refuge as part of fish use studies in recent years, and Table 3-8 lists those taxa that have been identified. These data show that tidal marsh provides habitat for a wide variety of invertebrates including crab, shrimp, mussels, clams, snails, amphipods, worms, spiders, and insects.

Table 3-8. Estuarine invertebrates identified within Bandon Marsh NWR (USFWS unpublished data).

Taxa	Common Name
Amphipoda	scuds
Brachyura	crab, Dungeness crab
Caridea	grass shrimp
Cnidaria	jellies
Gastropoda	snails
Insecta:	
Coleoptera	diving beetles
Diptera	mosquito, midge, other flies
Hemiptera	water boatmen
Megaloptera	fishflies
Odonata	damselflies and dragonflies
Isopoda	isopod
Nematode	round worms
Oligochaeta	marine worms
Polychaeta	bristle worms
Veneroida	clams

Mosquitoes: Mosquitoes are typical nematoceran dipterans with aquatic immature stages and aerial adult stages. Eggs must come in contact with water in order to survive. Mosquitoes have four larval stages (instars) and one aquatic pupal stage. The aerial adult emerges from the pupal stage onto the surface of the water, expands its wings, hardens its exoskeleton, and flies off. In general, it takes from 4–30 days for a mosquito to complete its life cycle, depending on seasonal and environmental factors and the species of mosquito (Alameda Mosquito Abatement District 2014). The biology, vector and potential, and pest ability of each mosquito species is different and influences decisions concerning control strategies. A more detailed account of mosquito biology and vector capabilities is presented in Appendix D.

Five species of mosquito were identified on Bandon Marsh NWR during the summer of 2013 (USFWS 2013c). The species included: *Aedes dorsalis, Aedes sticticus, Aedes cinereus, Culiseta particeps,* and *Culex tarsalis*. The most common (approximately 90% of all mosquitoes sampled and identified) and problematic mosquito species breeding within Bandon Marsh NWR (Ni-les'tun Unit) is the summer salt marsh mosquito. A multivoltine (producing multiple broods in a single season) species, it can produce numerous generations from flooding tides between April and October. Early work by Telford (1958) found that 12 broods and approximately eight generations occurred during one breeding season, though the number of generations per year does vary with respect to weather and tidal conditions. Eggs can remain viable for many years with only part of any given brood hatching during any single flooding event. Shallow pools of water filled by the highest tides of each month were found to be providing breeding habitat for salt marsh mosquitoes at extremely high levels in 2013. Adult dispersal paths are random, but they favor grassy areas for resting. Adults are aggressive day biting mosquitoes that have been found capable of traveling distances of more than 30 miles (Rees and Nielsen 1947). Western equine encephalitis, St. Louis encephalitis, and California encephalitis have been isolated from wild-caught *Aedes dorsalis* (Carpenter and LaCasse 1955, Randolph and Hardy 1988). Laboratory tests have demonstrated that the species is a potential vector of West Nile Virus (Goddard et al. 2002).

3.2.4 Noxious Plants and Exotic Animals

Historic use of the Coquille River and southern Oregon estuaries for the maritime industries and aquaculture has introduced and been a vector for the transport of marine invasive species which threaten the biological diversity of Bandon Marsh (Bax et al. 2003). Invasive plants and invertebrates such as Japanese eelgrass (*Zostera japonica*), smooth cordgrass (*Spartina alterniflora*), Asian tunicate (*Styela clava*), lacy crust bryozoan (*Conopeum tenuissimum*), Japanese orange-striped sea anemone (*Diadumene lineata*), Harris mud crab (*Rhithropanopeus harrisii*), European green crab (*Carcinus maenas*), Chinese mitten crab (*Eriocheir sinensis*), New Zealand burrowing isopod (*Sphaeroma quoianum*), New Zealand mud snail (*Potamopyrgus antipodarum*), Griffen's isopod (*Orthione griffenis*), and a variety of Asian and eastern United States clams have been recorded within the southern Oregon estuaries and within the lower Coquille River watershed and may occur on the Refuge (Dudoit 2006, Bilderback and Bilderback personal communication, Davidson et al. 2007, USGS 2009).

Non-native mammals that occur or have the potential to occur include feral cats (*Felis catus*) and dogs (*Canis lupus familiaris*), Norway (*Rattus norvegicus*) and black rats (*Rattus rattus*), house mouse (*Mus musculus*), nutria, and opossum (*Didelphis virginiana*) (Table 3-5; USFWS unpublished data). Non-native fish known or likely on the Refuge include mosquitofish, brown (*Ictalurus nebulosus*) and black bullhead (*Ictalurus melas*), largemouth (*Micropterus salmodes*) and smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), American shad (*Alosa sapidissima*), and bluegill (*Lepomis macrochirus*) (Table 3-7).

3.3 Human Environment

3.3.1 Cultural Resources

The Coquille River native people (the Nasomah) hunted, fished, and created river shoreline settlements for thousands of years (Byram and Shindruk 2010, Tveskov and Cohen 2007). The Coquille River provided native people a convenient transportation route to inland resources and access to the sea. Tributary streams and river side marshes were ideal locations for the use of fish traps or weirs (Byram 2002). Marsh and estuarine habitats have abundant waterfowl and adjacent dry uplands were suitable for constructing living quarters, hunting of land mammals and birds, and gathering of roots and berries. The banks of the lower Coquille River provided prime locations for prehistoric Native American villages and food procurement locations (Byram and Witter 2000).

The earliest Euro-American inhabitants of the Coquille River watershed were believed to be fur trappers, traders, and explorers. The first settlers established the present town site of Bandon in 1853. As the Euro-American population increased, it moved away from fur trading and diversified into fishing, forestry, and agriculture. In the early 1880s, the first cranberry bogs were planted in the area. Riparian timber was logged and the lowland areas were diked, drained, and then cleared for pasture and crop production. Upland forested areas were harvested and logs were transported by water using splash damming of streams, and by roads. The hydrology of the riverine and tidally influenced portion of the Coquille River was altered by dredging and maintenance for commerce and travel. Historic commerce activities in the lower Coquille River in the proximity of the town of Prosper, south of Bandon Marsh NWR's Ni-les'tun Unit, consisted of shipyards, lumber mills, salmon canneries, schools, and residential buildings (Byram and Shindruk 2010, Reid and Stroud 2003).

Within the approved boundary of the Bandon Marsh NWR, there are several recorded archaeological sites. Two of the sites are documented long-term occupation locations. Three sites have major midden components that may indicate occupation or food processing locations. The rest are single fish weirs or a complex of weirs in a discrete location. This pattern and density of sites extends both up and down river from the Refuge (Byram and Shindruk 2010, Byram et al. 2014).

3.3.2 Socioeconomics and Environmental Justice

The proposed project area is located along the southern Oregon coast in Coos County, approximately two miles north of the city of Bandon. Based on 2009 population data, Coos County has an estimated population of approximately 62,800 people (U.S. Department of Commerce 2011). From 1999 to 2009, the county population decreased by 0.3 percent, compared with an 11 percent increase for the entire state, and a 10 percent increase for the U.S. overall. County employment increased by two percent from 1999 to 2009, compared to an eight percent increase for the state, and an eight percent increase for the U.S. From 1999 to 2009, per capita income in Coos County increased by 13 percent, while Oregon and the U.S. increased by 4 and 9 percent respectively (U.S. Department of Commerce 2011). The population of Bandon decreased from 3,066 residents in 2010 to an estimated 3,046 residents in 2012 (U.S. Census Bureau 2013).

The largest industry sectors of Coos County include Local Government, Health Care and Social Assistance, and Retail Trade. The Coos County economy is also dependent on forestry products, fishing, agriculture, and tourism. As the economy shifts away from manufacturing forestry products, it is moving toward the service industry in support of its tourism industry. The largest employer is the combined state and local government. Natural resource-based industries (logging, sawmills, and support activities for agriculture and logging) totaled 1,890 jobs. Food services, retail stores, and hotels, which are impacted by refuge visitation, are also important contributors to the economy (3,899 jobs) (Minnesota IMPLAN Group, Inc. 2008).

Approximately 144,077 acres of Coos County was classified as farmland in 2007, a 13 percent decrease from 1997 (USDA 2007). In accordance with provisions of the Refuge Revenue Sharing Act, the Service makes annual payments to Coos County based on the appraised value of refuge lands and facilities. The 2012 refuge payment to Coos County for Bandon Marsh Refuge was $3,669. In 2010 there were roughly 4,800 visits to the Refuge (including both the Ni-les'tun and Bandon

Marsh units) and it was estimated that these users spent about $73,600 in the local community (USFWS 2013a).

3.3.3 Land Use

The Refuge was established "for the preservation and enhancement of the highly significant wildlife habitat of area known as Bandon Marsh, in the estuary of the Coquille River in the state of Oregon, for the protection of migratory waterfowl, numerous species of shorebirds and fish, including Chinook and silver salmon, and to provide opportunity for wildlife-oriented recreation and nature study on the marsh." The Refuge consists of 889 acres of lands managed to provide habitat for a variety of estuary-dependent and migratory wildlife species. The Service manages the Refuge consistent with the refuge missions and policies described in Section 1.2. Other than refuge approved recreational activities and operation and maintenance activities, no other land use exists on the Refuge. Management of this refuge has centered on protecting, improving, and increasing the amount of wetland habitat available for the residential wildlife species, estuarine-dependent fish, threatened and endangered species, and the thousands of waterfowl and tens of thousands of shorebirds that migrate and winter in the lower Coquille estuary.

Public Use of the Refuge: Several levels of public use occur on the Refuge, ranging from no activity in closed areas to seasonal waterfowl hunting, wildlife observation, photography, and interpretation. Over 4,700 people visit the Bandon Marsh NWR annually for the purposes of the annual shorebird festival, environmental education, waterfowl hunting, clamming and bird watching, and to hike the marsh trail at the Ni-les'tun overlook (USFWS 2013a). A large percentage of the Refuge is open to public access by foot or boat seasonally throughout most of the year.

Surrounding Land Uses: Bandon Marsh NWR is located within the long and narrow Coquille River estuary in Coos County along the southern Oregon Coast. Two cities are located on the shores of this estuary: Bandon (population about 3,000) is at the mouth, and Coquille (population about 3,800) about 19 miles upstream. The Bandon Marsh Unit is bordered by the Coquille River to the north and west, Riverside Drive to the east, and by tidal marsh and mudflats to the south. The North Spit of the Coquille River, including Bullards Beach State Park, is directly across the river from the Bandon Marsh Unit. The southernmost portions of the Bandon Marsh Unit are also within Bandon city limits. The Ni-les'tun Unit is on the north bank of the Coquille River and bounded by U.S. Highway 101 to the west; North Bank Lane, East Fahy Road, and a quarry, small tracts of rural residential, or forestland to the north; and private muted tidal marsh to the east. There are numerous homes, farms, and businesses immediately adjacent to the Refuge that would be affected by refuge management, with respect to habitat enhancement that would affect on-refuge mosquito production.

The estuary has historically been the hub of agriculture, navigation, commerce, recreation, and fisheries in the Coquille River Valley. Forest products, tourism, fishing and agriculture dominate the Coos County economy. Consequently, the forested uplands have historically been utilized for timber production and cranberry operations, while the alluvial valleys support agricultural operations, including beef, sheep, and dairy production.

3.3.4 Human Health and Safety Concerns

Coos County does not have a mosquito abatement district that is funded through taxes and fees to provide a service to the residents of the Bandon area. The control of mosquitoes has not been conducted by the county in the past because health threats (e.g., mosquito-borne diseases) or adverse impact (e.g., non-disease human health impacts) have not been a major concern in this area. Due to this lack of need, little to no background data is available on mosquito-borne diseases in Coos County (Rick Hallmark, Coos County Public Health Department, personal communication 2012). The Coos County Public Health Department staff received numerous requests for mosquito relief in the summer of 2013 and responded to documented allergic reactions from bites and public distress by issuing a health advisory and subsequently working with the Service to treat larval mosquitoes on the Ni-les'tun Unit of Bandon Marsh NWR (USFWS 2013c).

Below is a summary of the types of mosquito-borne diseases that have occurred in western Oregon in the past and have the potential to occur in the future. Though, it is important to note that mosquito bites can adversely impact human health, even in the absence of any pathogenic organism (see Section 1.3.1).

3.3.4.1 West Nile Virus (WNV)

Despite the number of human infections, WNV is primarily a wildlife disease. The virus is spread by mosquitoes from bird to bird. Mammals, including humans, are only incidentally infected. This may change as new mosquito vectors are identified. The transmission cycle initially involves only birds and is infectious for only three to five days. WNV is especially virulent in elderly and those with a compromised immune system. Although the potential to carry WNV is being detected in additional species of mosquitoes, the freshwater *Culex tarsalis* is still the primary transmission vector. WNV is the only documented primary mosquito-borne diseases known to occur in Coos County (Rick Hallmark, Coos County Public Health, personal communication 2012). One human case of WNV was documented in the city of Bandon in 2012; however, the location of where the individual contracted the disease is unclear (Rick Hallmark, Coos County Health Department, personal communication 2014). In addition, statewide surveys are conducted in order to detect the presence of WNV in mosquito and bird populations. In recent years, WNV has become more prevalent within the eastern portion of the state of Oregon. As Oregon moves to a more global economy and lifestyle, the potential for outbreaks of mosquito-borne diseases imported from other countries is likely to increase.

3.3.4.2 Malaria

Historic documents concerning mosquitoes and mosquito-borne diseases in Oregon focus on the presence of malaria and large nuisance populations of mosquitoes affecting the first immigrants and settlers. The most severe mosquito disease and pest outbreaks of the 1800s occurred in the Columbia River region and Willamette Valley of Oregon (Kohn 2008). In the mid-1920s mosquito control focused around problem areas of the Columbia and Willamette Rivers adjacent to the City of Portland (USDA 1972). Malaria was most likely never a major issue along the coastal areas probably because the climate was not sufficiently warm for a continuous period of time.

Malaria is caused by a blood parasite (*Plasmodium*) that is transmitted by mosquitoes. Immigrants and visitors from countries where malaria is endemic may act as parasite reservoirs and import the disease. In the Coos County area, mosquitoes are not monitored for the presence of malaria. Instead, the counties rely on state health departments to notify them of apparent malaria cases.

3.3.5 Aesthetics

3.3.5.1 Scenery

Numerous studies have attempted to assign economic benefits to wetlands and open space, but it is extremely difficult to quantify the value of scenery for aesthetic purposes. The draw and attachment that residents and visitors have for the southern Oregon coast area is largely due to the beauty of the remote beaches and the large amounts of open space created by local estuaries. Bandon Marsh NWR contributes to the aesthetic value of the city of Bandon with its large tracts of wetlands and undeveloped open space. Refuge wetlands support fish important to sport and commercial fisheries, improve water and air quality, help mitigate floods, support wildlife, and provide outdoor recreation opportunities. In addition, people enjoy wetlands for their beauty, wildness and solitude, and the constantly changing appearance due to the rise and fall of the tides.

3.3.5.2 Noise

Noise levels vary throughout the Refuge depending on proximity to roads and U.S. Highway 101 and adjacent land uses. The Refuge area is rural in nature and is generally outside of the Urban Growth Boundary of the city of Bandon. Human sources of sound include traffic on U.S. Highway 101, Riverside Drive, and North Bank Lane, motorized boat traffic on the Coquille River, aircraft overflights, and occasional target shooting or waterfowl hunting.

Chapter 4. Environmental Consequences

4.1 Overview of Effects Analysis

This chapter provides an analysis of the environmental consequences of implementing the alternatives described in Chapter 2. Impacts are described for the main aspects of the environments described in Chapter 3, including physical, biological, cultural, and socioeconomic resources. Refuge staff experience, existing databases and inventories, relevant plans, results of past and current research, and consultations with other professionals were used for this analysis. Considerations of the consequences of the proposed larvicides on biological resources relied heavily on the results and recommendations presented in the Toxicological Review and Environmental Effect Analysis included in Appendix C.

For the most part, boundaries for analysis of potential direct, indirect, and cumulative effects were at the project area level. Cumulative impacts, including impacts to refuge resources from reasonably foreseeable events and impacts resulting from interaction of refuge actions with actions taking place outside the Refuge, are addressed in the final section of this chapter. This analysis focuses on two aspects of each alternative – impacts associated with monitoring and surveillance activities, and impacts associated with larvicide application. The Refuge would adopt best management practices (BMPs), as articulated in this draft Plan/EA, which are designed to avoid or minimize potential environmental impacts.

The terms below were used to describe the scope, scale, and intensity of effects on natural, cultural, social (including recreational), and economic resources. Effects may be identified further as beneficial or negative.

Neutral or Negligible. Resources would not be affected (neutral effect) or the effects would be at or near the lowest level of detection (negligible effect). Resource conditions would not change or would be so slight there would not be any measurable or perceptible consequence to a population; fish, wildlife, or plant community, or other natural resources; recreation opportunity; visitor experience; or cultural resource. If a resource is not discussed, impacts to that resource are considered to be neutral.

Minor. Effects would be detectable within the Refuge, but localized, small, and of little consequence to a population; fish, wildlife, or plant community, or other natural resources; social and economic values, including recreational opportunity and visitor experience; or cultural resources. Mitigation, if needed to offset adverse effects, would be easily implemented and likely successful, based on knowledge and experience.

Moderate. Effects would be readily detectable and localized, with measurable consequences to a population; fish, wildlife or plant community, or other natural resources; social and economic values, including recreational opportunity and visitor experience; or cultural resources within the Refuge, but not readily detectable or measurable beyond the Refuge. Mitigation measures would likely be needed to offset adverse effects and could be extensive, moderately complicated to implement, and probably successful based on knowledge and experience.

Major (Significant). Region-wide effects would be obvious and would result in substantial consequences to a population; fish, wildlife, or plant community, or other natural resources; social and economic values including recreation opportunity and visitor experience; or cultural resources. Extensive mitigating measures may be needed to offset adverse effects and would be large-scale in nature, possibly complicated to implement, and may not have a high degree of probability for success. In some instances, major effects would include the irretrievable loss of the resource.

Time and duration of effects have been defined as:

Short-term or Temporary. An effect that generally would last less than a year or season.

Long-term. A change in a resource or its condition that would last longer than a single year or season.

4.2 Summary of Effects

4.2.1 General Effects of Proposed Mosquito Larvicides

The following information is based on, and contains excerpts from the Toxicological Review and Environmental Effects Analysis for Mosquito Larvicides Proposed for Use at Bandon Marsh National Wildlife Refuge presented in Appendix C. This toxicological report on the selected larvicides was prepared specifically for this Plan/EA, and is the basis for the assessments of the effects of the alternatives on each resource presented below.

4.2.1.1 Bacillus thuringiensis israelensis (Bti)

Bti is a bacterial toxin, classified by the EPA registration documents as a “Microbial Pesticide” (USEPA 1998), and is a variant of the common soil bacterium *Bacillus thuringiensis* (*Bt*). *Bti* has insecticidal activity against mosquitoes, black flies, and certain species of midge. *Bti* is a spore-forming bacterium that induces toxicity in insects via activation of a crystalline endotoxin contained within the bacterium. Activation of this toxin can only take place under specific conditions inside the gut of appropriate insect larva. Until the time of ingestion and transport to the gut, *Bti* is dormant in the environment and its toxin exists as an inactivated protoxin. The specificity of *Bti* to target hosts is believed to be due, in part, to the unusually alkaline gut of black flies and mosquitoes, with typical pH ranging from 10 to 12. A wide body of literature reveals no direct effects to other invertebrate or vertebrate species.

Bti has limited environmental persistence under most environmental conditions, but some literature does show it to persist or recycle in some cases. While initial toxicity (ability to be consumed by mosquito larvae) decreases quickly under most conditions, the actual spores and toxins can persist and accumulate under certain conditions. High amounts of organic matter (e.g., leaf litter) seem to encourage persistence. *Bti* has been shown to undergo rapid breakdown by sunlight and ultraviolet radiation (Glare and O’Callaghan 1988, Joung and Cote 2000, NPIC 2000). *Bti* also tends to adsorb to vegetation, organic, or other fine particulate matter in water within 3 to 4 days (NPIC 2000, Duchet et al. 2010). Once bacterial particles attach to soil particles, they lose their larvicidal activity (WHO 1999). *Bti* is relatively insensitive to variations in water pH (Glare and O’Callaghan 1988) and has been shown to be effective in salt and freshwater habitats. *Bti* is unlikely to contaminate groundwater, due to its high affinity for sediments and organic materials (NPIC 2000). *Bti* remains viable for longer in static than in moving water (WHO 1999), and is more effective at controlling target insects when water temperatures are higher.

General Bti Environmental Effects: According to the EPA, *Bti* does not pose risks to non-target birds, freshwater fish, freshwater aquatic invertebrates, estuarine and marine animals, arthropod predators/parasites, honey bees, annelids and mammalian wildlife or the environment when used according to label directions (USEPA 2007b). Lundstrőm et al. (2010) concluded that *Bti* did not reduce chironomid (midge) production in wetlands during a six year study and posed no risk to birds or other species that feed on chironomids. The EPA has not issued restrictions for use of *Bti* around water bodies, and at least one formulation (Vectobac GR™) is labeled for organic use. *Bti* is not likely to contaminate ground water. *Bti* gradually settles out or adheres to suspended organic matter. The use of *Bti* may result in temporary reductions in non-target insect populations, which has been shown in at least one instance to negatively affect bird (house martin; *Delichon urbica*) reproduction through reduced prey resources (Poulin et al. 2010). Nonetheless, insect populations have been shown to recover quickly after *Bti* treatment ceases (Lawler and Jensen 2000) and therefore *Bti* is not likely to affect insectivorous birds, mammals, or fish, as it is proposed for use at Bandon Marsh NWR. See Appendix C for a more comprehensive review of the direct and indirect environmental effects of *Bti*.

Persistence of Different Bti Formulations: The different *Bti* formulations may control mosquito larvae and remove them as potential prey items at different rates, which may result in different ecological effects of the different formulations. Whereas all of the liquid and single brood granular formulations are dosed to kill mosquito larvae quickly (e.g., 70–90% control in 24 hours and 100% control within 48 hours), the Fourstar *Bti* CRG™ product is designed to sustain lower levels of *Bti* in the aquatic environment for longer, thereby killing mosquito larvae more slowly. The more persistent *Bti* formulation (Fourstar *Bti* CRG™) may be applied to dry ground, prior to flooding, and will slowly release *Bti* through multiple wet/dry cycles (such as tidal cycles); it is labeled for 4 wetting cycles. The other products are not predicted to remain effective for mosquito control beyond one wet/dry cycle based on their label application rates and what is known about their environmental persistence. While all formulations of *Bti* are predicted to be safe for non-target organisms, the longer release Fourstar *Bti* CRG™ granules would be even less likely to have non-target effects on midges than the liquid products, due to the lower dose. The Fourstar *Bti* CRG™ granules are also less likely to have indirect food web effects than the higher dose formulations because they leave mosquito larvae as prey items in the system for longer.

Concerns with Bti Use at Bandon Marsh Refuge: There are virtually no concerns about direct toxicity of *Bti* to anything other than mosquitoes and possibly some species of chironomid midges at the Bandon Marsh Refuge. *Bti* has an excellent toxicity profile for use in sensitive habitats. The doses of *Bti* required to control chironomid species are several times higher than those required to control mosquitoes, therefore toxicity to non-target chironomid species is not anticipated with *Bti* applied at the labeled rates. Based on a review of the literature, concerns about use of *Bti* for mosquito control at Bandon Marsh are therefore limited to the reduction of mosquito larvae as prey items for other animals, specifically for the listed coho salmon, in its critical habitat. If treatment areas actually do overlap with listed coho salmon in space and time, and if mosquito larvae and adults are important prey items for salmon in Bandon Marsh, then the slow release formulation of *Bti*, (Fourstar *Bti* CRG™), would be preferred to shorter lasting *Bti* formulations. This slow release formulation is preferred because it is designed to provide a lower dose of *Bti* over a longer time period than other formulations and is therefore likely to retain mosquitoes in these habitats for longer (i.e., available to predators longer) than the *Bti* formulations that deliver a single pulse of a higher dose designed to kill mosquito larvae as quickly as possible. Although using an extended release formulation would result in a longer exposure to *Bti* to the environment at Bandon Marsh NWR, the toxicity profile of *Bti* is so benign and targeted towards mosquitoes, that deleterious effects to other species are not anticipated from its use.

Bti would be applied as directed on the label using recommended application rates. As with all products, application to tidally connected stream channels where salmon are likely to reside would be avoided during ground applications.

4.2.1.2 S-Methoprene (Methoprene)

Methoprene acts by mimicking a naturally-occurring insect growth regulating hormone (USEPA 1991) and due to this mode of action, was reclassified from a “chemical pesticide” to a “biochemical pesticide” in the EPA’s 1991 re-registration eligibility decision (USEPA 1991). A “biochemical pesticide” is defined by law (40 CFR 158.2000) by the following three properties: (1) It is a naturally-occurring substance or structurally-similar and functionally identical to a naturally-occurring substance; (2) It has a history of exposure to humans and the environment demonstrating minimal toxicity, or in the case of a synthetically-derived biochemical pesticide, is equivalent to a naturally-occurring substance that has such a history; and (3) It has a non-toxic mode of action to the target pest(s). Aquatic invertebrates can have either a complete or an incomplete life cycle; the latter does not have a pupal stage. In a normal complete life cycle, an invertebrate goes from egg to larva to pupa and then to adult. Methoprene inhibits this normal development by preventing maturation of the pupa to the adult reproductive stage. It does not interfere with larval mosquito growth, therefore its use as a mosquito larvicide will leave mosquito larvae in the aquatic system intact until they attempt to metamorphose, at which point they will die due to errors in development. Mammals, birds, fish, reptiles, and amphibians do not have this juvenile hormone nor share this biochemical pathway, which is what makes methoprene a fairly targeted insecticide.

General Methoprene Environmental Effects: Methoprene is essentially non-toxic to mammals, has some limited toxicity to birds, amphibians, and fish, and some toxicity to certain non-target invertebrates, probably because these invertebrates share the biochemical pathway on which methoprene acts in target organisms. Because hormones act on biological systems at exceedingly low levels, a very low concentration of methoprene is required in the environment to control target organisms. This fact, combined with its low toxicity to birds and mammals makes methoprene a reasonably attractive alternative to most other mosquito larvicides for most scenarios of use. Indeed methoprene has seen widespread global use since its initial commercialization as a pesticide in the mid-1970s. Methoprene has been shown to have some toxicity to certain other invertebrate species that use similar hormonal pathways for their development, such as marine crustaceans and some species of freshwater invertebrates. The toxicity to amphibians and fish in laboratory studies occurred at concentrations one to two orders of magnitude higher than the target environmental concentration of the formulated chemical sold for mosquito larvicide use. Specific studies of methoprene toxicity to non-target organisms, and how methoprene behaves in the environment are discussed in further detail in Appendix C.

Methoprene Target Specificity and Summary of Direct Effects to Non-target Invertebrates: The bulk of available literature suggests that methoprene is relatively safe for non-target invertebrate species when used in freshwater and marine habitats. Although sub-lethal chronic effects on endocrine systems and development have been shown to some non-target invertebrates, the majority of field and laboratory studies suggest that methoprene is one of the safest mosquito larvicides available, and effects to non-target invertebrate species are limited. Although toxicity has been found to invertebrates in laboratory studies, the levels of methoprene predicted to be lethal to even the most sensitive species are often an order of magnitude greater than predicted environmental concentrations when methoprene is used for mosquito control at the labeled application rates for natural habitats. Several studies supporting these conclusions are summarized in Appendix C.

Summary of Indirect Effects of Methoprene to Non-target Organisms: Several field studies have reported minimal effects to non-target invertebrate species with methoprene use. Several other studies, however, have suggested that increasing the duration of exposure may increase the likelihood of non-target indirect effects including depressing prey for predators such as fish. These studies are described in Appendix C. Although the various studies, taken as a whole, are inconclusive about the likelihood of indirect food-web effects occurring from the use of methoprene on the Refuge, the risk of such effects are clearly greater with longer duration formulations or repeated applications of methoprene that result in chronic exposure and potential cumulative effects of depressed populations of vulnerable invertebrate species. Of particular concern at the Refuge is the presence of juvenile coho salmon, and the possibility that methoprene application would depress food resources for them, although it is unknown to what degree invertebrates vulnerable to methoprene occur on the Refuge, or are important components of coho diet. Therefore, repeated use of long duration methoprene products would only occur if short duration formulations, or the ability to apply them in a timely manner, have been determined to be ineffective or unfeasible, respectively.

Persistence of Different Formulations and its Effects: Methoprene has been engineered into both rapid and slow release formulations as both liquids and granules for mosquito control. Both types of formulation (rapid and slow) and modes of delivery (liquids and granules) were evaluated in the toxicological review (Appendix C). The effects of formulation on environmental persistence of methoprene are summarized in this section.

All forms of methoprene used for mosquito control, including the less persistent formulations, employ some level of microencapsulation to enhance methoprene solubility and persistence in the environment. Yet the different formulations considered here range in anticipated longevity (according to their labeled application intervals) from 1–2 weeks to more than one month. Indeed, field studies that have examined the efficacy of some slow release methoprene formulations have found them to sometimes remain active for much longer than their label application interval implies. For example, Lawler and others (2000) found that Altosid™ pellets (Table 2-4) applied at a rate of 10.4 kg/ha (9.3 pounds per acre), and labeled for a 30-day application interval continued to control *A. dorsalis* mosquitoes for the entire duration of a 99-day study with just one application into a tidal salt marsh habitat in California.

All methoprene formulations considered here for mosquito control have the same target environmental concentration for the active ingredient in water. The concentration shown to be effective at controlling mosquitoes (the “effective concentration”) is below 1 µg methoprene per liter of water (µg /L=parts per billion or ppb). Several studies conducted by the EPA and others have shown this target concentration to be attained in microcosm studies, where concentrations measured in water after different formulations of methoprene were applied to microcosms were often below the analytical detection limits, that is, at concentrations below 1 µg methoprene per liter (1 ppb) (Ross et al. 1994). These studies were mandated by EPA in the 1991 re-registration eligibility decision (USEPA 1991) to verify that the pellet and other extended release granular formulations did not result in higher concentrations in the environment than did the liquids. Maximum environmental concentrations for formulations considered in this report (i.e. not briquettes) have been reported to range as high as 2.2 ppb, within a week of application at the higher labeled application rates (Ross et al. 1994). By comparison to the studies above, the environmental concentrations estimated in Table 4-1 are likely to be overestimates, relative to expected concentrations that may be found in the literature, and as such they are conservative and result in conservative estimates of screening level risk. A complete explanation of how these estimated environmental concentrations (EECs) relate to assessment of the potential risk posed by use of these products to each biological taxa is presented in Appendix C.

The Altosid™ liquid and single brood granule (SBG) formulations are the quick release formulations of methoprene (Table 2-4). These formulations (labeled for a 7–14 day application interval) are the most environmentally benign of the methoprene formulations considered here, because they have the shortest environmental persistence. If they are applied, for example, into salt marsh mosquito habitat as the monthly high tides recede (leaving breeding pools filled with water), it is likely that the methoprene would be degraded from the treatment area by the time the high tide returned to fill these pools again, and potentially spread it beyond the treatment area. The short duration of methoprene in the environment limits the duration of exposure in treated mosquito-bearing pools, which will limit its ability to produce chronic effects on non-target species. In addition, the returning tide also brings untreated water into the pool which would dilute any remaining methoprene concentration. Tidal dilution is expected to be considerable; for example, if tidal inundation of a previously isolated treated pool merely doubled the volume of water in the pool, this would halve the environmental concentration of methoprene. Despite this dilution potential, it is still preferable to keep methoprene in the treatment area, and these less persistent formulations provide the best opportunity to limit methoprene from moving into non-target areas during tidal cycles.

The Altosid™ extended release granules (Altosid XR-G™ formulation, Table 2-4) are designed for an intermediate level of environmental persistence; these are labeled for a 20-day application interval. The longer application interval limits the number of applications, thereby reducing applicator time and ensuring control of target mosquitoes for longer. More persistent formulations also reduce the risk of missing the developmental window during which mosquito larvae are sensitive to methoprene (generally the 4th instar) and limit physical habitat disturbance to the marsh if applied by ground-based methods. The Altosid XR-G™ formulation is labeled to be effective through "several floodings." Nevertheless, the increased persistence of this formulation may increase the risk to non-target organisms by increasing not the environmental concentrations, but rather the duration of methoprene exposure to non-targets.

Finally, the Altosid Pellets™ and Metalarv S-PT™ are the longest lasting methoprene formulations, labeled for 30 and 42 days, respectively. These formulations may release methoprene into the environment for substantially longer than the application interval recommended on the label, as other field studies have demonstrated mosquito control efficacy for up to 99 days when the longer lasting formulations are applied (Lawler and Jensen 2000). As with the intermediate formulation, Altosid XR-G™, these more persistent formulations would increase the duration of environmental methoprene exposure. Screening level risk calculations (Appendix C) done for this report for aquatic organisms do not account for exposure duration, however increased exposure time would increase the likelihood of observing the sublethal chronic effects, which require a longer time period to produce.

The formulation also affects the persistence of methoprene in a habitat through multiple wet/dry cycles. The following granular formulations are designed to persist through several wet/dry cycles or flooding events: Altosid XR-G™, Metalarv S-PT™, and Altosid Pellets™. The Altosid SBG™ is a quick-release granular formulation (designed as a granule to better penetrate vegetation), but is less persistent and is not expected to last through wet-dry cycles. The liquid formulations are also not designed to last beyond the point that a treated pool has dried.

Screening Level Ecological Risk Assessment for Methoprene and Aquatic Species: Risks to different classes of biota from application of methoprene as a larvicide to control salt marsh mosquitoes within the Bandon Marsh Refuge can be evaluated using the screening level risk assessment framework established by EPA (2004). Unlike *Bti* and CocoBear™, the toxic dose of methoprene can be stated in terms of its concentration in the environment, and therefore the risk to an organism can be quantified as a function of hazard and exposure. This process involves the estimation of risk for acute and chronic endpoints which were calculated and compared to pre-established Levels of Concern (LOCs) for different classes of aquatic organisms, and are presented in Appendix C, and summarized here. Other qualitative considerations, which may affect either hazard or exposure, and therefore increase or ameliorate risk, are also discussed in detail in Appendix C.

The EPA risk assessment methodology (USEPA 2004) uses the following stepwise framework: problem formulation, hazard identification, dose-response relationships, exposure assessment, and risk characterization. These steps allow for the comparison of an estimated environmental exposure with a reference dose associated with a toxic effect. This assessment focused only on the active ingredient, S-methoprene and on exposure to aquatic organisms. No inert ingredients or breakdown products were considered.

The results of this risk assessment for aquatic species are expressed as a Risk Quotient (RQ), which is the ratio of degree of exposure to the pesticide to the toxicity of the pesticide. Calculation of RQs is based upon available ecological effects data, pesticide-use data, fate and transport data, and estimates of exposure to the pesticide summarized in the literature review sections above (USEPA 2004). In this method, the EEC is compared to an effect level (toxicological endpoint) such as an LC_{50} (the concentration of a pesticide at which 50% of the organisms die in controlled laboratory study).

All ecological risk assessments require the risk assessor to make assumptions (USEPA 2004). Appendix C lists the assumptions made in this analysis for the estimation of risk to aquatic resources. To evaluate effects to aquatic taxa (fish and invertebrates) associated with the application of methoprene to the restored salt marsh on the Ni-les'tun Unit, the water-borne EECs of methoprene resulting from applications of the different formulations considered were estimated (Table 4-1).

Table 4-1. Estimated Environmental Concentrations (EEC) for methoprene products applied to six inches of water depth (typical of mosquito pools at the Refuge) of the different methoprene (=a.i.) formulations.

Product Name	a.i. (%)	Application Rate Min	Application Rate Max	Application Rate Polluted	EEC 6" Min (ppb)	EEC 6" Max (ppb)	EEC 6" Polluted (ppb)
Solid and granular formulations		(pounds per acre)					
Altosid SBG™	0.2	5	10	20	1.4	2.8	5.6
Altosid XR-G™	1.5	5	10	20	2.5	5.0	10.0
MetaLarv S-PT™	4.25	2.5	5	10	2.5	5.0	10.0
Altosid Pellets™	4.25	2.5	5	10	2.5	5.0	10.0
Liquid formulations		(ounces per acre)					
Altosid Liquid Larvicide™	5	3	4	Not Listed	1.1	1.4	Not Listed
Altosid Liquid Larvicide Concentrate™	20	0.75	1	Not Listed	1.1	1.4	Not Listed

Concerns with Methoprene Use at Bandon Marsh Refuge: Two main concerns arise regarding use of methoprene at Bandon Marsh Refuge: food web effects and bioconcentration. As with *Bti*, there may be food web effects to non-target animals that prey on adult mosquitoes, such as fish or bats. Nevertheless, if one considers mosquito larvae as prey for aquatic organisms, like fish or insect predators, methoprene would keep the mosquito larvae in the system for longer due to the fact that it targets the metamorphic life stage of the insect. Second, as discussed above, methoprene bioconcentrates, whereas *Bti* does not. The effects of bioconcentration of methoprene in aquatic species are not particularly well documented, but it has been shown to have low mammalian toxicity, and is approved for use in drinking water cisterns (WHO 1999) and livestock feed (USEPA 1991). Given that fish seem to eliminate methoprene quickly (within approximately two weeks) after exposure ceases, the less persistent formulations which limit the duration of non-target exposures, would be more benign in this regard. See Section 5.7.2 of Appendix C for further details about methoprene bioconcentration.

Ground-based applications are preferred so that salmon and their habitat may be avoided when applying methoprene. The short duration methoprene formulations are preferred (Altosid SBG, Altosid Liquid Larvicide, and Altosid Liquid Larvicide Concentrate) over the slow-release methoprene formulations because they lessen the duration of exposure for non-target aquatic organisms. Methoprene should not be applied where it is likely that tidal cycles or significant rain events will flush it into areas where salmon may be exposed within 3 days post-application.

4.2.1.3 CocoBear™ surface film

Mosquito larvae and pupae dwell within water, and during this life cycle stage, most types of mosquitos must periodically surface to breathe air. Normally when surface-breathing types of larvae and pupae come to the surface to breathe, they will penetrate the water surface with their siphon (breathing) tube, and use surface tension to hold in that position as needed. CocoBear™, as with all mosquito larvicide oils, works by killing mosquito larvae and pupae thru physical means.

CocoBear™ is an oil-based, hydrophobic product and has a density of 0.868 g/mL; both of these factors allow it to stay on top of the water surface. Surfactant components in the product formulation help CocoBear™ spread across the water surface, leaving a thin layer on top of the water. When larvae and pupae approach the water surface to breathe, most cannot penetrate to the atmosphere because of the layer of CocoBear™ on the water surface, and subsequently are unable to breathe. If they do penetrate the film, the oil's surface tension on the siphon tube is so low that they fall below, and again are unable to breathe. Larvae and pupae can also inhale the oil into their siphon tube and trachea causing asphyxiation. In essence, CocoBear™ kills by the physical means of suffocation.

General CocoBear™ Environmental Effects: CocoBear™ works by suffocating invertebrates that reside on the water surface or must surface to breathe. The mode of action of the surficial oil is not specific to mosquito pupae. Due to its environmental behavior (floating on the water surface, adhering to soil and vegetation, relatively rapid breakdown), CocoBear™ is unlikely to dissolve into the water column at high concentrations. Therefore fish and other aquatic organisms that do not generally rise to the water surface to breathe are not likely to become exposed to this compound. Nonetheless, due to the newness of this product and the limited information on its toxicity to aquatic life, and the conservation objectives of Bandon Marsh Refuge, the precautionary principle would dictate avoiding habitats containing fish or other aquatic species when using this product. This is manageable, since the target mosquitoes generally do not breed in pools with fish or many other species. Other concerns about the effects of animals coming into contact with this product include oiling of bird feathers contacting the treated water, which could result in the breakdown of feather insulation properties, or transfer of oil or surfactants to eggs. These effects are mitigated by the small amounts of CocoBear™ that are likely to be encountered by any single animal, and its low toxicity to vertebrates, but the primary control of these potential effects would be its anticipated infrequent use on small areas (see below).

Concerns with CocoBear™ Use at Bandon Marsh Refuge: CocoBear™ application would be considered only if early-stage larvicides have not prevented the potential of significant numbers of adult mosquitoes leaving the Refuge. At Bandon Marsh Refuge all applications of CocoBear™ would be ground-based and limited in spatial extent, i.e., no single application totaling more than ¼ acre (0.1 hectare). Projected use at Bandon Marsh Refuge is that CocoBear™ would only be applied to small, brackish to hypersaline, and species-poor water bodies containing predominantly late-stage mosquitoes. Before treatment, habitat would be visually assessed for non-target invertebrate, fish, or amphibian species (terrestrial or aquatic stages) to avoid exposure to these species. When applied at label rates (3–5 gallons per acre) only a very thin film of product remains on the water surface, so individual animals would likely only be exposed to small amounts. The risk to birds or other vertebrates from direct spraying would be minimized by highly specific application methods directly to water, with careful control of overspray or drift. CocoBear™ is dispersed using a surfactant of undisclosed (by the manufacturer) identity. Some surfactants, while often having multiple uses including as ingredients in food products, can exert some level of aquatic toxicity. Based on a qualitative assessment of the toxicity of CocoBear™ (Appendix C), use of this product would be very limited in time and space.

4.2.2 Summary of Effects Characterizations

Table 4-1 provides an overview of the effects under each alternative by indicator. The alternatives are compared side by side under each topic, and both the positive and negative effects of implementing each alternative are described. The effects related to implementing each alternative are described in terms of the change from current conditions (i.e., the environmental baseline). Alternative C, the No Action alternative would continue present management actions with no change. Nonetheless, the consequences of implementing Alternative C may have minor to moderate negative effects.

The following resources would not be affected by any of the alternatives:

- Climate: None of the alternatives would change the climate in the lower Coquille estuary area.
- Topography: None of the alternatives would affect the site topography.
- Soils and Geology: None of the alternatives would have any effect on the soils or geology of the Refuge.
- Environments – open water, mudflats, tidal marsh, and seasonal wetlands: None of the alternatives would change the abundance or distribution of the general environments found on the Refuge.
- Noxious Weeds/Exotic Plants: Noxious weeds and exotic plants will continue to be present within the plant community on the Refuge, and will not be affected by any alternatives.
- Cultural Resources and Historic Properties: None of the alternatives would affect existing cultural resources of the Refuge.
- Land Use: None of the alternatives would change the purposes for which the Refuge is managed. No public uses would be restricted on the Refuge as a result of any of the alternatives. The Refuge would remain a major section of open space along the northern edge of the city of Bandon.

Table 4-2. Summary of environmental effects of the alternatives.

	Alternative A (Preferred)	**Alternative B (No Synthetic Larvicides)**	**Alternative C (No Action)**
EFFECTS TO PHYSICAL ENVIRONMENT			
Air quality	Negligible short-term	Negligible short-term	Neutral
Water quality	Minor negative to negligible short-term	Negligible short-term	Neutral
EFFECTS TO BIOLOGICAL ENVIRONMENT			
Vegetation	Negligible	Negligible	Neutral
Mammals	Negligible to negative minor short-term	Negligible to negative minor short-term	Neutral to negligible
Birds	Negligible to negative minor short-term	Negligible to negative minor short-term	Neutral to negligible
Reptiles and amphibians	Negligible to negative minor short-term	Negligible to negative minor short-term	Neutral to negligible
Fish	Negligible	Neutral	Neutral
Invertebrates	Negligible to moderate negative short-term	Negligible to minor negative short-term	Neutral
EFFECTS TO HUMAN ENVIRONMENT			
Social and economic resources	Moderate positive long-term	Moderate positive long-term	Moderate negative long-term
Health and safety	Moderate positive long-term	Minor to moderate positive long-term	Moderate negative short-term
Aesthetics	Neutral	Neutral	Moderate negative short-term
ADDITIONAL EFFECTS			
Cumulative Effects	Minor to moderate positive, long-term	Minor to moderate positive, long-term	Minor negative short-term

4.3 Effects to the Physical Environment

4.3.1 Effects to Air Quality

<u>Alternative A: Preferred Alternative</u>

Overall effects are expected to be negligible. Regular mosquito monitoring activities would not have any adverse effects on air quality. Mosquito monitoring and surveillance activities would be limited to setting/checking adult mosquito traps and dipping for larvae on the Refuge. Monitoring and surveillance activities on the Refuge can occur by vehicle, amphibious ATV, or foot, and the minor increase in emissions from additional motorized vehicle trips compared to normal traffic in the area would be negligible.

The aerial application of larvicides if and when large areas of control are needed on the Ni-les'tun Unit could temporarily affect air quality. These potential effects would be minimized with the following BMPs:

- Employ wind speed restrictions on spraying.
- Apply only dust-free solid (granular) formulations of larvicides if available.
- Employ pre-calibrated automated GPS control of spraying apparatus to minimize and precisely target spray area.

<u>Alternative B: Mosquito Control without Synthetic Larvicides</u>

The effects of Alternative B on air quality would be the same as described under Alternative A.

<u>Alternative C: No Mosquito Larvicide Application</u>

Under this alternative, no pesticides would be used to control mosquitoes. This would eliminate emissions associated with aircraft and equipment used to apply pesticides. Effects of monitoring would be the same as for Alternative A.

4.3.2 Effects to Hydrology and Water Quality

<u>Alternative A: Preferred Alternative</u>

Overall effects are expected to be negligible to minor. This alternative includes regular mosquito monitoring and surveillance activities conducted by CCPH. These activities would not affect water resources because, on the Refuge, this work consists of walking or driving to the sample sites. No contaminants would be introduced to the Refuge's water resources through monitoring activities.

The application of larvicides on the Refuge would affect water resources because larvicides would be directly applied to mosquito breeding pools. However, we do not expect application of larvicides to result in major adverse effects to water quality on the Refuge. The following information was gathered from a report supporting a statewide NPDES permit for discharges of aquatic pesticides to waters of the United States by CCPH (Pesticide General Permit Number 2300A), and the toxicological review in Appendix C.

- *Bti: Bti* is not expected to have any measurable effect on water quality and occurs naturally in most aquatic environments.

- Methoprene: Methoprene is not expected to have a major impact on water quality. Methoprene has shown to be effective against mosquitoes at levels below those that can be detected in water by any currently available test approved by the EPA.
- CocoBear™: No environmental fate or persistence data is available at this time for the end use product, CocoBear™. Data on the formulation's two main constituents and surfactant component are available and described in Appendix C. Regarding mosquito larvicide oils, the 2007(a) EPA registration documents for aliphatic solvents cites information obtained from the Centers for Disease Control and Prevention (CDC), which states, "surface film larvicides generally have a shorter environmental persistence (approx. 2–3 days) than most chemical larvicide alternatives" (USEPA 2007a). Based on the chemical profiles described in Appendix C, this product is unlikely to dissolve in or contaminate groundwater. Rather, it is likely to sorb to vegetation and other organic matter, and ultimately undergo degradation by microbes.

BMPs for the application of pesticides to mitigate potential negative effects to water resources include:

- Where mosquito control is needed, use the most effective product that poses the lowest risk to abiotic and biotic resources.
- Apply pesticides only where monitoring and surveillance data justify its use.
- Observe wind speed restrictions on spraying.
- Apply only according to the label.

<u>Alternative B: Mosquito Control without Synthetic Larvicides</u>

The impacts of this alternative would be the same as described under Alternative A as it applies to the use of *Bti*, i.e., negligible effect. No contaminants would be introduced to the Refuge's water resources through monitoring activities.

<u>Alternative C: No Mosquito Larvicide Application</u>

Under this alternative, no pesticides would be used to control mosquitoes. Therefore, there would be no effect to water resources on the Refuge from control. Additionally, no contaminants would be introduced to the Refuge's water resources through monitoring activities.

4.4 Effects to the Biological Environment

Table 4-3 summarizes the fate and biological effects of larvicides that would be used under Alternatives A and B. More details about specific taxa effects follow the table, and are also presented in Appendix C in greater detail.

Table 4-3. Summary of fate and biological effects of larvicides proposed for use in the Preferred Alternative.

Name	Degradation	Effects on Wildlife	Effects on humans
Bacillus thuringiensis israelensis (*Bti*)[1, 2, 4]	Foliar half-life 1-4 days, soil half-life averages 4 months.	Nontoxic to birds and fish, minimal toxicity to bees and other non-target insects; indirect food web effects may occur if use is prolonged.	Adverse effects not likely from label applications of *Bti* on the Refuge.
Methoprene[3]	Degrades rapidly in water; half-life < 2 days in alfalfa; low persistence in soil w/ half-life up to 10 days; aquatic half-life 30-40 hours.	Slightly to moderately toxic to fish, highly toxic to some species of estuarine invertebrates; slightly toxic to birds; but exposure to toxic amounts highly unlikely due to amount needed for mosquito control is < 1ppb; indirect food web effects may occur if use is prolonged.	Methoprene is practically non-toxic when ingested or inhaled and slightly toxic by dermal absorption.
CocoBear™ (Oil film)	Low solubility; does not enter water column; Environmental fate not determined (see Appendix C for general analysis of components)	Films are potentially lethal to any aquatic insect that lives on the water surface or requires contact with the air-water interface to breathe; low toxicity to vertebrates; possible physical effects to fur, feathers, skin.	May cause eye irritation; otherwise acute and chronic effects are unknown; exposure unlikely.

4.4.1 Effects to Vegetation

Alternative A: Preferred Alternative

Overall effects on vegetation would be negligible. Trampling impacts to vegetation could occur during access (on-foot, amphibious ATVs) within the tidal marsh to conduct mosquito management. The use of vehicles such as amphibious ATVs that traverse wetland areas have a much greater impact on vegetation than foot access, and would be minimized. Persistent use of particular tracks creates depressions that may result in additional shallow water pooling and may create mosquito breeding habitat, and would be avoided. The following BMPs would be implemented under the Preferred Alternative to reduce negative impacts to vegetation:

- Limit the number of travel pathways used by vehicles within the marsh
- Avoid vehicle use in soils that form track ruts
- Avoid vehicle use over fragile (non-resilient) vegetation

The application of larvicides are not likely to adversely affect vegetation directly because the larvicides used for mosquito control are not known to harm plants, with the exception of CocoBear™ which may damage leaves on direct contact (Clarke mfg. CocoBear™ fact sheet). CocoBear™ would be applied by hand directly to water surfaces, avoiding direct application to plants. It is not known how reductions in certain invertebrate populations as a result of repeated larvicide applications would impact specific invertebrate-plant interactions (e.g., pollination) within the tidal marsh of the Refuge, however, we anticipate that the overall limited amounts of larvicides applied to select areas of the marsh would not result in any substantial adverse effects to invertebrate-plant interactions.

Alternative B: Mosquito Control without Synthetic Larvicides

Effects on vegetation would be the same as described under Alternative A, i.e., negligible effect.

Alternative C: No Mosquito Larvicide Application

Effects on vegetation would be the same as described under Alternative A, i.e., negligible effect.

4.4.2 Effects to Mammals

Alternative A: Preferred Alternative

The overall effect of this alternative on mammals would be negligible to minor. The Preferred Alternative has the potential to impact mammals in two ways – first, through physical disturbance resulting from vehicles and foot traffic, and second through the application of larvicides. Traffic effects on habitat include compacted soil, disturbed nests and tunnels, and disruption of vegetation cover. Vehicle travel can disrupt daily activity (e.g., movements) and has the potential to cause mortality of small mammals. Under the Preferred Alternative we would implement the following BMPs to reduce potential impacts:

- Minimize the number and extent of travel pathways used by vehicles within the marsh
- Use only low-ground pressure, tracked vehicles; or travel on foot

The use of larvicides for the purpose of mosquito management is not likely to directly affect native mammal populations of the Refuge. Adverse effects on mammals from *Bti*, methoprene, and

CocoBear™ are not expected (Appendix C) when applied according to the label instructions. *Bti* has practically no acute or chronic toxicity to mammals (USEPA 1998). Extensive acute toxicity studies indicated that *Bti* is virtually innocuous to mammals (Siegel and Shadduck 1992). These studies exposed a variety of mammalian species to these bacteria at moderate to high doses and no pathological symptoms, disease, or mortality were observed. Methoprene is not considered toxic to mammals (Appendix C). Impacts to the mammalian community as a result of reduced invertebrate populations are not expected because most mammal species that inhabit wetlands of the Refuge are herbivorous (invertebrates are not a primary component of their diet) or, they do not generally consume species that may be affected by the larvicides. The exceptions to this could be certain bat species that do feed on mosquitoes, and have benefitted from the recent abundance of mosquitoes. However, due to very low bat reproductive rates, local populations have not had time to increase in response to the abundant food made available by the mosquito outbreak, so any stress resulting from removal of this food resource should be minor.

<u>Alternative B: Mosquito Control without Synthetic Larvicides</u>

The overall effect of this alternative on mammals would be negligible to minor. Under this alternative, impacts related to access for mosquito management are the same as described under Alternative A. Effects associated with methoprene and CocoBear™ would be avoided. This alternative would include the application of *Bti* only for mosquito control. This biorational is not known to directly affect vertebrate species (Appendix C).

There is an increased chance that adequate control of mosquitoes would not be achieved without the use of methoprene or CocoBear™, due to the restricted time window for application of *Bti* to be effective. This is certainly the case prior to construction and adequate functioning of additional marsh channels. In this case, there may be an increased threat to mammals of exposure to mosquito-borne disease or mortality from excessive bites. There may also be a minor positive effect of more food availability due to more mosquitoes and other insects that would have been reduced in number by larvicide application.

<u>Alternative C: No Mosquito Larvicide Application</u>

The minor effects of the possibility of more mosquitoes under this alternative are the same as described in Alternative B. Effects of monitoring are the same as in Alternative A.

4.4.3 Effects to Birds

<u>Alternative A: Preferred Alternative</u>

The overall effect of this alternative on birds would be negligible to minor. Impact to birds that use the Refuge may occur during human access for mosquito monitoring, surveillance and control, as well as the application of larvicides. Impacts to birds and their nests related to trampling and disturbance may occur as a result of ground access via foot or vehicle (amphibious ATV). However, impacts would be minimized by limiting vehicle trails, and training field technicians to avoid disturbing nests by being aware of adult bird behavior that indicates a nearby nest.

Bti has practically no acute or chronic toxicity to birds (USEPA 1998) (Appendix C). Methoprene is also considered practically non-toxic to birds (Appendix C, USEPA 2001). CocoBear™ is not known to cause direct chronic or acute avian toxicological effects to birds, but mineral oil spirits have been shown to disrupt avian embryonic development (Morris and Siderius 1990). Moreover, because CocoBear™ is a surface oil, it may coat the feathers of birds that land in treated areas, causing oiling of eggs that bird may be incubating or matting of feathers and loss of ability to thermoregulate (Appendix C). Exposure to birds is mitigated by the anticipated limited use of CocoBear™, and the small amounts of it likely to be encountered by individual birds.

Non-target effects to birds from larvicide application may occur as a result of a reduced food base. There is the potential for *Bti* and methoprene to kill close relatives of mosquitoes, such as midge larvae (family Chironomidae), which can be abundant in wetlands and form a significant portion of the food base for other wildlife, including certain birds (Batzer et al. 1993, Cooper and Anderson 1996, Cox et al. 1998). However, early-stage larvicides (*Bti* and methoprene) applied according to label rates designed to kill mosquitoes do not generally reach concentrations high enough to kill non-target invertebrates (Appendix C). CocoBear™ does kill other aquatic larvae that need to breathe air, but its persistence is extremely transient (Appendix C), and non-target species populations tend to recover quickly, so food web effects are also transitory.

Positive effects on birds of effective mosquito control include lower risks of mosquito-borne disease that can infect birds, such as WNV, and lower exposure of birds, especially nestlings, to mosquito bites that can cause high stress or death from blood loss. As of February 2006, 284 bird species have been listed in the CDC WNV avian mortality database. The list includes wildlife that inhabit tidal marsh such as bald eagles, waterfowl, grebes, herons, egrets, cormorants, songbirds (marsh wren, common yellowthroat, song sparrow), and rails (Virginia rail and American coot).

To reduce the potential for negative impacts to bird populations the following BMPs would be implemented under this alternative:

- Limit the number of travel pathways used by vehicles (amphibious ATVs) within the marsh.
- Provide field personnel training on measures to avoid impacts to nesting birds.

<u>Alternative B: Mosquito Control without Synthetic Larvicides</u>

The overall effect of this alternative on birds would be negligible. See Alternative A for effects related to access. Only effects related to *Bti* described in Alternative A apply to this alternative. It is possible that adequate control of mosquitoes would not be accomplished without the use of methoprene or CocoBear™, due to the necessity for timely application of *Bti*. In this case, there may be an increased threat to birds of exposure to mosquito-borne disease, or mortality to nestlings from excessive bites. There may also be a positive effect of more food availability due to more mosquitoes and other insects that would otherwise have been reduced in number by larvicide application.

<u>Alternative C: No Mosquito Larvicide Application</u>

Effects on birds as a result of mosquito monitoring activities under this alternative are the same as Alternative A, although lack of mosquito management may have a negative effect on bird populations of the Refuge if mosquito populations remain very high (See Alternative B).

4.4.4 Effects to Reptiles and Amphibians

<u>Alternative A: Preferred Alternative</u>
Under this alternative, effects on reptiles and amphibians are expected to be negligible to minor. These species tend to avoid tidal areas of the Refuge, so direct exposure to larvicides would be minimal. Effects on reptiles and amphibians may occur through reductions in insects that serve as food source (Hoffman et al. 2008), through direct contact from larvicides application, or from trampling of individuals or habitat (e.g., traffic by amphibious ATVs).

<u>Alternative B: Mosquito Control without Synthetic Larvicides</u>

The impacts of this alternative are the same as those described under Alternative A. However, due to the necessity for timely application of *Bti* for it to be effective, it is possible that the inability to use methoprene or CocoBear™ under this alternative decreases the chance that adequate control of mosquitoes would be achieved. In this case, there may be an increased threat to reptiles and amphibians of exposure to mosquito-borne disease, or mortality from excessive bites. There may also be a positive effect of more food availability due to more mosquitoes and other insects that would otherwise be reduced in number by larvicide application.

<u>Alternative C: No Mosquito Larvicide Application</u>

Under this alternative, mosquito monitoring would have the same effects as Alternative A. Possible effects of increased numbers of mosquitoes and other insects are the same as described for Alternative B.

4.4.5 Effects to Fish

<u>Alternative A: Preferred Alternative</u>

The overall effect of the Preferred Alternative on fish is expected to be negligible. Mosquito monitoring and surveillance activities are not expected to adversely affect fish because these activities would not occur within open tidal waters of the Refuge (e.g., sloughs, channels, adjacent river) and are not expected to adversely affect water quality (e.g., turbidity, dissolved oxygen). The Preferred Alternative does include the application of larvacides under certain conditions. Negative direct effects on fish populations are not expected from the proposed larvicides at application concentrations appropriate for mosquito control, with the possible exception of CocoBear™ (Appendix C). There is the potential for larvicides to reduce invertebrate food resources to the extent that food becomes limiting to fish populations. However, field studies of the larvicides included in this alternative have found that invertebrate communities quickly recover from all but prolonged and repeated (i.e., over multiple years) applications (Appendix C), which are unlikely to happen under this plan.

Coho salmon, eulachon, and green sturgeon are special status (i.e., federally or state listed) fish that have the potential to occur on the Refuge. Larvicides would be applied according to label instructions, which preclude application of concentrations toxic to fish. The potential for secondary effects to fish by reduction of food resources by larvicide application is addressed in the Effects on Invertebrates section below.

<u>Alternative B: Mosquito Control without Synthetic Larvicides</u>

The overall effect of the Preferred Alternative on fish is expected to be neutral. Mosquito monitoring and surveillance would have no effects on fish as described under Alternative A. Effects on fish populations, including special status species, are not expected from *Bti* (Appendix C). Due to the more limited toxicity of *Bti*, it is not as likely to cause indirect food web effects on fish, as described in Alternative A. The possibility of more abundant mosquitoes and other invertebrates under this alternative may have a positive effect on food resources for fish.

<u>Alternative C: No Mosquito Larvicide Application</u>

Monitoring would not adversely affect fish, as in Alternative A. The possibility of more abundant mosquitoes and other invertebrates under this alternative may have a positive effect on food resources for fish.

4.4.6 Effects to Invertebrates

<u>Alternative A: Preferred Alternative</u>

The overall effect of the Preferred Alternative on invertebrates is expected to be negligible, with the exception of mosquitoes and certain other species that may be susceptible to the larvicides proposed, where the effect would be moderate in the short term. Monitoring and surveillance activities are not expected to adversely affect invertebrate populations. Chemical treatment of mosquito populations on the Refuge has the potential to adversely affect invertebrates and these are described below.

Bti: The effect on local populations of invertebrate species over time with periodic or continued use of *Bti* is unknown, but potential for negative effects is a possibility (Section 4.2.1, and Appendix C). Host range and effect on non-target organisms indicates that *Bti* is relatively specific to the Nematocera suborder of Diptera (flies), in particular filter-feeding mosquitoes (Culicidae) and blackflies (Simuliidae) (Glare and O'Callaghan 1998). It is pathogenic to some species of midges (Chironomidae) and Tipulidae, although to a lesser extent than mosquitoes and biting flies, and is not reported to affect a large number of other invertebrate species (Glare and O'Callaghan 1998). *Bti* concentration is important with regard to effects on non-target organisms. Of particular concern is the potential for *Bti* to kill non-biting midge larvae (family Chironomidae). Chironomid larvae are often the most abundant aquatic insect in wetland environments and form a significant portion of the food base for other wildlife (Batzer et al. 1993, Cooper and Anderson 1996, Cox et al. 1998), but it is unknown to what extent that is true on the Refuge. Reduced invertebrate populations as a result of food web effects (e.g., reduction of nematoceran Diptera) have been shown in studies of *Bti* (Hershey et al. 1998).

Methoprene: Because methoprene is a juvenile hormone (JH) mimic and all insects produce JH, there is concern about potential adverse effects on non-target aquatic insects when this larvicide is used for mosquito control (Appendix C). As with *Bti*, there is concern regarding potential negative effects on chironomid larvae due to their importance in food webs. As with any pesticide, toxicity is a factor of dose plus exposure. At mosquito control application rates, methoprene is present in the water at very small concentrations (2-10 ppb, initially). With regard to exposure, chironomid larvae occur primarily in the benthos (i.e., living at the bottom of a stream), either within the sediments and/or within cases constructed of silk and detritus. Thus, there may be differences with regard to exposure to methoprene between chironomid and mosquito larvae, the latter occurring primarily in the water column. The published literature on the effects of methoprene to chironomids is not as extensive as that for *Bti*. However, there is evidence for toxicity to chironomid and other aquatic invertebrates from methoprene treatments. In summary, there is evidence for minor adverse non-target effects from methoprene even when applied at mosquito control rates.

CocoBear™: Surface oils are potentially lethal to any aquatic insect that lives at the water surface and requires periodic contact with the air-water interface to obtain oxygen. The film interferes with larval orientation at the air-water interface and/or increases wetting of tracheal structures, thus suffocating the organism. There is no information about other species of aquatic invertebrates susceptible to surface films that may be present on the Refuge, or their relative importance to marsh ecology. BMPs for application to reduce risk to non-targets include targeted application only to pools with high numbers of late fourth instar or pupa mosquitoes, at minimally effective application rates according to the label.

<u>Alternative B: Mosquito Control without Synthetic Larvicides</u>

The overall effect of the Preferred Alternative on invertebrates is expected to be neutral or negligible. There would be no adverse impacts to invertebrates from continued mosquito monitoring and surveillance activities. Under this alternative we would allow only the application of *Bti*, and effects of methoprene and CocoBear™ would be avoided. Use of *Bti* may have temporary minor negative effects on certain invertebrate populations as described under Alternative A.

<u>Alternative C: No Mosquito Larvicide Application</u>

Under this alternative no effects to invertebrates are expected because no larvicides would be applied at the Refuge. Monitoring is not expected to adversely affect invertebrate populations.

4.5 Effects to the Social and Economic Environment

4.5.1 Effects to Socioeconomics and Environmental Justice

<u>Alternative A: Preferred Alternative</u>

The NEPA requires discussion of an alternative's potential economic and social effects. Executive Order 12898 "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," required federal agencies to "identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations."

The Preferred Alternative would have no negative social, economic or environmental justice effect if implemented. The Preferred Alternative would not divide or disrupt an established community or its economic activities. It is not anticipated to negatively impact minority, elderly, disabled, low income, or other special interest groups. However, there may be public controversy generated about the use of larvicides on the Refuge. Reports of large numbers of mosquitos may have reduced tourist visitation and tourism related spending in the Bandon area in 2013. Implementation of the Preferred Alternative is expected to have a moderate positive impact on the economic climate of the local area, if tourists perceive that the Bandon area will not have excessively high number of mosquitoes in 2014.

Alternative B: Mosquito Control without Synthetic Larvicides

Impacts would be the same as for Alternative A, except there may be slightly less public concern about the use of pesticides on the Refuge, since methoprene, the use of which some groups oppose, would not be used.

Alternative C: No Mosquito Larvicide Application

This alternative has the potential to have long-term (more than one year) moderate negative effects on the local community, since it would likely result in a serious mosquito infestation both on and off the Refuge at least until mosquito breeding habitat removal can be completed. Based on widespread complaints resulting from the summer 2013 situation, which would likely recur, local tourist facilities, such as Bullards Beach State Park, nearby private lodging businesses, and golf courses could potentially suffer loss of patronage; and local residents, farmers, and ranchers could be prevented from normal outside activities and suffer increased health and safety risks.

4.5.2 Effects to Human Health and Safety

Alternative A: Preferred Alternative

The primary purpose of mosquito control on the Refuge is to protect human health and safety, and implementation of the Preferred Alternative would have a moderate positive effect. There would be no adverse effects on human health and safety from mosquito monitoring and surveillance. Under this alternative, the potential exists for human exposure (i.e., CCPH staff, refuge visitors, and refuge staff) to pesticides, particularly with aerial applications. Mosquito control and monitoring techniques would evolve with changes in mosquito habitat and the risks of human health threats or adverse impacts. To minimize the potential effects of human exposure to pesticides on the Refuge, the following BMPs would be implemented:

- Prior to the application of any larvicide, CCPH must identify the treatment locations, treatment schedule, and identify the larvicide and application method to be used. CCPH must provide this information to the Refuge Manager within 24 hours of proposed application.
- CCPH as well as others (e.g., elected officials, Service, contractors) will work to inform the community and address citizen concerns.
- All personnel involved with ground applications of larvicides will be trained to minimize exposure by following label guidelines, and appropriate use of personal protective equipment.
- If aerial application of larvicide is deemed necessary, the Refuge Manager will post a notice at the Refuge Office and at all visitor parking areas, and jointly with CCPH issue a press release, with information on the dates of aerial larvicide application. Every effort will be made to evacuate all people from the treatment area during the aerial treatment.

Alternative B: Mosquito Control without Synthetic Larvicides

There would be no adverse effects to human health and safety from mosquito monitoring and surveillance activities. Due to the necessity for timely application of *Bti* for it to be effective, it is possible that the inability to use methoprene or CocoBear™ under this alternative decreases the chance that adequate control of mosquitoes would be achieved, at least in the near term before habitat modification has its intended effect. In this case, there may be an increased risk of exposure to mosquito-borne disease, or other health issues from mosquito bites.

Alternative C: No Mosquito Larvicide Application

This alternative has the potential to have a moderate negative effect on the quality of life of refuge visitors and nearby residents who have not historically been exposed to the high mosquito populations that are likely to result from no larvicide applications, at least in the near term before habitat modification has its intended effect. Potential human health and safety effects include interference with normal outdoor activities, health risks from reactions to mosquito bites and disease infection, and increased exposure to pesticides used by private landowners attempting to control mosquitoes. The public perception of unmanaged "nuisance" mosquitoes originating from the Refuge would contribute to existing negative attitudes toward the ecological services provide by the Refuge, and wetlands in general.

4.5.3 Effects to Aesthetics

Alternative A: Preferred Alternative

Mosquito management activities are not expected to affect the scenery of the Refuge or noise levels at the Refuge. There would be no change to the noise environment, except that potential aerial applications of larvicides would temporarily increase noise in the vicinity of the Refuge.

Alternative B: Mosquito Control without Synthetic Larvicides

This alternative would have the same neutral effects as the Preferred Alternative.

Alternative C: No Mosquito Larvicide Application

If mosquito infestations are high before habitat management has its intended effects, there would be a temporary minor to moderate negative effect on aesthetics as outdoor activities could become unpleasant due to mosquito bites. The minor temporary negative effects of a low flying airplane applying larvicides over the Refuge would be avoided under this alternative.

4.6 Cumulative Effects

The Council on Environmental Quality (CEQ) regulations for implementing the provisions of NEPA defines several different types of effects that should be evaluated in an EA including direct, indirect, and cumulative. Direct and indirect effects are addressed above. This section addresses cumulative effects. The CEQ (40 CFR § 1508.7) provides the following definition of cumulative effects:

"The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions."

Cumulative impacts are the overall, net effects on a resource that arise from multiple actions. Impacts can "accumulate" spatially, when different actions affect different areas of the same resources. They can also accumulate over the course of time, from actions in the past, the present, and the future. Occasionally, different actions counterbalance one another, partially canceling out each other's effect on a resource. But more typically, multiple effects add up, with each additional action contributing an incremental impact on the resource. In addition, sometimes the overall effect is greater than merely the sum of the individual effects, such as when one more reduction in a population crosses a threshold of reproductive sustainability, and threatens to extinguish the population.

Alternative A: Preferred Alternative

Cumulative effects resulting from repeated or multiple year implementation of the Preferred Alternative on the Refuge, such as vegetation and wildlife impacts due to the long-term use of amphibious ATVs and larvicides, are addressed above, and range from neutral to minor. The Service expects these impacts to lessen substantially as habitat modification reduces mosquito production on the Refuge, and monitoring and larvicide application activities are reduced accordingly.

Effects beyond the Refuge include an increase in the capacity of the CCPH to monitor and respond to mosquito-related public health issues in the county, and establishment of a model for other regional land managers for how to effectively control mosquitoes when they become a problem as an unintended result of restoration or other landscape manipulation. These effects are minor to moderate, and should extend into the long term.

Alternative B: Mosquito Control without Synthetic Larvicides

This alternative would have the same neutral effects as the Preferred Alternative.

Alternative C: No Mosquito Larvicide Application

The numbers of mosquitoes produced on the Refuge before habitat modification had time to effectively minimize production capacity could cause members of the community to react by pressuring CCPH or private pest control operators to apply pesticides (larvicides and adulticides) to lands outside of the Refuge. These pesticides may not be as environmentally benign as those approved for use by the Service, and therefore could result in minor, localized negative effects by killing non-target species and affecting landowners that do not want pesticides applied. These pesticides in the environment would be cumulative to pesticides applied for other reasons, such as agricultural or structural pest control.

Chapter 5. Compliance, Consultation, and Coordination with Others

Coos County Public Health Department
Coos County Commissioners
Coos County Planning Department
Marin-Sonoma Mosquito Abatement District
San Mateo County Mosquito Abatement District
Oregon State University Entomology Department
Oregon Department of Health Services
Oregon Mosquito and Vector Control Association
Oregon Department of Fish and Wildlife
Oregon Watershed Enhancement Board
Oregon State Historic Preservation Office
Oregon Division of State Lands
National Oceanic and Atmospheric Administration - Fisheries
City of Bandon
Senator Ron Wyden
Senator Jeff Merkley
Representative Peter DeFazio
State Representative Wayne Krieger
State Senator Jeff Kruse
Port of Bandon
Oregon State Parks and Recreation
Valent Biosciences Corporation
Ducks Unlimited
Napa County Mosquito Abatement District
Jackson County Vector Control
Xerces Society
Confederated Tribes of the Siletz Indians
Coquille Indian Tribe
Cascadia Wildlands
Cape Arago Audubon Society
Kalmiopsis Audubon Society
South Slough Estuarine Research Reserve
Oregon Habitat Joint Venture
The Freshwater Trust
The Wetlands Conservancy
Bandon Dunes Golf Resort
The Nature Conservancy
Shoreline Education for Awareness
Coquille Watershed Association
Multnomah County Vector Control
Benton County Environmental Health – Insect and Rodent Control

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Appendix A. Appropriate Use Finding and Compatibility Determination

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Finding of Appropriateness of a Refuge Use

Refuge Name: Bandon Marsh National Wildlife Refuge

Use: Mosquito management

This form is not required for wildlife-dependent recreational uses, take regulated by the State, or uses already described in a refuge CCP or step-down management plan approved after October 9, 1997.

Decision criteria:	**YES**	**NO**
(a) Do we have jurisdiction over the use?	**X**	
(b) Does the use comply with applicable laws and regulations (federal, state, tribal, and local)?	**X**	
(c) Is the use consistent with applicable executive orders and Department and Service policies?	**X**	
(d) Is the use consistent with public safety?	**X**	
(e) Is the use consistent with goals and objectives in an approved management plan or other document?	**X**	
(f) Has an earlier documented analysis not denied the use, or is this the first time the use has been proposed?	**X**	
(g) Is the use manageable within available budget and staff?	**X**	
(h) Will this be manageable in the future within existing resources?	**X**	
(i) Does the use contribute to the public's understanding and appreciation of the Refuge's natural or cultural resources, or is the use beneficial to the Refuge's natural or cultural resources?	**X**	
(j) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see section 1.6D. for description), compatible, wildlife-dependent recreation into the future?	**X**	

Where we do not have jurisdiction over the use ("no" to (a)), there is no need to evaluate it further as we cannot control the use. Uses that are illegal, inconsistent with existing policy, or unsafe ("no" to (b), (c), or (d)) may not be found appropriate. If the answer is "no" to any of the other questions above, we will generally not allow the use.

If indicated, the refuge manager has consulted with State fish and wildlife agencies. Yes _ **X**_ No ___

When the refuge manager finds the use **appropriate** based on sound professional judgment, the refuge manager must justify the use in writing on an attached sheet and obtain the refuge supervisor's concurrence.

Based on an overall assessment of these factors, my summary conclusion is that the proposed use is:

Not Appropriate_____ Appropriate__**X**___

Refuge Manager:_______________________________________ Date:______________________

If found to be **Not Appropriate**, the refuge supervisor does not need to sign concurrence if the use is a new use.

If an existing use is found **Not Appropriate** outside the CCP process, the refuge supervisor must sign concurrence.

If found to be **Appropriate**, the refuge supervisor must sign concurrence.

Refuge Supervisor:_______________________________________ Date:______________________

A compatibility determination is required before the use may be allowed.

FWS Form 3-2319
02/06

Finding of Appropriateness of a Refuge Use

Supplement to FWS Form 3-2319

Mosquito Management

Further Explanation of Answers Provided for the Decision Criteria:

Project: Monitoring and application of larvicide to treat larval mosquitoes

Summary: The Refuge proposes to allow mosquito management on refuge lands and waters within Bandon Marsh NWR.

In August 2011, a tidal marsh restoration project was completed on the Ni-les'tun Unit of Bandon Marsh NWR. The previous century of land management, as a diked and drained salt marsh that was converted to pastureland, had left this historic tidal marsh area with approximately 15 miles of drainage ditches. These straight- line ditches were largely altered by discing and in many cases filled in while 5 miles of new sinuous tidal channels were created during restoration. The lowering of perimeter dikes and removal of tide gates allowed the tides to return and twice daily flood the 400-acre historic salt marsh. The resulting settling of filled ditches and uneven areas of terrain, combined with the impacts from heavy equipment needed for the restoration project, left ruts and numerous shallow areas that fill with tidal flows and strand water as higher tides recede.

During the summer of 2013, the shallow ponds were found to be providing breeding sites for salt marsh mosquitoes (*Aedes dorsalis*) at extremely high levels. This was an unintended and unanticipated consequence of the large scale tidal marsh restoration. The Refuge received numerous calls, emails, and letters from the surrounding public concerning unprecedented levels of biting mosquitoes and associated health impacts. This public outcry precipitated an August 22, 2013 Coos County Public Health Advisory and a subsequent refuge-based Emergency Declaration, due to excessive numbers of mosquitoes being produced on the Refuge and impacting the health and well-being of local residents. These emergency actions allowed the Refuge to work with Coos County Public Health (CCPH) in an effort to protect the public by reducing mosquito production on the Ni-les'tun Unit. On the 12th of September, to abate the health situation, CCPH contracted and applied a larvicide on the Ni-les'tun Unit.

The Refuge is developing a long-term Integrated Marsh Management (IMM) approach for implementation in 2014. This Integrated Pest Management-based approach proposes to reduce mosquito breeding habitat in the long term with construction of additional tidal channels that would drain mosquito breeding pools with each tide, and in the short term allow the monitoring of mosquitoes and the treatment of mosquito breeding habitat with larvicide as a Refuge Use. This use on the Refuge would be allowed under a Special Use Permit (SUP) issued to CCPH. The Service's intention in allowing mosquito abatement actions by CCPH is to address increased mosquito numbers created by restoration of the Ni-les'tun salt marsh and to protect the health and safety of the public while the long-term aspects of the IMM approach are developed and implemented.

For each of the findings listed on FWS Form 3-2319, a justification has been provided below:

(a) Do we have jurisdiction over the use?
The Service has jurisdiction over Refuge Uses on Bandon Marsh NWR. The Service would authorize CCPH to treat refuge marsh with larvicide through a SUP for mosquito abatement. The permit would allow application of approved mosquito larvicides on the Ni-les'tun Unit of Bandon Marsh NWR as part of the long-term IMM approach. Best management practices and stipulations to ensure compatibility would be detailed in the SUP and strictly adhered to. The Service would have no jurisdiction or control over any mosquito abatement activities on non-refuge lands.

(b) Does the use comply with applicable laws and regulations (federal, state, tribal, and local)?
All proposed mosquito management activities will comply with all applicable laws and regulations, including the National Environmental Policy Act and Endangered Species Act. Any restrictions or qualifications that are required to comply with laws and regulations would be specified in the SUP.

(c) Is the use consistent with applicable executive orders and Department and Service policies?
Mosquito management activities on national wildlife refuges, including surveillance and monitoring, and when needed, the use of larvicide, are generally accomplished by local or county mosquito abatement or vector control districts through SUPs. However, there is no established mosquito abatement district or vector control district for Coos County where the Refuge is situated. Furthermore, the Service does not have a national mosquito policy. The proposed IMM approach consists, in part, of a phased approach to mosquito larvicide application described in the Draft EA, and is consistent with the principles of Integrated Pest Management (IPM). The approach includes ongoing coordination with CCPH and incorporates appropriate Service policy related to how the Service addresses mosquito issues on national wildlife refuges. Guiding policies include: Comprehensive Conservation Planning Process (602 FW 3), Step-Down Management Planning Policy (602 FW 4), Biological Integrity, Diversity, and Environmental Health (601 FW 3), Integrated Pest Management (569 FW 1), Appropriate Refuge Uses (603 FW 1), and Compatible Uses (603 FW 2). Development of all proposed mosquito management actions would be guided by and consistent with these and other applicable policies for protection of refuge resources.

(d) Is the use consistent with public safety?
Throughout the development of mosquito management strategies, the Refuge would ensure that each proposed action is consistent with public safety. The objective of monitoring mosquitoes and the use of larvicide treatment would be to reduce excessive adult mosquito numbers through control of larval mosquitoes, in order to protect human health and safety. The Refuge would allow monitoring and the application of larvicide to refuge lands in accordance with the SUP, which would include stipulations to ensure public safety.

(e) Is the use consistent with goals and objectives in an approved management plan or other document?
As discussed in the Description of Management Direction for Response to Mosquito-borne Diseases portion of the Bandon Marsh NWR Comprehensive Conservation Plan (CCP) (USFWS 2013) the use of pesticides to control mosquitoes in order to protect wildlife and/or human health would be allowed on refuge lands only if local, current population monitoring and/or disease surveillance data indicate refuge-based mosquitoes pose a health threat to humans and/or wildlife. The Integrated Pest Management (IPM) Appendix within the CCP does not specifically address effects of mosquito control with pesticides based upon identified human health threats and presence of disease-carrying mosquitoes. However, the basic framework to assess potential effects to refuge biological resources and environmental quality from application of insecticides for mosquito management would be

similar to the process described in the IPM appendix for use of other pesticides. The proposed use would utilize this IPM framework to evaluate and minimize impacts to refuge resources consistent with goals and objectives in the approved CCP.

(f) Is the use manageable within available budget and staff?
The monitoring of mosquitoes and the application of larvicide would be conducted by CCPH and/or their agents (i.e., mosquito abatement contractor). If needed, refuge personnel may assist CCPH with mosquito monitoring on the Refuge, as well as conducting post treatment mosquito larvae and adult monitoring to determine efficacy of control throughout the refuge treatment area. The proposed use is manageable with available budget and staff.

(g) Will this be manageable in the future within existing resources?
Within the first few years, the need for mosquito management is expected to decline as the long-term IMM approach is developed and implemented (e.g., habitat manipulation); however, the use at current levels would be manageable in the future with the existing resources.

(h) Does the use contribute to the public's understanding and appreciation of the Refuge's natural or cultural resources, or is the use beneficial to the Refuge's natural or cultural resources?
The use contributes to the public's understanding and appreciation of the Refuge's natural resources through addressing and reducing the public health and safety concerns that are posed by extremely high mosquito populations. The thorough evaluation of the potential impacts to all refuge resources from mosquito management, and the availability of the evaluation documents (e.g., CCP, Environmental Assessments), will provide the public an opportunity to understand and appreciate the correlations between biotic, abiotic and anthropogenic factors that lead to an abundance of mosquitoes as well as the role that mosquitoes and other invertebrates play in the tidal marsh environment.

(i) Can the use be accommodated without impairing existing wildlife-dependent recreational uses or reducing the potential to provide quality (see Section 1.6D, 603 FW 1, for description) compatible, wildlife-dependent recreation into the future?
Monitoring of mosquitoes would occur on both units of Bandon Marsh NWR, and larvicide treatments would be restricted to the Ni-les'tun Unit's tidally flooded shallow depressions that represent mosquito breeding habitat. During the potential monitoring and treatment period (March through September) the public use on the Ni-les'tun Unit consists of wildlife observation, photography and interpretation in the salt marsh, and from the viewing deck and a short trail that leads into the marsh. These areas would be closed to the public during the treatment period if aerial application of larvicide is determined to be necessary. No priority public uses on Bandon Marsh Unit would be interrupted in order to carry out monitoring of mosquitoes. The use can be accommodated without impairing existing or future wildlife-dependent recreational uses.

Compatibility Determination

Use: Mosquito management, to include monitoring of mosquitoes and application of specific larvicides to reduce mosquito production on the Ni-les'tun Unit of Bandon Marsh National Wildlife Refuge

Refuge Name: Bandon Marsh National Wildlife Refuge

County and State: Coos County, Oregon

Establishing and Acquisition Authorities:
Bandon Marsh National Wildlife Refuge (NWR or Refuge) was authorized by Public Law 97-137, of December 29, 1981 and established by the authority of the Fish and Wildlife Act of 1956, as amended [16 U.S.C. 742a-742j] to protect migratory bird habitat. Additional lands were added to the Refuge in the 1990s through the Refuge Recreation Act of 1962, as amended [16 U.S.C. 460k-4]. Public Law 105-321 (95 Stat. 1709; Oregon Public Lands Transfer and Protection Act of 1998) amended P.L. 97-137 to authorize boundary expansion of Bandon Marsh NWR from 300 to 1,000 acres. Legal authorities used for establishment of the Refuge include the Endangered Species Act of 1973, as amended [16 U.S.C. 1531-1544] and the Migratory Bird Conservation Act of 1929, as amended [16 U.S.C. 715-715d, 715e, 715f-715r].

Refuge Purpose(s):

> "for the preservation and enhancement of the highly significant wildlife habitat … for the protection of migratory waterfowl, numerous species of shorebirds and fish … and to provide opportunity for wildlife-oriented recreation and nature study on the marsh" [95 Stat. 1709, dated Dec. 29, 1981] and Public Law 97-137 – Dec. 29, 1981 and H.R. 2241 March 2, 1981.
>
> "for the development, advancement, management, conservation, and protection of fish and wildlife resources" [16 U.S.C. 742f (a)(4)]; "for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to the terms of any restrictive or affirmative covenant, or condition of servitude" [16 U.S.C. 742f (b)(1) (Fish and Wildlife Act of 1956)].
>
> "particular value in carrying out the national migratory bird management program" [16 U.S.C. 667b (An Act Authorizing the Transfer of Certain Real Property for Wildlife)].

National Wildlife Refuge System Mission:

> "The mission of the System is to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans." (National Wildlife Refuge System Administration Act of 1966 as amended, 16 U.S.C. 668dd-668ee).

Description of Use:

A. What is the Use?

The use is mosquito management which includes mosquito monitoring and, when warranted, larvicide application to manage mosquito populations within an Integrated Marsh Management (IMM) approach. The proposed monitoring and larvicide application, and potential impacts, are described in a Draft Plan and Environmental Assessment for Mosquito Control (USFWS 2014a) which this Compatibility Determination is appended to and which is hereby incorporated through reference. The IMM approach also includes habitat management which would involve the excavation of an additional 40,000 linear feet of low-order tidal channels within the tidal wetlands on the Ni-les'tun Unit of Bandon Marsh National Wildlife Refuge (Refuge). Expansion of the tidal channel network would increase the tidal prism and water exchange, while greatly reducing the number of shallow depressions that trap water providing mosquito breeding habitat. The proposed habitat manipulation and potential impacts are addressed in a Draft Supplemental Environmental Assessment for tidal marsh restoration (USFWS 2014b). Mosquito management is not a priority public use of the Refuge System under the National Wildlife Refuge System Administrative Act of 1966 (16 U.S.C. 668dd-668ee) as amended by the National Wildlife Refuge System Improvement Act of 1997.

B. Where would the use be conducted?

In 2011, the U. S. Fish and Wildlife Service (Service), a team of cooperators, and experts in the field of Oregon tidal marsh ecology and restoration completed a 420-acre tidal marsh restoration project on the Ni-les'tun Unit of the Refuge. The restoration project involved, in part, the disruption of 11 miles of shallow drainage ditches by discing, filling of 4 miles of larger ditches, and construction of 5 miles of new sinuous tidal channels. A large portion of the perimeter dike was lowered and three water control structures were removed adjacent to the Coquille River to allow for full tidal flow across the historic and newly restored tidal marsh. After construction (2012–2013), depressions that hold water inadvertently remained in many of the shallow ditches that were disced, along some large ditches where the fill settled, and within the tracks left by heavy equipment. Monthly high tides fill many of the depressions and retain water long enough to permit salt marsh mosquitoes (*Aedes dorsalis*) time to complete their development. These shallow depressions filled with tidal waters create ideal breeding habitat for the salt marsh mosquito and this has resulted in unprecedented mosquito production on the Refuge. As the IMM approach is implemented, the proposed habitat management to drain the artificial mosquito breeding sites would be occurring concurrently with mosquito monitoring and application of larvicides for control. Adult and larval mosquito monitoring would be conducted on both units of the Refuge; however, larvicide treatments would be restricted to an area of approximately 300 acres containing mosquito breeding habitat within the Ni-les'tun Unit.

C. When would the use be conducted?

Due to the 2013 documented increase in the number of breeding mosquitoes on the Ni-les'tun Unit, the Refuge in cooperation with Coos County Public Health (CCPH) proposes to implement an important portion of the IMM approach by monitoring the Refuge's adult and larval populations of mosquitoes, and perform control efforts when mosquitoes have the potential to affect public health and safety on and adjacent to the Refuge. Refuge monitoring and control is proposed by CCPH to take place between March and late September, during which time most of the higher tidally influenced areas (approximately 300 acres) on the Ni-les'tun Unit may support large numbers of mosquito larvae. Habitat manipulation would take place during the spring/summer on the Ni-les'tun Unit. The construction of additional tidal channels would increase tidal flows allowing the ponded areas to drain during each low tide cycle and thereby eliminating the mosquito breeding habitat.

CCPH would monitor mosquito populations on the Refuge from March through September potentially using a variety of adult trap styles (e.g., dry ice traps) and dip-collection methodology for larvae within the Bandon Marsh NWR. Common species collected in 2013 include *Aedes dorsalis*, *Aedes sticticus*, *Aedes cinereus*, *Culiseta particeps*, and *Culex tarsalis*. Of the five species of mosquitoes present in 2013, about 90% of the mosquitoes sampled were the salt marsh mosquito making this species the target of management.

The Service anticipates that the physical manipulation of the marsh to increase the tidal prism and water exchange, while greatly reducing the number of shallow depressions that trap water providing mosquito breeding habitat, may essentially preclude, or at least greatly reduce, the need for larvicide treatment into the future. However, due to the magnitude and complexity of the issue and the subsequent public health concerns, larvicide treatments are proposed for use for as long as necessary to reduce the potential for public health threats and adverse impacts to public health to a manageable level. The potential use of larvicide would be evaluated each year based on monitoring results, and stipulations on its use would be contained in the annual SUP issued to CCPH.

<u>D. How would the use be conducted?</u>
CCPH proposes to monitor adult and larval mosquitos with the use of traps and dip-collection methodology. As part of the IMM approach to reduce the level of adult mosquitoes that pose a health threat or adverse impact to public health and safety, mosquito larvae would be killed with the application of a larvicide (*Bti*, Methoprene, Cocobear™ – 10% surface film mineral oil) to active mosquito breeding habitat when larval number thresholds, as set by CCPH and agreed upon by the Service, are exceeded as determined through monitoring. Adult and larval mosquito monitoring would be conducted on both units of the Refuge; however, larvicide treatments would be restricted to the mosquito breeding habitat within the Ni-les'tun Unit. In 2013, the Refuge documented the extent of mosquito production habitat to be within approximately 300 acres of tidally influenced salt marsh. These mosquito breeding areas are subject to change depending on the results of proposed IMM habitat enhancement actions. As the IMM approach is implemented, along with new monitoring results or information on sensitive resources, habitat enhancement and control site locations may be modified.

Mosquito larvae numbers on the Refuge are affected by a number of factors such as tides, weather conditions (e.g., temperature, humidity, winds), precipitation, and time of year (e.g., day length). The primary factor contributing to the production of salt marsh mosquitoes, however, is the tidally driven filling of the shallow depressions where this species lays its eggs. These depressions containing the eggs must dry out and then reflood before the eggs will successfully hatch. Due to the seasonal uncertainty of water levels resulting from the above factors, and the resulting uncertainty of the levels of mosquito hatches, the type and total amount of larvicide to be used, and times, dates, and exact locations of application (magnitude and frequency) cannot be predicted in advance but must be carefully determined through frequent monitoring. In addition, due to the lack of baseline data and no previous mosquito abatement district efforts in Coos County or any other coastal county in Oregon, the CCPH and refuge staffs are learning on-the-job about the mosquito breeding habitat distribution on Refuge, the correlations between biotic, abiotic and anthropogenic factors that lead to an abundance of mosquitoes, and the methods that can be successfully used for management. In some cases, certain areas may need repeated habitat enhancement or control treatments. If large areas of hatch occur, aircraft application of larvicide may also be needed.

To protect sensitive fish and wildlife and cultural resources, along with the effort to reduce spread of invasive plant species, sampling periods and frequency, as well as type of access (4WD vehicle, tracked amphibious ATV, foot traffic only) would be determined by the Refuge in conjunction with CCPH. Because the locations of sensitive species may change over time, the Refuge would establish sampling and treatment stipulations on an annual basis through the Special Use Permit (SUP) process described in 5 RM 17. CCPH would establish larval abundance thresholds, which if exceeded would warrant the use of larvicide application to protect public health. The Refuge would meet annually with CCPH and review monitoring and control data pertinent to the establishment of thresholds. The SUP process would allow the Refuge to concur and work with CCPH to establish terms and conditions, including working within thresholds, to reduce impacts to fish and wildlife populations. CCPH staff would request approval from the Refuge Manager to apply larvicide to treat larval mosquito populations when warranted, that is, when threshold levels are reached or exceeded, as demonstrated through monitoring.

Larvicide would be applied to the refuge tidal habitat (ponded water) harboring mosquito larvae to prevent larval mosquitoes from maturing into adults. Larvicides kill larval mosquitoes by interfering with the insect's maturation stages, preventing the insect from transforming from larvae to pupae or pupae into the adult stage, thereby precluding additional production of adult flying mosquitoes and subsequent reproduction. Larvicides proposed for use are either a contact or ingested insecticide. Larvicides are generally most effective on early larval instars but the use of a surface mineral oil film (Cocobear™) would affect late larval and pupal stages.

All monitoring results and applications of larvicide are required to be reported to the Refuge in an annual report submitted to the Refuge by CCPH. The areal extent of treatments and frequency of treatments is likely to vary annually in response to water levels, weather conditions and larval mosquito populations.

E. Why is the use being proposed?

This IMM approach was determined to be necessary to reduce an unprecedented salt marsh mosquito population on the Refuge. This approach involves concurrent habitat management actions to reduce the presence of mosquito breeding habitat while at the same time conducting monitoring of mosquito numbers and when warranted use of larvicides for control purposes. The Refuge's tidal marsh restoration and land alteration actions on the Ni-les'tun Unit of Bandon Marsh NWR during 2009–2011 are thought to be one of the contributing factors to the increased mosquito population on the Refuge. The creation of additional breeding environments for mosquitoes on the Refuge was an entirely unintended and unanticipated consequence of the tidal marsh restoration.

The tidal marsh restoration project was completed in August 2011 by a team of cooperators and experts in the field of Oregon tidal marsh ecology and restoration. Without known or suspected concerns with mosquitoes in the past, mosquito control measures (e.g., elimination of shallow depressions) were not fully integrated into the 2009–2011 tidal marsh restoration project on the Ni-les'tun Unit. Over the past decades, no previous salt marsh restorations completed by the Refuge Complex or its many partners on the Oregon Coast experienced this situation. The previous century of agricultural management as a diked and drained pastureland had left this historic tidal marsh with approximately 15 miles of drainage ditches, which were largely altered and filled in, while 5 miles of new sinuous tidal channels were created during restoration. The resulting uneven areas of terrain, combined with the impacts from heavy equipment needed for the project, left ruts and shallow areas that strand water as higher tides recede.

Active U.S. Fish and Wildlife Service involvement in mosquito abatement at that time was required to address responsibilities commensurate with our alteration of the landscape and its amenable conditions for mosquito population growth. In June of 2013, the Refuge began to inventory and monitor mosquitoes with the assistance of Oregon State University. Five species of mosquitoes were identified, however the majority of the population (>90%) was identified as the salt marsh mosquito. The numerous shallow ponds that develop during the highest tides of the month were found to be providing breeding sites for salt marsh mosquitoes at extremely high levels. In addition, adult trapping data confirmed that large numbers of adult females were using the restored tidal marsh as a breeding site and dispersing to adjacent habitats on the Refuge and nearby private lands.

The Service received numerous calls, emails and letters from the surrounding public concerning unprecedented levels of biting mosquitoes and associated health impacts. This public outcry precipitated an August 22, 2013, Coos County Public Health Advisory and a subsequent refuge-based Emergency Declaration, due to excessive numbers of mosquitoes being produced on the Refuge and impacting the health and well-being of local residents. These emergency actions allowed the Refuge to work with CCPH in an effort to protect the public by reducing mosquito production on the Ni-les’tun Unit. If left untreated, each generation of salt marsh mosquitoes breeds and grows much larger than the previous, and this species is capable of producing up to eight generations per season. On the Ni-les’tun restoration area, spring and summer monthly high tides re-flood the shallow depressions/pools, with resulting mosquito hatch and major fly-off of adult mosquitoes 8–10 days later if not controlled in the larval stage. In the fall, females produce overwintering (diapause) eggs. In early September 2013, the Service, working with CCPH, was concerned that the final egg deposition by adult mosquitoes produced in the late summer, if not treated, would then hatch the following spring and continue the cycle of increase. Treatment to reduce the number of larvae hatching in September was planned and would be expected to lower the number of subsequent adults that would produce overwintering eggs to be deposited on the Refuge. To abate the health and safety situation, CCPH contracted and applied a larvicide on the Ni-les’tun Unit of the Refuge on the 12th of September, 2013.

The proposed IMM approach was deemed necessary in the wake of the 2013 County Health Advisory and a refuge-based Emergency Declaration due to excessive numbers of mosquitoes being produced on the Refuge, and impacting the health and well-being of local residents. The 2013 emergency declaration allowed actions to be taken immediately to abate the situation with the application of a larvicide (USFWS 2013), to protect the health and safety of the public while a long-term IMM approach is developed. The Service proposes to allow monitoring and treatment of mosquito breeding habitat with the use of larvicide as a refuge use that would be allowed under a SUP issued to CCPH.

Availability of Resources:
The monitoring of mosquitoes and the application of larvicide would be conducted by CCPH and their agent (e.g., mosquito abatement contractor). Refuge personnel may assist CCPH with mosquito monitoring on Refuge, as well as conducting post treatment mosquito larvae and adult monitoring to determine efficacy of control throughout the refuge treatment area. Refuge staff is available for these tasks.

Anticipated Impacts of the Use(s):
The purpose of this section is to evaluate how the use could affect the refuge purposes and the Refuge System mission; refuge goals, objectives, and management activities; fish, wildlife, plants, and their habitats; the biological integrity of the Refuge and the Refuge System; other refuge uses; and public safety. The potential direct, indirect, individual and cumulative impacts of the use on refuge water quality, sediment quality, migratory birds, fish, estuarine organisms, mammals, and terrestrial invertebrates, and the biological integrity of the Refuge, are discussed in detail in the Draft Plan and Environmental Assessment for Mosquito Control (USFWS 2014a). The potential impacts of the use on the Service's ability to achieve refuge goals and objectives, as well as potential impacts to other refuge uses and to public safety, are discussed below. Activities and considerations necessary to mitigate potentially negative direct, indirect, one-time, and cumulative effects are detailed in the section "Stipulations to Ensure Compatibility."

Public Safety:
The objective of monitoring mosquitoes and the use of larvicide treatment, as specified in the SUP issued to CCPH, would be to reduce excessive mosquito numbers through control of larval mosquitoes, in order to protect human health and safety. The Refuge would allow the application of larvicide to refuge lands following the guidance of the stipulations in a signed SUP. The monitoring of mosquitoes and the application of larvicide, as needed to protect public health, is expected to have a positive impact on public safety through the reduction of mosquitoes and their associated adverse health impacts.

Impacts to Refuge Purpose, Goals, Objectives and Management Activities:
Bandon Marsh NWR was established for "the preservation and enhancement of the highly significant wildlife habitat … for the protection of migratory waterfowl, numerous species of shorebirds and fish … and to provide opportunity for wildlife-oriented recreation and nature study on the marsh." Refuge goals, objectives and refuge management actions focus on protecting and restoring estuarine, stream-riparian, and forested habitats, as well as providing opportunities for wildlife-dependent public use.

The proposed use includes monitoring and surveillance of mosquitoes as well as potential application of three mosquito larvicides. Monitoring and surveillance work consists of walking or driving to the sample sites, and walking through the marsh. Trampling impacts to vegetation could occur during access (on-foot, amphibious ATVs) within the tidal marsh to conduct monitoring and surveillance, and these activities have the potential to temporarily impact mammals and birds through physical disturbance resulting from vehicles and foot traffic. However, through attention to practices designed to minimize disturbance and impacts, overall effects to refuge resources, including water quality, vegetation, birds, mammals and fish, from regular mosquito monitoring and surveillance activities are expected to be negligible.

The three mosquito larvicides proposed for use are *Bacillus thuringiensis serovar israelensis* (*Bti*, a microbial pesticide), S-Methoprene (a biochemical pesticide and insect growth regulator), and Cocobear™ (a mineral oil based surficial oil). The Service has concluded that these products, when used at the proposed rate and under the specified conditions, are expected to have limited impacts to other organisms due to lack of toxicity to most life forms. According to the EPA, *Bti* does not pose risks to non-target birds, freshwater fish or invertebrates, estuarine and marine animals, arthropod predators or parasites, honey bees, annelids and mammalian wildlife or the environment when used according to label directions. Methoprene is essentially non-toxic to mammals, has some limited toxicity to birds, amphibians, and fish, and some toxicity to certain non-target invertebrates;

however, the toxicity to amphibians and fish in laboratory studies occurred at concentrations one to two orders of magnitude higher than the target environmental concentration of the formulated chemical sold for mosquito larvicide use. CocoBear™, which works by suffocating invertebrates that reside on the water surface or must surface to breathe, would be considered only if early-stage larvicides have not prevented the potential of significant numbers of adult mosquitoes leaving the Refuge. Primary control of potential effects from CocoBear™ would be its anticipated infrequent use on very small areas. The chemicals in the proposed larvicides degrade very rapidly in water, soil and sediment under both aerobic and anaerobic conditions. Application methods to minimize impacts to non-target species would include avoiding ground application of all products to tidally connected stream channels where salmon are likely to reside and utilizing short duration formulations to lessen the duration of exposure for non-target aquatic organisms. The potential for human exposure (i.e., CCPH staff, refuge visitors, and refuge staff) to larvicides would be minimized through evacuation of visitors from the Refuge prior to any aerial application. Monitoring activities and larvicide application would not preclude other refuge management activities. Therefore, monitoring of mosquitoes and use of larvicide to control larval mosquitoes as needed to protect public health is not expected to have an impact on the Service's ability to fulfill these purposes, nor to meet the goals and objectives as defined in the CCP.

<u>Impacts to other priority refuge uses:</u>
Monitoring of mosquitoes would occur on both units of Bandon Marsh NWR, and larvicide treatments would be restricted to the Ni-les'tun Unit's tidally flooded shallow depressions that are documented mosquito breeding habitat. During the potential treatment period (March through September) the public use on the Ni-les'tun Unit consists of wildlife observation, photography and interpretation in the salt marsh, from the viewing deck and a short trail that leads into the marsh. These areas would be closed to the public during the treatment period if aerial application of larvicide is determined to be necessary. No priority public uses on Bandon Marsh Unit would be interrupted in order to carry out monitoring of mosquitoes. The use is expected to have a positive impact on priority public uses on the Refuge through the reduction in mosquito numbers and accompanying threats and adverse impacts to public health.

Public Review and Comment:
Following the August 2013 issuance of a Public Health Advisory by CCPH and the Emergency Declaration by the Refuge Complex's Project Leader, Refuge and Service Regional Office staff initiated discussions on potential treatment prescriptions to control the mosquito source population for the remainder of the mosquito season. Participants in the discussion included managers and biologists from other National Wildlife Refuges, vector control biologists with Mosquito Abatement Districts (MAD) and Vector Control Districts (VCD), health experts from CCPH, and technical representatives from mosquito treatment providers that are familiar with salt marsh mosquitoes and their human and wildlife health threat. The option of pesticide treatment to reduce the health threat and emergency situation was first brought into the public debate at this time. Jackson County VCD was contacted by CCPH about the mosquito situation at Bandon Marsh because Coos County has no historic or established MAD or VCD. Subsequent to the discussions and guidance from Jackson County VCD, CCPH released a Draft "Proposal for Mosquito Control on the Bandon Marsh Refuge and Surrounding Area" to inform the public on the proposal and obtain approval of the County Commissioners to implement the plan. Coos County Commissioners and the City of Bandon considered the plan for approval and made the recommendation that it be vetted by the public prior to implementation due to the sensitive nature of the potential effects to the local community. The county hosted a public meeting in Bandon on September 9th to hear concerns of the citizens, and

subsequently made the decision to use larvicide only on the Ni-les'tun Unit of the Refuge as soon as possible. During all this time, the governor's office, Oregon Senators Ron Wyden and Jeff Merkley, and Representative Peter DeFazio were kept informed of the situation as it developed. These emergency actions allowed the Refuge to work with CCPH in an effort to protect the public by reducing mosquito production on the Ni-les'tun Unit. In order to abate the health situation, CCPH contracted Vector Disease Control International to apply a larvicide on the Ni-les'tun Unit of the Refuge on September 12th.

The Service is committed to working with Coos County Commissioners, CCPH, and the City of Bandon to develop and implement of the Service's proposed IMM approach to reduce mosquito habitat on the Refuge. This IMM approach strives to be compatible with people who make their home and livelihood near the Refuge, as well as the fish and wildlife that use Bandon Marsh Refuge. The Service's communication goal is to ensure the public and interested stakeholders are kept informed, with factual and timely information, of the progress in developing and implementing the IMM approach and its implementation. The two primary objectives of our communication plan are to (1) conduct outreach to ensure the public, local officials, and interested stakeholders understand refuge planning processes, how public input is utilized in the planning process, important decision points, and how those decisions were made; and (2) inform congressional contacts, state and local officials of important decision points and information prior to final decisions or actions.

The proposed IMM approach, including mosquito management, is being vetted by the public, the media, Coos County, and Congressional representatives. Key audiences, including individuals and community groups, have been identified and the Service will maintain regular communication with these audiences throughout the process of review and decision making. Media outreach will include news releases to a targeted outlets list. Other outreach will include communication of current information through the Service's Pacific Region Facebook page, Twitter account, and website as well as the Oregon Coast NWRC website. A "mosquito" web page, established on the Bandon Marsh Refuge website, provides links to the draft environmental documents as well as a Questions and Answers document that will be updated regularly as new information becomes available.

Determination:

______ Use is Not Compatible

__X__ Use is Compatible with Following Stipulations

Stipulations Necessary to Ensure Compatibility:

1. SUP permittee will attend a pre- and post-season coordination meeting with refuge staff and will provide a plan of operation prior to commencement of work.
2. SUP permittee agrees to minimize disturbance and impacts to wildlife, fish and habitats.
3. Only Service-approved mosquito larvicide will be applied on refuge wetlands and only after pesticide use proposals (PUPs) are approved. Larvicides will be applied only according to the label.
4. Minimize potential negative effects to water resources through use of the most effective product that poses the lowest risk to abiotic and biotic resources; application of larvicides only where monitoring and surveillance data justify its use; observation of wind speed restrictions on spraying; and avoiding application of larvicides during high tides and avoid

open water areas of the Refuge (e.g., sloughs, channels, adjacent river) during ground applications.

5. Application methods to minimize environmental impacts from methoprene use will include preferential use of ground-based applications so that salmon and their habitat may be avoided when applying methoprene; preferential use of short duration methoprene formulations over the slow-release methoprene formulations to lessen the duration of exposure for non-target aquatic organisms; and avoiding application of methoprene where it is likely that tidal cycles or significant rain events will flush it into areas where salmon may be exposed within 3 days post-application.
6. To avoid unnecessary impacts to vegetation and creation of additional mosquito breeding pools, the number and extent of travel pathways used by vehicles within the marsh will be minimized. Only low-ground pressure, tracked vehicles, or foot travel will be utilized. Limit the number of travel pathways used by vehicles (amphibious ATVs) within the marsh.
7. To reduce the potential for negative impacts to bird populations, field personnel will be provided training on measures to avoid impacts to nesting birds.
8. Permittee and refuge staff will follow all BMPs specified in the EA for minimizing negative environmental impacts from monitoring and larvicide application.
9. The SUP permittee is responsible for ensuring that all agents working for the permittee (e.g., mosquito abatement contractor) and conducting activities allowed by the SUP permit are familiar with and adhere to the conditions of this permit.
10. The U.S. Fish and Wildlife Service may have employees / representatives present during all fieldwork.
11. SUP permittee will coordinate all larvicide application in advance (minimum 24 hours) with the South Coast Refuge Manager to ensure there is no conflict with refuge management.
12. The SUP permittee will provide the Refuge with a report of activities under this permit by December 31st of the calendar year of the SUP issuance. This report shall include larval and adult monitoring results and a map identifying all treated areas and records of application (dates, site treatment, name of larvicide applied, quantity applied (pounds/gallons).
13. SUP permittee agrees to acknowledge Bandon Marsh NWR and the U.S. Fish and Wildlife Service in all written and oral presentations of data collected.
14. Post treatment mosquito monitoring will be conducted by CCPH and may involve assistance from the Service to determine efficacy of control using dip method for larval counts, pupae to adult hatch brooders, and mosquito light traps for adults.

Justification:
The Service, in consultation with CCPH and vector control experts, evaluated all the possibilities that would be effective in immediately reducing the refuge-based mosquito population and associated health threats and adverse impacts to public health, and preventing its recurrence in future years. The options considered included increasing the population of non-native mosquitofish (*Gambusia affinis*), construction of bat and bird boxes to increase these insect foraging species populations, habitat manipulation, and the use of insecticides. The treatment with the highest combined expectation of success and low environmental risk was a holistic approach including monitoring, habitat manipulation, and larvicide use, collectively referred to as an IMM approach. As proposed to be conducted from March through September when waterfowl and fish numbers are lowest in Bandon Marsh NWR, the actions included in this approach are expected to result in negligible to negative minor short-term direct overall effects to wildlife, and negligible to moderate negative short-term direct effects to non-target organisms. The Ni-les'tun Unit may be closed to public use during an aerial application of the larvicide for a short period of time; however, the wildlife viewing,

photography, and interpretation facilities on Bandon Marsh Unit, which are located away from the treatment area but within a short distance, would still be open for use. These factors, along with the short duration of individual treatments and the expected reduction in mosquito numbers, are expected to have a moderate positive long-term impact on refuge priority public uses. The associated disturbance to wildlife from these activities is expected to be negligible. It is estimated that wildlife populations would find sufficient food resources and resting places such that their abundance and use of the Refuge would not be measurably lessened from allowing this use to occur. The relatively limited number of individual animals and plants that may be negatively affected by monitoring activities and larvicide application would not cause wildlife populations to materially decline, the physiological condition and production of refuge species would not be impaired, their behavior and normal activity patterns would not be altered dramatically, and their overall welfare would not be negatively impacted. Thus, allowing the monitoring of mosquitoes and the application of larvicide to control mosquitoes on refuge lands, under the stipulations described above, is not expected to materially detract or interfere with the purposes for which the Refuge was established or the Refuge System mission.

Mandatory Re-Evaluation Date:

______ Mandatory 15-year reevaluation date (for wildlife-dependent public uses)

__X__ Mandatory 10-year reevaluation date (for all uses other than wildlife-dependent public uses)

NEPA Compliance for Refuge Use Decision: (check one below)

_______Categorical Exclusion without Environmental Action Statement

_______Categorical Exclusion and Environmental Action Statement

______ Environmental Assessment and Finding of No Significant Impact

_______Environmental Impact Statement and Record of Decision

References:

USFWS (U.S. Fish and Wildlife Service). 2013. Environmental assessment: MetaLarv S-PT treatment on the Ni-les'tun Unit to control salt marsh mosquitoes. U.S. Department of the Interior, Fish and Wildlife Service, Region 1, Bandon, OR. 60 pp. Available at: http://www.fws.gov/oregoncoast/bandonmarsh/Mosquito.html.

USFWS. 2014a. Draft Plan and Environmental Assessment for Mosquito Control for Bandon Marsh National Wildlife Refuge, Bandon, OR. 209 pp.

USFWS. 2014b. Draft Supplemental Environmental Assessment for the Ni-les'tun Unit of the Bandon Marsh National Wildlife Refuge Restoration Project. U.S. Department of the Interior, Fish and Wildlife Service, Region 1, Bandon, OR. 59 pp.

Use: Mosquito management, to include monitoring of mosquitoes and application of specific larvicides to reduce mosquito production on the Ni-les'tun Unit of Bandon Marsh NWR

Refuge Determination:

Prepared by: ______________________________ ____________
(Signature) (Date)

Refuge Manager/
Project Leader Approval: ______________________________ ____________
(Signature) (Date)

Concurrence:

Refuge Supervisor: ______________________________ ____________
(Signature) (Date)

Regional Chief,
National Wildlife
Refuge System: ______________________________ ____________
(Signature) (Date)

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Appendix B. Public Health Authority: Coos County, Oregon

Coos County Public Health
1975 McPherson #1
North Bend, Oregon 97459

Phone: 541-751-2425
Fax: 541-751-2653

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Appendix C. Toxicological Review and Environmental Effects Analysis for Mosquito Larvicides Proposed for Use at Bandon Marsh National Wildlife Refuge

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Toxicological Review and Environmental Effects Analysis for Mosquito Larvicides proposed for use at Bandon Marsh National Wildlife Refuge

Prepared for

Mosquito Pesticide Plan and Environmental Assessment for Bandon Marsh National Wildlife Refuge
Oregon Coast National Wildlife Refuge Complex
2127 Marine Science Drive, Newport, OR 97411

Prepared by

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March 4, 2014

1 Table of Contents

2 Glossary of terms and abbreviations

a.i.	Active Ingredient
BCF	Bioconcentration Factor
Bti	*Bacillus thuringiensis* serovar israelensis
CAS	Chemical Abstracts Service
EEC	Estimated Environmental Concentration. The estimated pesticide concentration in an environment such as the water in a wetland.
EC_{50}	Median Effects Concentration. A statistically derived concentration of a substance that can be expected to cause an effect in 50% of test animals. It is usually expressed as the weight of substance per weight or volume of water, air or feed (e.g., mg/l, mg/kg, or ppm).
LC_{50}	Median Lethal Concentration. A statistically derived concentration of a substance that can be expected to cause death in 50% of test animals. It is usually expressed as the weight of substance per weight or volume of water, air or feed (e.g., mg/l, mg/kg or ppm).
LD_{50}	Median Lethal Dose. A statistically derived single dose that can be expected to cause death in 50% of the test animals when administered by the route indicated (oral, dermal, inhalation). It is expressed as a weight of substance per unit weight of animal (e.g., mg/kg).
lbs	Pounds
LOC	Level of Concern
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
mg/kg/day	Milligram Per Kilogram Per Day
mg/L	Milligrams Per Liter – In water, this is equal to parts per million
µg/L	Micrograms Per Liter – In water, this is equal to parts per billion
NOAEC	No Observed Adverse Effect Concentration
NOAEL	No Observed Adverse Effect Level
NOEC	No Observable Effect Concentration
NOEL	No Observed Effect Level
ppb	Parts Per Billion - in water, this is equal to micrograms (µg of a substance per liter of water, or µg/L)
ppm	Parts Per Million - in water, this is equal to milligrams (mg of a substance per liter of water, or mg/L)
RED	Reregistration Eligibility Decision. USEPA licensing document for pesticides.
Refuge	Bandon Marsh National Wildlife Refuge
RQ	Risk Quotient = Exposure/Toxicity
Service	US Fish and Wildlife Service
USEPA	US Environmental Protection Agency

3 Introduction

3.1 Summary of mosquito control products considered

This document summarizes the potential environmental effects from three mosquito larvicides: *Bacillus thuringiensis* serovar israelensis (*Bti*, a Microbial Pesticide), S-Methoprene (a Biochemical Pesticide and Insect Growth Regulator), and CocoBear™ (a mineral oil based surficial oil). No other pesticides were considered for this analysis. The summary of potential pesticide effects is limited to the tidal salt marsh areas of Bandon Marsh National Wildlife Refuge (Refuge), as some of the assumptions made for this report apply specifically to this habitat. The literature review focuses on a single target pest, the summer salt marsh mosquito, *Aedes dorsalis*, a vector that may transmit diseases such as West Nile Virus. The review also focuses specifically on species that might be affected by any of these pesticides (non-target species) in the Bandon Marsh Refuge tidal salt marsh habitat. The marsh is designated critical habitat for a threatened fish species, the Coho or Silver Salmon (*Oncorhynchus kisutch*), therefore special consideration has been given to this species and its potential prey items in this report.

3.2 Role of this report in the Integrated Marsh Management approach at Bandon Marsh Refuge

The Service has developed a comprehensive Integrated Marsh Management (IMM) Approach, which is described in two separate environmental assessment documents, to address the mosquito overabundance at Bandon Marsh Refuge. The IMM approach provides a long-term strategy to eliminate the majority of the salt marsh mosquito breeding habitat by modifying site hydrology. The environmental consequences of alternatives for accomplishing this habitat modification are described in a separate Supplemental Environmental Assessment (USFWS 2014). In order to control mosquito production on the Refuge until the habitat reduction project can be implemented and have its intended effect, the Service anticipates a need to use pesticides, and is therefore producing a Pesticide Application Plan and Environmental Assessment. The Pesticide Application Plan and Environmental Assessment relies on the toxicological review and environmental effects analyses presented in this report for the selection of larvicidal products, and the proposed phased approach for their application, to be consistent with an integrated pest management approach to managing Refuge mosquito populations effectively and with minimal non-target environmental effects. The intent of this IMM approach is to limit use of larvicides in the long term by relying on monitoring and habitat alteration as a primary approach to mosquito control.

3.3 Chemical formulations

The USEPA registration process for pesticides considers primarily the toxicity and environmental persistence of the active ingredient (a.i.), however in most cases the active ingredient is combined with other so-called “inert” ingredients that alter the environmental behavior or the toxicity of the chemical (USEPA 2013). All inert ingredients in USEPA registered products must appear on a pre-approved list before being used in a formulation (USEPA 2013). These inert ingredients may be surfactants, adjuvants, or other ingredients designed to enhance the toxicity, increase the bulk of the product, lengthen its persistence in the environment, or otherwise improve its ability to reach the target species. These inert ingredients are not intended to have non-target toxicity but in some cases they do. For example an ingredient included in some formulations of the herbicide Roundup to penetrate the waxy cuticle in plants was demonstrated to be lethal to frogs (Relyea et al. 2005a, 2005b, 2005c). All of the pesticide products considered in this report are formulated so that inert ingredients comprise the majority (80-99% by weight) of the formulation. Consequently, environmental exposure to these ingredients may be greater than exposure to the assessed active ingredient. USEPA currently has no specific method of accounting for this potential additional toxicity and risk, but it cannot be ignored. We therefore address the uncertainty associated with inert ingredients qualitatively. To provide the benefit of the doubt to the species, when we have incomplete information regarding inert ingredients, we assume these inert ingredients may contribute additional stress to the system. Where the manufacturers have shared information about the inert ingredients with us and have allowed us to share it here, we have included it in our evaluation. If manufacturers have refused to share this information with us, we make our best effort to discuss these uncertainties qualitatively.

3.4 Concentrations and units

Toxicologists are notorious for reporting chemical concentrations in different units. For example, the same chemical in water might be reported in Mols (M), micromoles (mM), nanomols (nM), milligrams per liter (mg/L), which is the same as parts per million (ppm) in water, micrograms per liter (µg/L), which is the same as parts per billion (ppb) in water. All of these units will result in a different number reported to describe the same amount of “stuff” in the water. To further complicate matters, the authors of pesticide studies may report how many micrograms of the active ingredient there are per liter or how many micrograms of the technical pesticide formulation there are in a liter of water or a gram of food. For the exact same amount of the chemical, those reported values (µg of a.i. versus µg of technical formulation) may differ by several orders of magnitude (e.g., if the formulation is only 1% active ingredient by weight). Sometimes the paper is not specific enough to evaluate whether the authors were reporting “parts” of the a.i. or the technical formulation when they list concentrations of “parts per billion”. Needless to say, these differences in units and lack of specificity regarding what reported concentrations represent make comparison of studies in the toxicological literature sometimes challenging. To eliminate such confusion for the reader here, we have translated as many of these concentrations as possible into standard units.

3.4.1 Water concentrations

For concentrations in water, we have translated all concentrations into parts per billion (ppb) of the active ingredient. We used ppb because it is considered more standard for chemical concentrations in water and was scaled more appropriately for expected environmental concentrations of chemicals considered here. For those studies using molar concentrations of S-methoprene (molecular weight of 310.48 grams/Mol) we used a conversion factor of 1 ppb=1µg/L=3.2nM. Using this conversion factor, use of S-methoprene at labeled application rates should result in environmental concentrations of approximately 3 nanoMolar (nM).

3.4.2 *Bti* Counts

For biorational pesticides, like *Bti*, much of the toxicology literature is reported in "Colony Forming Units" (CFUs), which has no direct translation to ppm or ppb in water, despite the ability to make such calculations, based on label information. The results of such calculations based on % a.i. by weight may be misleading because they do not account for the potency of the *Bti* formulation, which is only loosely standardized.

3.4.3 Dosing Studies

For studies that administer chemicals to animals orally, dermally, by injection, or otherwise, chemical content can be reported as milligrams per kilogram (mg/kg, equal to ppm) of the food, or the authors may convert that food concentration or dose to mg/kg per body weight of the animal. For dosage data, we have reported the values in mg/kg or ppm (as is the standard with these data) and done our best to repeat the level of available clarity as to whether the dose was per kg of body weight of the animal or of the diet. Where this was not possible, the citations are provided so that the reader may obtain the original study and interpret it for themselves.

A summary of the available literature for each of these pesticides and their anticipated effects on the environment of Bandon Marsh Refuge follows.

4 *Bacillus thuringiensis* var. israelensis

Bacillus thuringiensis serovar israelensis (*Bti*) is a bacterial toxin, classified by the USEPA registration documents as a "Microbial Pesticide" (USEPA 1998). There are different strains of *Bacillus thuringiensis* (USEPA 1998), however, this report covers only *Bti*. There is a vast scientific literature on *Bti*. We have made our best effort to summarize the literature here in a way that is meaningful to USFWS resource management, but this is by no means a comprehensive literature review. For such a review please see the following references: Boisvert and Boisvert (2000) reviewed 75 laboratory and field studies collectively evaluating target and non-target effects of *Bti* on nearly 400 species. The World Health Organization wrote a comprehensive literature for *Bti* (WHO 1999). The USEPA (1998) summarized basic environmental behavior and the results of their toxicity screening analyses conducted for licensing *Bti* as a pesticide (many of the primary licensing studies are not publically available) in their re-registration eligibility document (USEPA 1998). There are also more recent studies referenced in the individual sections below.

4.1 Mode of action

Bti is an aerobic, gram positive, spore forming bacteria. It forms sharp crystals encapsulated in a parasporal body or protoxin. When that parasporal body dissolves, the crystals are released and if appropriate receptors are present, the sharp crystals may perforate the gut cavity of target insects to cause sickness and death. Different strains of *Bt* are specific to different insects, because the protoxin is only activated following ingestion if the gut pH is correct and the insect has the correct receptors for the toxin. In order to be activated, the crystal containing the protoxin must dissolve within the gut of the insect. This dissolution only occurs within a narrow pH range, which varies by *Bt* strain, to conform to the physiological properties of the target insect. If a *Bti* crystal is ingested into a gut environment with the wrong pH, the parasporal membrane will not dissolve and the protoxin will pass through the organism. Once the protoxin is activated, several different toxins may bind to receptors on the gut membrane to result in adverse effects. These receptors are believed to be species specific, so that even an activated toxin may pass through an organism that does not have the proper receptors. The multiple toxins bind with different toxin-specific receptors in the gut, acting both alone and synergistically, with an end result of larval starvation and death. A large body of evidence suggests that animals without an extremely alkaline gut (pH 10–12) and without specific intestinal receptors may eat *Bti* and remain unaffected. Boisvert and Boisvert (2000) provide a thorough review of this process.

4.2 History and patterns of use

4.2.1 Discovery

An isolate of *Bacillus thuringiensis* was first registered for use as an insecticide in the United States in 1961 (USEPA 1998). It was not known at the time that there were different subspecies of *Bt*. *Bacillus thuringiensis* var. israelensis (serovar H-14) was discovered in 1976 in dead mosquitoes from a pond in the Negev desert in Israel (Goldman and Margalit 1977). Researchers were aware of the insecticidal activity of *Bt* at the time and were looking specifically for a strain more targeted towards larval mosquitoes (Lacey 2007). *Bti* has since seen extensive field use to control both black flies and mosquitoes in both freshwater and salt water natural habitats, as well as more artificial catch-basin or storm water systems.

4.2.2 Regulation of toxic impurities

Previously, a number of fermentation-based *Bt* products tested at high doses were found to exhibit intrinsic toxicity to nontarget organisms including *Daphnia magna*, honeybees, insects, rainbow trout, bluegill, mice, and rats. The most sensitive species to these toxic effects was *Daphnia magna.* Investigations conducted to determine the cause of this toxicity found that these effects were not the result of the *Bt* endotoxin, but heat-labile soluble exotoxins contaminating the technical material. The Environmental Protection Agency's (USEPA) 1998 Reregistration Eligibility Decision (USEPA 1998) addressed this issue by mandating standardization of the manufacturing process for all *Bt* production and introducing new quality control measures, including toxicity testing on mice and *Daphnia magna* prior to sale. In order to meet these new guidelines, production batches must contain negligible quantities of toxic impurities. As a result of these changes instituted by USEPA, adverse effects of exotoxins in *Bt* products are not anticipated to result from use of *Bti* to treat mosquitoes.

4.2.3 Specificity of *Bti* to mosquitoes and black flies

This distinction between *Bti* and other *Bt* strains is important because different strains of *Bacillis thuringiensis* are toxic to different organisms. This report does not cover *Bacillis thuringiensis* (*Bt)* crops (those genetically engineered to produce *Bt* toxins), nor does it cover other strains of *Bt* that target other organisms like moths (vars. *kurstaki* and *aizawai strains*; NPIC 2000) or beetles (*tenebrionis strain*). *Bti* is highly specific to the larvae of mosquitoes, black flies, and certain types of chironomid midges. *Bti* has been used as a mosquito larvicide since the 1970s. Different bacterial toxins, *Bacillus sphericus* and

Spinosad (*Saccharopolyspora spinosa)* also target mosquitoes, but were not considered in this assessment. Some *Bti* formulations are labeled for use on organic crops (e.g., Valent Biosciences, http://publichealth.valentbiosciences.com/products/vectobac/wg-wdg), due to their high level of target specificity and otherwise excellent toxicological and environmental health profile.

4.3 Behavior of the active ingredient in the environment

Bti has limited environmental persistence under most environmental conditions, but some literature does show it to persist or recycle in some cases. While initial toxicity (ability to be consumed by mosquito larvae) decreases quickly in most cases, the actual spores and toxins can persist and accumulate under certain conditions. High amounts of organic matter (e.g., leaf litter) seem to encourage persistence. *Bti* has been shown to undergo rapid breakdown by sunlight and ultraviolet radiation (Glare and O'Callaghan 1988, Joung and Cote 2000, NPIC 2000). *Bti* also tends to adsorb to vegetation, organic, or other fine particulate matter in water within 3 to 4 days (NPIC 2000, Duchet et al. 2010). Once bacterial particles sorb to soil particles, they lose their larvicidal activity (WHO 1999). Perhaps due to these tendencies to sorb to vegetation and breakdown in the soil environment due to microbial degradation, the toxicity of *Bti* has been shown to diminish rapidly in unsterilized soils (Joung and Cote 2000). In systems with high organic matter, *Bti* spores may persist via recycling in that organic material and may be remobilized during floods (Tetreau et al. 2012, WHO 1999). In one study, *Bt* spore counts in soil declined by a factor of 10 in the first 2 weeks after application and then remained constant for 8 months (WHO 1999). Unformulated *Bt* has a half-life of only a few hours on foliage, although when formulated, it should last longer (see next section for discussion of persistence of different formulations). *Bti* is relatively insensitive to variations in water pH (Glare and O'Callaghan 1988) and has been shown to be effective in salt and freshwater habitats. *Bti* is unlikely to contaminate groundwater, due to its high affinity for sediments and organic materials (NPIC 2000). *Bti* remains viable for longer in static than in moving water (WHO 1999), and is more effective at controlling target insects when water temperatures are higher.

4.4 *Bti* products considered for use

We considered the *Bti*-based products in the following table (Table 1) for use at Bandon Marsh Refuge. These choices were based on recommendations from several mosquito control experts familiar with the species of salt marsh mosquito (*Aedes dorsalis*) and the environmental conditions in areas of the Refuge requiring treatment. The longevity of the formulation will vary based on environmental conditions, but relative longevity can be inferred by the label-recommended application interval (Table 1). Longer intervals imply greater longevity of the product.

Table 1. *Bti* products considered with active content and application rates from product labels.

Product Name	USEPA Registration Number	Active Ingredient (%)	Application Interval (days)	Application Rate (Lower)	Application Rate (Upper)	Application Rate (Max)
Solid and Granular Formulations				***(lbs product per acre)***		
Fourstar *Bti* CRG™	85685-4	10	40	7.5	10	20
Teknar G™	73049-403	1.7	7-14	2.5	10	20
Teknar CG™	73049-403	1.7	7-14	2.5	10	20
VectoBac GS™	73049-10	2.8	7-14	2.5	10	20
VectoBac GR™	73049-486	2.8	7-14	2.5	10	20
Vectobac G™	73049-10	2.8	7-14	2.5	10	20
AquaBac 200G™	62637-3	2.86	7-14	2.5	10	20
AquaBac 400G™	62637-1	5.71	7-14	5	8	8
Liquid Formulations				***(oz. product per acre)***		
Teknar SC™	73049-435	5.6	Not listed	4	32	32
Aquabac XT™	62637-1	8	Not listed	4	32	32
VectoBac 12AS™	73049-38	11.61	Not listed	4	32	32

4.5 Persistence of different formulations

Most *Bti* formulations sold commercially serve to increase the persistence of *Bti* from that of the raw active ingredient. The shorter term products may be effective for as few as 3 days, the longer term formulations for longer than one month (pers. comm., R. Sjogren, Central Life Sciences). Most formulations of *Bti* are different sizes of solid granules or aqueous suspensions of the *Bti* active ingredient. Most products are labeled for a 7–14 day application interval (Table 1). Until recently, there was not a formulation of *Bti* that was designed to last more than approximately one week in the environment. In 2013, Central Life Sciences began marketing a more persistent product, labeled for an application interval of 40 days. This extended release, granular formulation (Fourstar *Bti* CRG™; http://www.centralmosquitocontrol.com/products.php?type=13&family=fourstar) is designed to release *Bti* into the water column more slowly over this extended period (pers. comm. R. Sjogren, Central Life Sciences). The amount of *Bti* released per unit time by this product (e.g., per day) is actually somewhat lower than the liquid or other granular formulations, and this difference in design may affect how quickly mosquito larvae that ingest it are killed.

4.6 Target specificity and summary of direct effects to non-target organisms

4.6.1 Invertebrates

Bti has been shown to have toxic activity against mosquitoes, black flies, and certain species of midge. No direct effects of *Bti* toxicity have been found for aquatic invertebrates other than black flies, mosquitoes, and midges. In toxicity studies performed in support of product registration, *Bti* was not toxic or pathogenic to green lace-wing larvae (order Neuroptera), parasitic hymenoptera, predaceous coleopteran, honey bees, grass shrimp or copepods (USEPA 1998). Moderate toxicity to daphnia was attributed to factors other than the delta-endotoxin (see discussion above regarding the regulation of impurities) and is not expected with current formulations due to quality control requirements in product manufacture (USEPA 1998).

Direct toxicity testing of *Bti* at concentrations of 50 to several hundred times the dose that killed 50% of the study population (LD_{50}) for the mosquito, *Culex pipiens*, resulted in no effects to individuals within several orders of crustaceans (Amphipoda, Decapoda, Anostraca, Cladocera, Ostracoda, Copepoda, and Isopoda), insects (Ephemeroptera. Odonata, Hemiptera, Coleoptera, and Trichoptera), tubellarian worms, and Gastropod snails (Garcia et al. 1980). Individuals of several species exhibited normal molting and reproduction during the study period, including notonectids, damselflies, dragonflies, ephydrid flies, and a species of Tricoptera, indicating that growth and development continued to occur after ingestion of *Bti*. No effect was found to dipteran brine flies in the family Ephydridae.

The gut pH of black flies and mosquitoes is an unusually alkaline environment that rarely exists within other species (pH range: 10–12). Acidity is measured using a log scale, therefore a change of one point in the pH scale represents an order of magnitude change in the hydrogen ion concentration (which is what the pH scale quantifies). Results for most species in these studies were well below this range and therefore unable to activate the *Bti* toxin. Intestinal pH ranged from 5.5 to 7.2 in the dragonfly order Odonata, with samples from the families Aeshnidae and Libellulidae (Saxena 1978, Joose and Verhoef 1987). In Lepidoptera, midgut pH was measured in 60 species from 20 families (Case 1978). The majority (75%) of species had a gut pH between 7.0 and 9.0, with only one species reaching a pH of 10.0. Within the family Lycaenidae, pH levels ranged from 8.2 to 8.7. Within the order Coleoptera, digestive tract pH ranged from 5.5 to 9.0 in 4 species and from 7.5 to 10.2 in 2 species (Grayson 1958). Because of the large number of species associated with each of these insect orders, the number of investigations is relatively limited. Results of these studies show a small percentage of species with slight overlap of the typical pH in the gut of a black fly or mosquito, which ranges from 10 to 12.

The only invertebrate taxa other than black flies and mosquitoes to show sensitivity to *Bti* are the dipteran midges, and that sensitivity has varied among studies. Midges within the families Dixidae, Ceratopogonidae, and Chironomidae were affected by treatments of *Bti* spores, but at concentrations of 50 to several hundred times the LD_{50} for the mosquito, *Culex pipiens* (Garcia et al. 1980). Abundance of chironomids exposed to the standard application rate of 9 kg/ha used by the Minneapolis-St. Paul Metropolitan Mosquito Control District did not differ from controls (Liber et al. 1998). *Bti* concentrations required to reduce chironomid abundance in mesocosms by 25, 50 and 75% were 1.5–2.0X, 2.1–3.3X and 3.5–11.0X the operational application rate. Charbonneau et al. (1994) detected no reduction in benthic invertebrates, including chironomids, following application of Vectobac™ G at up to 5 times the operational application rate for mosquito control. Follow-up studies of chironomid toxicity in the lab found that *Bti* was less toxic to these species under field conditions.

In a review of effects to odonates (dragonflies) exposed to *Bti* for mosquito control, Lacey and Mulla (1990) concluded that *Bti* applied at larvicidal or higher rates had no noticeable adverse effects on odonates either through direct exposure to spores or secondary exposure via consumption of treated mosquito larvae or prey reduction. Their review also assessed effects to Coleoptera and revealed no adverse effects on dytiscid or hydrophilid beetle larvae from lab and field studies. In a study that examined the effects of black fly suppression upon predatory insects, predators continued to consume black fly larvae after larvae were killed by *Bti* at recommended application rates for black fly control in artificial and natural streams, and exhibited no adverse effect, even when larvae were treated at levels greatly exceeding the application rate (Wipfli and Merritt 1994). Black fly larvae remained attached to substrate for over two weeks following a *Bti* application. The authors concluded that *Bti* appeared to be harmless to non-target benthic invertebrates, even at applications rates greatly exceeding those required for black fly control. No effects were detected to survival, emergence, or growth in sixteen taxa of non-target Ephemeroptera, Plecoptera, Tricoptera, and Diptera.

For mollusks, no adverse effects were detected in 15 different species including mussels, oysters, and snails exposed to *Bti* (Glare and O'Callaghan 1998). A study of the freshwater Unionid mussel *Obliquaria reflexa* found no mortality or signs of external stress from *Bti* exposure up to 200 times the suggested application rate (Waller 1992). The author reported that these results agreed with an earlier study in which no effects were found to the freshwater mussel *Anodonta imbecilis* exposed to twice the rate of *Bti* applied to Tennessee Valley Authority reservoirs. Another study found no effects to mussels (*Pelecypoda sp.*) or freshwater snails (*Physa sp.*) exposed to concentrations of *Bti* over 100 times the lethal dose for mosquitoes (Garcia et al. 1980). In a field study of ponds occurring within a natural stream system, no change was detected in the average number of gastropods between treated and untreated pools (Dickman 2000). Though stomach and intestinal tract pH are available for only a subset of aquatic species, investigations of several mollusks have found intestinal pH levels to average between 6 and 8 (Yonoe 1925, Barlocher et al. 1989, Areekijseree et al. 2004, Greenfield 2009), well below the range of species known to activate the *Bti* toxin.

4.6.2 Fish

In toxicity studies performed by the registrant, *Bti* was not toxic or pathogenic to either freshwater (trout and bluegills) or estuarine (sheepshead minnow) fish species (USEPA 1998). In addition, no effects on behavior or reproduction were observed in resident fish in field studies in areas of *Bti* treatment (USEPA 1998). Exposure to *Bti* at 10 times the effective field concentration had no effect on swimming performance of crimson-spotted rainbowfish (*Melanotaenia duboulayi*) (Hurst et al. 2007). Of teleost fish possessing a true stomach, pH generally ranges from 1 to 4, and from 6.5 to 9 in the intestine (Kleinow et al. 2008). The typical pH in the gut of a black fly or mosquito ranges from 10 to 12, an unusually alkaline environment for the activation of *Bti* that is unlikely to exist within fish species.

4.6.3 Amphibians and Reptiles

To our knowledge no toxicity studies of *Bti* to reptiles and amphibians have been performed, however direct effects are not expected from *Bti* exposure because no direct toxic effects have been observed to any other vertebrate taxa (USEPA 1998). Frog tadpoles may be the most likely life stage to directly ingest *Bti* granules in water or through food items. Bjorndal (1997) indicates that herbivorous tadpoles have a poorly differentiated stomach with a neutral pH, while carnivorous tadpole stomachs have a low pH. Since most digestion occurs in the midgut, pH values there are expected to be lower. These low pH values are not sufficient to activate the *Bti* protoxin and therefore there should be no direct effects of *Bti* on tadpoles. This study also indicated that stomach and intestinal pH values in the aquatic turtle *Pseudemys nelsoni* ranged from 1.8 to 7.3. These values are below thresholds required to activate *Bti* if incidental ingestion of *Bti* through its food resources were to occur.

4.6.4 Birds

Direct effects are not expected from *Bti* exposure to birds. *Bti* was not toxic or pathogenic to mallards or bobwhite quail fed *Bti* at either 3.1 g/kg/day or 5 ml/kg/day for 5 days (USEPA 1998). Based on observations of chickens, pigeons, pheasant, duck, and turkey, pH values in avian digestive tracks ranged from lows of 1.4 to 4.8 in the stomach (proventriculus and gizzard) to highs of 5.6 to 7.2 in the ileum (Denbow 1999). No direct toxic effects are anticipated to any avian species from *Bti* use.

4.6.5 Mammals

To date, no known mammalian health effects have been demonstrated for any strain of *Bacillus thuringiensis*, including *Bti* (USEPA 1998).

4.6.6 Plants

As *Bti* must be ingested and activated to have a toxic effect, there is no clear *Bti* exposure pathway for plants as they have no mechanism for ingestion. In its Reregistration Eligibility Decision for *Bacillus thuringiensis*, USEPA was unable to find any reports of adverse effects to plants despite its extensive use on vegetation (USEPA 1998). Therefore, it is not anticipated that *Bti* use will result in any adverse effects to plants.

4.7 Summary of indirect effects to non-target organisms

4.7.1 Invertebrates

Field studies of effects following Bti use for mosquito control: Two studies detected possible negative effects to invertebrate populations resulting from food web disruption following *Bti* use for mosquito control. In a comprehensive 10-year study, 27 wetlands in Wright County, Minnesota were selected in 1988 by the Natural Resources Research Institute (Duluth, MN) to serve as locations to study the long-term effects of mosquito larvicides, including *Bti*. In these studies, *Bti* was applied as Vectobac™ G granules at 12 kg/ha every 3 weeks from roughly April through July. Results of these studies varied in their detection of effects to non-target invertebrates. Niemi et al. (1999) found that 3 years of relatively continuous *Bti* treatments in Minnesota wetlands from 1991 to 1993 reduced total insect density and richness on treated sites for 2 of the 3 study years. Effects were observed broadly across insect taxa, with dipteran species most strongly affected, especially the Chironomidae (Hershey et al. 1998). The authors (Hershey et al. 1998) suggested that direct effects to dipterans led to indirect effects to other insect groups due to disruption of the invertebrate food web, and cautioned about the use of short-term studies due to a 2 to 3 year lag time to detect these effects. However, no effects were observed on growth, reproduction, or community composition for zooplantkton despite this reduction (Niemi et al. 1999). In a follow-up study during 1997–1998, no differences were found in the total mean density of macroinvertebrates (Balcer et al. 1999). The only treatment effects found were a reduction in the density and biomass of chironomids within the subfamily Chironominae alone, which consists mostly of non-predatory species, yet no effect of treatment was found for chironomids as a whole. Differences in the results between these study years and the 1991–1993 study years may have been due to drought conditions in the first study, increasing the susceptibility of organisms (Balcer et al. 1999). In addition, analysis of dosage data for both studies suggests higher than planned doses in 1992 and 1993, when treatment effects were detected, which may have contributed to the difference in results (Read 2002).

Field studies of effects following Bti use for black fly control: Virtually every field evaluation of *Bti* for non-target organisms in black fly treatments has demonstrated a lack of adverse effects (e.g., Colbo and Undeen 1980, Molloy and Jamnback 1981, Burton 1984, Duckitt 1986, Pistrang and Burger 1984, Gibbs et al. 1986, Merritt et al. 1989, Jackson et al. 1994, Brancato 1996, Jackson et al. 2002). These tests have been performed throughout much of North America. Two studies (Molloy 1982, Merritt et al. 1989) indicated minor effects on a single genus of chironomid, the filter-feeder Rheotanytarsus, with reductions of 23% and 27%, respectively. A Canadian study (Back et al. 1985) showed that net-winged midges in the genus *Blepharicera* were affected when dosage rates were 3–15 times greater than operational dosages. These net-winged midges, however, occur only in fast-flowing water with beds of large rocks and boulders. The Merritt et al. (1989) reference is one of the broadest, most comprehensive studies on non-target effects and was conducted in Michigan, and revealed no effects to macroinvertebrate diversity or species richness. In Pennsylvania, areas where *Bti* has been used extensively for a quarter of a century (e.g., in more than 30 counties twice per week for more than 4 months each year), no adverse effects were noted on non-target organisms (Pennsylvania's Black Fly Suppression Program 2008).

4.7.2 Fish

Several studies have evaluated Pennsylvania’s long-term use of *Bti* for black fly control and found no effects to fish. Comparison before and after *Bti* treatment of the North Branch of the Susquehanna River found that the fish community was not affected by repeated treatments, despite a high proportion of the diet comprising black flies and midges for darter species in the area (Brancato 1996). Gut analysis found that darters feed on the most abundant and easily accessible aquatic invertebrates in the drift, and likely exhibit switching behavior between prey items as needed. Following application of the Vectobac™ 12AS *Bti* formulation for black fly control at 6 locations on the Susquehanna River, fish species composition and abundance did not change, despite the fact that black flies were an important source of food for some of the fish species present (Jackson et al. 2002). Similar results were found in Betsie River, Michigan, where no effects to mortality or weight change of caged rock bass; or fish numbers, species composition, length-weight relationships or rock bass diet were detected following application of *Bti* (Teknar HP-D™) for black fly control (Merritt et al. 1989).

Direct effects are not expected from potential *Bti* exposure to any fish species of concern. Indirect effects may still be possible if fish species rely upon *A. dorsalis* as a significant source of food, or if the suppression of these mosquito larvae would reduce other prey species.

4.7.3 Birds

A limited number of studies have looked at indirect effects to birds following mosquito control. A series of investigations occurred in Minnesota wetlands. Hanowski et al. (1997a) and Niemi et al. (1999) found no evidence that 3 years of *Bti* treatments (applied as Vectobac™ G granules) for mosquito control in surrounding wetlands in Minnesota had any negative effects on reproduction, growth of nestlings, or foraging behavior of adult breeding red-winged blackbirds. This was in spite of reductions in insect density and richness in one of the studies (Niemi et al. 1999). Hanowski et al. (1997b) censused 19 species of birds before, during, and after 3 years of *Bti* treatment for mosquito control in Minnesota wetlands and found no evidence that breeding bird communities or individual species were affected by the treatment. In the Camargue region of France, reduced breeding success of house martins, (as measured by clutch size and fledgling survival) was correlated with the intake of *Bti*-sensitive Nematocera and their predators at the nest level (Poulin et al. 2010). Nematocera are a significant food source for house martins in this region, accounting for approximately 35% of the diet of birds on control sites. Indirect effects may be possible if avian species rely upon *A. dorsalis* species as a significant source of food, or if the suppression of mosquitoes would reduce other important prey species.

4.7.4 Mammals

Bats routinely forage on adult aquatic invertebrates such as mayflies and caddisflies, as evidenced by observations of bats congregating and foraging in emerging swarms of these invertebrates over water bodies. Their reliance on mosquitoes is less well studied but often debated. Reiskind and Wund (2009) conducted controlled enclosure experiments to assess predation of adult mosquitoes by long-eared bats (*Myotis septentrionalis*). This study found a 32% reduction in mosquito egg-laying activity within bat enclosures and concluded that reductions were a result of predation versus other factors, such as changes in mosquito behavior. The authors caution that these results under controlled conditions may not apply to natural situations. Gonsalves and others (2013a) radio-tracked the small insectivorous bat, *Vespadelus vulturnus,* in Australia to assess behavior in response to population fluctuations in the mosquito, *Aedes vigilax*. Like other *Aedes* mosquitoes, this species lives in salt marshes and exhibits large population shifts in response to flooding and tidal cycles thereby becoming a nuisance and potential disease carrier to humans. While acknowledging some inherent biases in the study regarding tidal cycles, the authors concluded that short-term shifts in foraging patterns by this bat were correlated with fluctuations in mosquito distribution and abundance. The authors concluded that mosquitoes were an important dietary component for *Vespadelus vulturnus* and that broad scale mosquito control programs, which may reduce larval mosquito populations up to 98%, may affect some bat species. Gonsalves and others (2013b) examined diets of 5 bats species and concluded that mosquitoes were most important to bats with smaller body size. These results also indicated that some bat species preference may exist, making some bats more reliant on mosquitoes as a resource than other species.

Based on foraging habits of other mammals likely to be present in Bandon Marsh Refuge, indirect effects to other mammals from mosquito control activities using *Bti* are unlikely.

4.7.5 Amphibians and Reptiles

To our knowledge, indirect effects to mammals following *Bti* use for suppression of mosquitoes have not been evaluated in the field. Most members of these classes of organisms consume insects as their primary food source, therefore indirect effects on them due to food source suppression are possible.

4.7.6 Plants

Indirect effects may be possible if plants rely upon *A. dorsalis* as obligate pollinators. Mosquitoes are not known to be obligate pollinators of plants in the treatment area. No indirect effects of *Bti* use are anticipated for plants.

4.8 Inability to calculate screening level risk for *Bti* products

No quantitative assessment of screening level risk for *Bti* products was made because there was no reasonable way to make estimates and compare them to literature values. First, there is no reasonable way to relate label application rates to expected environmental concentrations. It is possible to calculate environmental concentrations in mg/L or ppm in water (and others have done so in the past), based on the percent active ingredient information on the labels; however these calculations result in numbers that are difficult to interpret, because they do not account for the potency of the formulated compound in a meaningful way. This potency is determined by bioassay in the lab and is not federally standardized, nor does it relate back to the primary toxicological literature, which reports doses in "colony forming units" or CFUs. Second, there is ample information showing that *Bti* is essentially non-toxic to non-target organisms. Due to this low toxicity, the USEPA did not require the second-tier toxicity testing that would provide the numbers needed to calculate chronic risk to organisms exposed to *Bti* in the environment (USEPA 1998). A review of the literature suggests that *Bti* has an extremely favorable toxicological profile relative to other mosquito control options and that ecological risk from *Bti* application is low.

4.9 Qualitative comparison of different *Bti* formulations

The different *Bti* formulations may control mosquito larvae and remove them as potential prey items at different rates, which may result in different ecological effects of the different formulations. Whereas all of the liquid and single brood granular formulations are dosed to kill mosquito larvae quickly (e.g., 70-90% control in 24 hours and 100% control within 48 hours), the Fourstar *Bti* CRG™ product is designed to sustain lower levels of *Bti* in the aquatic environment for longer, thereby killing mosquito larvae more slowly. For example, at the higher labeled application rate of 10 lbs per acre, and 70 degrees F (Table 1), one might expect 50% of the larvae to die in the first and second instar, 35% of larvae to die in the third instar, and 14–15% to die in the fourth instar (pers. comm. R. Sjogren, Central Life Sciences, all numbers are approximate, and are influenced by environmental factors such as temperature and other factors described above). In warmer temperatures, the granules will dissolve faster, releasing more *Bti* to kill more early instars. Cooler temperatures will cause the granules to dissolve more slowly, thereby allowing the larvae to develop to later instars prior to death. It is likely that remaining instars will be sluggish and sick, thereby moving more slowly in the water. This may actually enhance their availability as prey items while they are sluggish, but alive. The more persistent *Bti* formulation (Fourstar *Bti* CRG™) may be applied to dry ground, prior to flooding, and will slowly release *Bti* through multiple wet/dry cycles (such as tidal cycles); it is labeled for 4 wetting cycles. The other products are not predicted to remain effective for mosquito control beyond one wet/dry cycle based on their label application rates and what is known about their environmental persistence. While all formulations of *Bti* are predicted to be safe for non-target organisms, the longer release Fourstar *Bti* CRG™ granules would be even less likely to have non-target effects on midges than the liquid products, due to the lower dose. The Fourstar *Bti* CRG™ granules are also less likely to have indirect food web effects than the higher dose formulations because they leave mosquito larvae as prey items in the system for longer.

4.10 Concerns with *Bti* use at Bandon Marsh Refuge

There are virtually no concerns about direct toxicity of *Bti* to anything other than mosquitoes and possibly some species of chironomid midges at the Bandon Marsh Refuge. *Bti* has an excellent toxicity profile for use in sensitive habitats. The doses of *Bti* required to control chironomid species are several times higher than those required to control mosquitoes, therefore toxicity to non-target chironomid species is not anticipated with *Bti* applied at the labeled rates. Based on a review of the literature, concerns about use of *Bti* for mosquito control at Bandon Marsh are therefore limited to the reduction of mosquito larvae as prey items for other animals, specifically for the listed Coho salmon, in its critical habitat. If treatment areas actually do overlap with listed Coho salmon in space and time, and if mosquito larvae and adults are important prey items for salmon in Bandon Marsh, then the longer formulation of *Bti*, (Fourstar *Bti* CRG™), may be preferred to shorter lasting *Bti* formulations. This slow release formulation is preferred because it is designed to provide a lower dose of *Bti* over a longer time period than other formulations and is therefore likely to retain mosquitoes in these habitats for longer than the *Bti* formulations that deliver a rapid pulse of a higher dose, designed to kill mosquito larvae as quickly as possible.

Although using an extended release formulation will result in a longer exposure to *Bti* to the environment at Bandon Marsh NWR, the toxicity profile of *Bti* is so benign and targeted towards mosquitoes, that deleterious effects to other species are not anticipated from its use.

5 S-methoprene

Like *Bti*, there is a vast scientific literature on S-methoprene, as it has been used widely since its initial registration as a pesticide in the US in 1975 (USEPA 1998). We have made our best effort to summarize the literature here in a way that is meaningful to USFWS resource management, but this is by no means a comprehensive review of the existing scientific literature. For such a review please see the following references: Henrick (2007) provided a broad general review of the mode of action of S-methoprene and its history and patterns of use, as well as a relatively recent summary describing laboratory and field studies of effects to non-target species. The Canadian Council of Ministers of the Environment also wrote a fairly comprehensive grey literature review document summarizing S-methoprene information and providing an analysis of the existing toxicology literature in 2007, including the potential for effects to non-target aquatic organisms (CCME 2007). The USEPA (1991) summarized basic environmental behavior and the results of their toxicity screening analyses conducted for licensing S-methoprene as a pesticide (many of the primary licensing studies are not publically available) in their re-registration eligibility document (USEPA 1991). There are also more recent individual studies referenced in the sections below.

5.1 Mode of action

S-methoprene acts by mimicking a naturally-occurring insect growth regulating hormone (USEPA 1991) and due to this mode of action, was reclassified from a "chemical pesticide" to a "biochemical pesticide" in the USEPA's 1991 re-registration eligibility decision (USEPA 1991). A "biochemical pesticide" is defined by law (40 CFR 158.2000) by the following three properties: (i) It is a naturally-occurring substance or structurally-similar and functionally identical to a naturally-occurring substance; (ii) It has a history of exposure to humans and the environment demonstrating minimal toxicity, or in the case of a synthetically-derived biochemical pesticide, is equivalent to a naturally-occurring substance that has such a history; and (iii) It has a non-toxic mode of action to the target pest(s). Aquatic invertebrates can have either a complete or an incomplete life cycle; the latter does not have a pupal stage. In a normal complete life cycle, an invertebrate goes from egg to larva to pupa and then to adult. S-methoprene inhibits this normal development by preventing maturation of the pupa to the adult reproductive stage. It does not interfere with larval mosquito growth, therefore its use as a mosquito larvicide will leave mosquito larvae in the aquatic system intact until they attempt to metamorphose, at which point they will die due to errors in development. Mammals, birds, fish, reptiles, and amphibians do not have this juvenile hormone (JH) nor share this biochemical pathway, which is what makes S-methoprene a fairly targeted insecticide.

S-methoprene is essentially non-toxic to mammals, has some limited toxicity to birds, amphibians, and fish, and some toxicity to certain non-target invertebrates, probably because these invertebrates share similar biochemical pathways to those on which S-methoprene acts in target organisms. Because hormones act on biological systems at exceedingly low levels, a very low concentration of S-methoprene is required in the environment to control target organisms. This fact, combined with its low toxicity to birds and mammals makes S-methoprene a reasonably attractive alternative to most other mosquito larvicides for most scenarios of use. Indeed S-methoprene has seen widespread global use since its initial commercialization as a pesticide in the mid-1970s. S-methoprene has been shown to have some toxicity to certain other invertebrate species that utilize JH or similar hormonal pathways for their development, such as marine crustaceans and some species of freshwater invertebrates. The toxicity to amphibians and fish in laboratory studies occurred at concentrations 1 to 2 orders of magnitude higher than the target environmental concentration of the formulated chemical sold for mosquito larvicide use. The specific studies of S-methoprene toxicity to non-target organisms are discussed in further detail in the sections below.

5.2 History and patterns of use

Licensed originally by the USEPA in 1975, and reregistered in 1991, S-methoprene has multiple insecticidal uses ranging from ant bait to pet flea treatments to use in animal feedstuffs to control fly production in the fecal matter of livestock (USEPA 1991). It is recommended by the World Health Organization for use in human drinking water cisterns to control mosquitoes at concentrations of up to 1000 ppb (WHO 2008). Since its initial approval, S-methoprene has seen global use in both freshwater and estuarine natural habitats as well as storm drains, sewers, and other human-made areas that accumulate shallow pools of water and serve as breeding areas for mosquitoes. Only patterns of use related to mosquitoes in natural environments are discussed further here.

5.3 Behavior of the active ingredient in the environment

The active ingredient, S-methoprene, degrades quickly, however it is engineered into different commercial formulations for use as a mosquito larvicide. The inert ingredients in these formulations increase the environmental persistence of the S-methoprene. The differences among the technical formulations considered for use at Bandon Marsh Refuge are discussed below; this section pertains to only the active ingredient. Unless specifically referenced, available environmental behavior information presented here was taken from the reregistration eligibility document for S-methoprene (USEPA 1991).

Methoprene is the common name for isopropyl-(2E,4E,7R,S)-11-methoxy-3,7,11-trimethyldodeca-2,4-dienoate. Its CAS number is 40596-69-8 or 65733-16-6. The molecular formula for S-methoprene is $C_{19}H_{43}O_3$, shown in Figure 1. Its molecular weight is 310.48 g per mol.

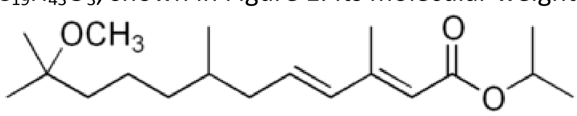

Figure 1. Structure of S-methoprene.

Methoprene molecules may occur in two slightly different shapes, which are mirror images of each other, called enantiomers and termed “R-” or “S-” methoprene, based on their specific three-dimensional structure. Only the “S” enantiomer is thought to be biologically active, working by mimicking the juvenile hormone (JH) naturally occurring in insects. Most current formulations considered here contain only the “S” enantiomer.

S-methoprene is highly transient in the environment where it is rapidly broken down by microbes and light (Schooley et al. 1995). Unformulated S-methoprene is only slightly soluble in water (Kidd and James 1991). It is degraded rapidly by sunlight both in water and on surfaces like vegetation and soil. One study estimated the half-life (the time it takes for half of a substance to dissipate, break down, or otherwise go away) of S-methoprene in pond water at 30 hours (for an initial concentration of 1 ppb) to 40 hours (at an initial concentration of 10 ppb; Menzie 1980). The half-life on vegetation was less than 2 days when applied at a rate of 1 pound per acre (Meister 1992). Concentrations of S-methoprene have been found to be reduced by >90% within 3 days after treatment for a variety of aquatic ecosystems. S-methoprene exhibited rapid degradation in both sterile and non-sterile pond water exposed to sunlight, where >80% degraded within 13 days. S-methoprene breaks down at the same rate in both fresh and saltwater, but breaks down more quickly at high temperatures. Degradation has been shown to proceed faster at 20°C (10–35 day half-life) compared with 4.5°C (half-life > 35 days).

In water, S-methoprene is only slightly soluble and has been shown to adsorb to sediments and suspended solids in the water (K_{oc}=23,000; Kidd and James 1991). S-methoprene is also relatively immobile, that is, likely to remain in the top few inches of soil or sediment rather than leach to ground water. In field leaching studies, S-methoprene was observed only in the top few inches of the soil even after repeated washings with water (USEPA 1982, Zoecon Corporation 1974b). These properties, along with its low environmental persistence, make it unlikely to contaminate ground water.

S-methoprene has low persistence in soils due to rapid metabolism in soil and sediment under both aerobic and anaerobic conditions (estimated half-life of 10–14 days). Microbial degradation of S-methoprene occurs quickly in many soil types under a variety of environmental conditions. In soil, microbial degradation is rapid and appears to be the major route of its disappearance (USEPA 1982, USEPA 2001). S-methoprene also readily undergoes degradation by sunlight (US Environmental Protection Agency 2001). After 3 days in pond water with an initial concentration of 420 ppb, three metabolites resulted from the degradation of S-methoprene: methoxycitronellic ester, hydroxycitronellic acid, and methoxycitronellic acid. After 13 days, the major degradate was methoxycitronellic acid (Menize 1980). S-methoprene ultimately undergoes complete breakdown where the end degradation product is CO_2.

5.4 S-methoprene products considered for use

We considered the S-methoprene-based products in the following table (Table 2) for use at Bandon Marsh Refuge. As with *Bti*, these choices were based on recommendations from several mosquito control experts familiar with the species of mosquito (*Aedes dorsalis*) and the environmental conditions of areas requiring treatment at the Refuge.

Table 2. S-methoprene products considered, application rates, and estimated environmental concentrations.

Product Name	USEPA Registration Number	S-methoprene (%)	Minimum Labeled Rate	Maximum Labeled Rate	"Polluted" Labeled Rate Polluted	Persistence (days, from label)
Solid and granular formulations			***(pounds per acre)***			
Altosid SBG™	2724-421	0.2	5	10	20	5-10 days
Altosid XR-G™	2724-427	1.5	5	10	20	several floodings
MetaLarv S-PT™	87276-7-53883	4.25	2.5	5	10	up to 42 days
Altosid Pellets™	2724-448	4.25	2.5	5	10	up to 30 days
Liquid formulations			***(ounces per acre)***			
Altosid Liquid Larvicide™	2724-392	5	3	4	Not Listed	Not Listed, reapply when control of mosquitoes stops
Altosid Liquid Larvicide Concentrate™	2724-446	20	0.75	1	Not Listed	Not Listed, reapply when control of mosquitoes stops

5.5 Persistence of different formulations

S-methoprene has been engineered into both rapid and slow release formulations as both liquids and granules for mosquito control. Both types of formulation (rapid and slow) and modes of delivery (liquids and granules) were evaluated for this analysis. The effects of formulation on environmental persistence of S-methoprene are discussed in this section.

All forms of S-methoprene used for mosquito control, including the less persistent formulations, employ some level of microencapsulation to enhance S-methoprene solubility and persistence in the environment. Yet the different formulations considered here range in anticipated longevity (according to their labeled application intervals) from 1–2 weeks to more than one month. Indeed, field studies that have examined the efficacy of some slow release S-methoprene formulations have found them to sometimes remain active for much longer than their label application interval implies. For example, Lawler and others (2000) found that Altosid™ pellets (Table 2) applied at a rate of 10.4 kg/ha (9.3 pounds per acre), and labeled for a 30 day application interval continued to control *A. dorsalis* mosquitoes for the entire duration of a 99 day study with just one application into a tidal salt marsh habitat in California.

All S-methoprene formulations considered here for mosquito control have the same target environmental concentration for the active ingredient in water. The concentration shown to be effective at controlling mosquitoes (the "effective concentration") is below 1 µg S-methoprene per liter of water (µg/L=parts per billion or ppb). Several studies conducted by the USEPA and others have shown this target concentration to be attained in microcosm studies, where concentrations measured in water after different formulations of S-methoprene were applied to microcosms were often below the analytical detection limits, that is, at concentrations below 1 µg S-methoprene per liter (ppb, Judy and Howell 1992, Ross et al. 1994). These studies were mandated by USEPA in the 1991 re-registration eligibility decision (USEPA 1991) to verify that the pellet and other extended release granular formulations did not result in higher concentrations in the environment than did the liquids. For example, Ross and others (1994) applied several different S-methoprene formulations to freshwater microcosms and measured S-methoprene for up to 35 days post-treatment. Of the 432 water samples they analyzed, 85% were below 1 ppb and 71% were below the analytical detection limits of 0.2 ppb. Maximum environmental concentrations for formulations considered in this report (i.e. not briquettes) have been reported to range as high as 2.2 ppb, within a week of application at the higher labeled application rates (Judy and Howell 1992, Ross et al. 1994). In a more recent study at field sites in the Seattle area (Sternberg et al. 2012), the authors reported that "Chemical analyses of water samples collected from Altosid-treated basins in 2008 yielded results similar to those in efficacy trials in 2006. S-methoprene was detected in only 2 of the 45 water samples collected. The highest concentration occurred 1 wk post-treatment (11.4 ppb)." These authors mention in their discussion that the highest result was anomalous, however, and they believed they had gotten some of the Altosid™ briquet used for treatment in that water sample; this formulation is not being considered for use at Bandon Marsh Refuge. By comparison to the studies above, the environmental concentrations estimated in Table 3 are likely to be overestimates, relative to expected concentrations that may be found in the literature, and as such they are conservative and result in conservative estimates of screening level risk.

The Altosid™ liquid and single brood granule (SBG) formulations are the quick release formulations of S-methoprene (Table 2). These formulations (labeled for a 7–14 day application interval) are the most environmentally benign of the S-methoprene formulations considered here, because they have the shortest environmental persistence. If they are applied, for example, into salt marsh mosquito habitat as the monthly high tides recede (leaving breeding pools filled with water), it is likely that the S-methoprene would be degraded from the treatment area by the time the monthly high tides returned to fill these pools again. This transience in the environment limits the duration of exposure in treated mosquito-bearing pools, which will limit its ability to produce chronic effects on non-target species. Limited persistence is also likely to limit the spatial extent of S-methoprene exposure by not allowing S-methoprene to move with an outgoing tide into other habitats. Tidal dilution is expected to be considerable, in most Bandon Marsh NWR habitats considered for mosquito treatment. Despite this dilution potential, it is still preferable to keep S-methoprene in the treatment area, and these less persistent formulations provide the best opportunity to limit S-methoprene from moving into non-target areas during tidal cycles.

The Altosid™ extended release granules (Altosid XR-G™ formulation, Table 2) are designed for an intermediate level of environmental persistence; these are labeled for a 20 day application interval. The longer application interval limits the number of applications, thereby saving applicator time and ensuring control of target mosquitoes for longer. More persistent formulations also reduce the risk of missing the developmental window during which mosquito larvae are sensitive to S-methoprene (generally the 4th instar) and limit physical habitat disturbance to the marsh if applied by ground-based methods. The Altosid XR-G™ formulation is labeled to be effective through "several floodings". Nevertheless, the increased persistence of this formulation may increase the risk to non-target organisms by increasing not the environmental concentrations, but rather the duration of S-methoprene exposure to non-targets.

Finally, the Altosid Pellets™ and Metalarv S-PT™ are the longest lasting S-methoprene formulations, labeled for 30 and 42 days, respectively. These formulations may release S-methoprene into the environment for substantially longer than the application interval recommended on the label, as other field studies have demonstrated mosquito control efficacy for up to 99 days when the longer lasting formulations are applied (Lawler et al. 2000). As with the intermediate formulation, Altosid XR-G™, these more persistent formulations will increase the duration of environmental S-methoprene exposure. Screening level risk calculations0 for aquatic organisms do not account for exposure duration, however increased exposure time will increase the likelihood of observing the sublethal chronic effects, which require a longer time period to produce.

The formulation also affects the persistence of S-methoprene in a habitat through multiple wet/dry cycles. The following granular formulations are designed to persist through several wet/dry cycles or flooding events: Altosid XR-G™, Metalarv S-PT™, and Altosid Pellets™. The Altosid SBG™ is a quick-release granular formulation (designed as a granule to better penetrate vegetation), but is less persistent and is not expected to last through wet-dry cycles. The liquid formulations are also not designed to last beyond the point that a treated pool has dried.

5.6 Target specificity and summary of direct effects to non-target organisms

The bulk of available literature suggests that S-methoprene is relatively safe for non-target invertebrate species when used in freshwater and marine habitats. The Canadian government created a useful summary of this literature, along with a figure that plots levels of toxicity to different classes of organisms, relative to target mosquitoes (CCME 2007). Although sublethal chronic effects on endocrine systems and development have been shown to some non-target invertebrates, the majority of field and laboratory studies suggest that S-methoprene is one of the safest mosquito larvicides available, and effects to non-target invertebrate species are limited. Although toxicity to invertebrates has been found in laboratory studies, the levels of S-methoprene predicted to be lethal to even the most sensitive species are often an order of magnitude greater than predicted environmental concentrations when S-methoprene is used for mosquito control at the labeled application rates for natural habitats. Several studies supporting these conclusions are summarized below. Unless specifically referenced, available effects information presented herein was taken from the reregistration eligibility document for S-methoprene (USEPA 1991).

5.6.1 Invertebrates

We reviewed the ECOTOX database to identify all studies that found effects of S-methoprene on different classes of organisms at concentrations environmentally relevant for mosquito control, which we defined conservatively as being less than 100 ppb. We were not able to obtain and review all of these studies, but this mode of analysis allowed us to identify approximately 65 studies not necessarily referenced in the USEPA registration documents (USEPA 1991) that tested the effects of S-methoprene at low parts per billion levels, i.e. approaching expected environmental concentrations for mosquito control. The majority of effects documented were to non-target invertebrates in particular these were sublethal effects on primarily Daphnia spp. and marine crustaceans.

5.6.1.1 Studies that found effects at environmentally relevant concentrations (10 ppb or less)

A general theme of these studies is that some non-target invertebrates, such as certain marine crustaceans, may have hormonal analogues to juvenile hormone (which S-methoprene mimics) and therefore S-methoprene may act on similar biochemical pathways in these non-target species (e.g., as a methyl farnesoate analogue, Wang et al. 2005).

5.6.1.1.1.1 Shrimp, Crabs, and Estuarine Invertebrates

In one study all mysid shrimp, *Neomysis integer*, exposed to S-methoprene (0.01, 1, and 100 ppb) for 96 hours had lower vitellin levels compared to the controls, however these results did not differ statistically from controls due to high variation in the response. In a different study of embryonic development in this same mysid shrimp species, embryos exposed to 1 and 100 ppb S-methoprene/L had a significantly lower hatching success and lower survival rates (Ghekiere et al. 2006). Growth and metamorphosis in the estuarine shrimp, *Paleomonetes pugio* were inhibited at S-methoprene concentrations at or above 8 ppb for at least 8 days, and younger larvae were more sensitive than older larvae (McKenney and Celestial 1993). In a different study, concentrations ≥8 ppb strongly reduced survival, especially in early larval stages for *P. pugio* exposed for the duration of their larval cycle (McKenney and Matthews 1990). These same authors later studied a different shrimp species *Mysidopsis bahia* in the laboratory throughout their lifecycle and found significant reduction in number of young produced per female in concentrations ≥2 ppb (Celestial and McKenney 1994). In a laboratory study, reductions in survival, increased length of development period, and increased abnormalities were found with mud crabs (*Rhithropanopeus harrisii*) exposed from hatching to the first crab stage to S-methoprene at concentrations as low as 10 ppb (Christiansen et al. 1977).

5.6.1.1.2 Daphnia

S-methoprene may act as an endocrine disruptor in the water flea (planktonic crustacean), *Daphnia* spp, affecting survival, sex ratios and reproduction at environmentally relevant concentrations (≤10 ppb). In one laboratory study, exposure of *Daphnia pulex* to S-methoprene resulted in a decrease in the incidence of all-male broods and an increase in the incidence of all-female broods compared with controls at nominal concentrations ≥10 ppb (Peterson et al. 2000). In a different laboratory study, survival of *Daphnia* was reduced at concentrations as low as 10 ppb and reproduction was impaired at 0.5 ppb (Fortin and Solomon 1988).

5.6.1.1.3 Chironomids

Ali (1991) evaluating S-methoprene (Altosid Liquid Larvicide™ 5%) efficacy against midges (Chironomidae) in experimental ponds found that at 0.28 kg a.i./ha (1.5 lbs a.i./A) was effective against *tanytarsini* and *chironomini*, however this formulation had very little effect on chironomids when it was applied at 0.015 kg a.i./ha (0.075 lbs ai/A).

5.6.1.2 Studies that found no effects at environmentally relevant concentrations (10 ppb or less)

Although there is a substantial body of literature showing sublethal and chronic effects to non-target crustaceans, there is also a substantial body of literature that either failed to detect negative effects of S-methoprene at environmentally relevant concentrations or found effects at concentrations much higher than those predicted in the environment in a mosquito control scenario. Especially in field studies, there is much evidence to suggest minimal, if any non-target environmental effects of S-methoprene.

5.6.1.2.1 Shrimp, Crabs, Lobsters, and estuarine invertebrates

In a field study comparing the presence, density, or size of fairy shrimp (*Eubranchipus bundyi*) populations in freshwater wetlands treated with S-methoprene for three years, no differences were found between treated areas and untreated control sites (Batzer and Sjogren 1986). Other studies (Gibson 2008, Dove et al. 2005, Butler 2005) determined that exposure of lobster (*Homarus americanus*) larvae to 0.05 ppb S-methoprene did not affect molting or survivability. No behavioral effects (on swimming or phototaxis) were found on larval mud crabs (*Rhithropanopeus harrisii*) exposed to environmentally-relevant concentrations of S-methoprene, less than 1 ppb (Forward and Costlow 1977).

5.6.1.2.2 Other

In laboratory tests, Levy and Miller (1978) exposed the planarian *Dugesia dorotocephala* to 5 ppb S-methoprene for 24 hours and found no recognizable immediate or delayed effects to the viability, behavior, or asexual reproductive capacity. Tietze et al. 1994 found that both *Bti* and S-methoprene could be used in tires with predatory copepods without significant deleterious effects to the copepod population, leading to better mosquito control. Correspondingly, S-methoprene was not harmful to copepods that prey on mosquitoes in a different study, at concentrations up to 100 ppb (Fortin and Solomon 1988). A sizeable amount of work was done to document the environmental effects of co-application of S-methoprene with *Bti* in freshwater wetlands in Minnesota, and the long term ecological effects of mosquito control. These *Bti* and S-methoprene co-application studies show few non-target effects and are summarized in a separate section below.

5.6.1.3 Studies that found effects at concentrations higher than expected in the environment (more than 10 ppb)

Numerous studies in the toxicology literature document deleterious effects of S-methoprene, but at concentrations much higher those expected when S-methoprene is used according to labeled rates for mosquito control in natural habitats.

5.6.1.3.1 Freshwater invertebrates

In a study examining the acute and chronic effects of S-methoprene on the survival and reproduction of the freshwater cladoceran *Moina macrocopa*, the 24-hour LC_{50} was 510 ppb and the 48-hour LC_{50} was 340 ppb (Chu et al. 1997). S-methoprene was found to control nuisance midge larvae in wastewater treatment ponds at concentrations of 50 ppb S-methoprene reduced midge emergence by 80%, however this concentration is approximately an order of magnitude higher than expected in natural settings for mosquito control (Craggs et al. 2005). Olmstead and LaBlanc (2000, 2001) also found S-methoprene negatively affected developmental systems for *Daphnia magna* at environmentally-relevant concentrations. In these studies, S-methoprene affected the development of female sex characteristics at 25 ppb S-methoprene and reduced growth rate and molt frequency at 50 ppb.

5.6.1.3.2 Shrimp, crabs, and estuarine invertebrates

S-methoprene halted development and reduced survival of larval stages of mud crabs (*Rhithropanopeus harrisii*), but these were exposed to concentrations ranging from 100 to 1000 ppb S-methoprene (Celestial and McKenney 1994). Ahl and Brown (1990, 1991) found that S-methoprene interrupted or accelerated molting of the free swimming brine shrimp (*Artemia*) and increased activity of certain enzyme systems associated with these developmental pathways at concentrations as low as $1x10^{-7}$ M (~30 ppb). Their results suggested that these brine shrimp shared similar biochemical pathways with target insects, thus producing S-methoprene sensitivity. Lee and others (1999) found effects of S-methoprene on blue crab hatching and estimated 55 ppb to be the S-methoprene concentration at which 50% of the embryos failed to hatch (EC_{50}). In a 3-week exposure of mysid shrimp (*Neomysis integer*), growth rates were reduced and molting was delayed at S-methoprene concentrations of 100 ppb. For adult grass shrimp (*Palaemonetes pugio*), the 96-hour LC_{50} was 1000 ppb S-methoprene; a chronic reproductive test with this species showed no impacts with exposure to 1000 ppb S-methoprene (Wirth et al. 2001). Barber et al. 1978 found no effect of S-methoprene at reported concentrations of 20 ppb active ingredient on molting of *Paleomonetes pugio*. Verslycke et al. (2004) conducted 96-hr LC_{50} tests with the estuarine mysid shrimp (*Neomysis integer*) with a suite of chemicals (including S-methoprene); the methoprene LC_{50} was 320 ppb. In the original licensing studies acute LC_{50} values were found to be >100,000 ppb for freshwater shrimp and >100 ppb for estuarine mud crabs (Zoecon Corporation 1974b). Several field studies indicated no effects of S-methoprene to non-target estuarine invertebrates in conjunction with mosquito control. Aerial application of Altosid Liquid Larvicide™ to control mosquito larvae for a mangrove swamp in Florida did not affect sentinel non-target amphipods (Talitridae) or flying insects (Lawler et al. 1999). Similarly, no detectable effects (mortality) to non-target water boatman (*Trichocorixa reticulata*) or the abundance of other invertebrate species was found after treating salt marsh ponds with sustained-released S-methoprene (Altosid Pellets™) for mosquito control; S-methoprene continued to control mosquitoes through 99 days after treatment (Lawler et al. 2000).

5.6.1.3.3 Other

The licensing tests with earthworms and bees found little, if any, toxic effects of S-methoprene on contact (Kidd and James 1991, Zoecon Corporation 1974b).

5.6.2 Fish

S-methoprene has some toxicity to fish, but the values from these studies suggest there is a reasonable margin of safety for fish when S-methoprene is applied to natural habitats for mosquito control at the labeled rates. Relative to the expected environmental concentrations, most of the laboratory based, acute toxicity studies for fish provide a reasonable margin of safety for those species tested. For example, the 96-hour LC_{50} for bluegill sunfish was 1,520 ppb S-methoprene. The 96-hour LC_{50} for rainbow trout was >50,000 ppb S-methoprene. In a laboratory study of crimson spotted rainbowfish (*Melanotaenia duboulayi*), neither *Bti* nor S-methoprene had acute toxic effects at up to 10 and 12.5 times the expected environmental concentrations and both larvicides were shown to be substantially more benign than alternatives (Brown et al. 2002). The 96-hour LC_{50} values for S-methoprene were 4,600 ppb for bluegill sunfish, 4,400 ppb for rainbow trout, and >100,000 ppb for channel catfish and largemouth bass (Kidd and James 1991, US National Library of Medicine 1995). Altosid™ had little effect, if any, on exposed non-target mosquito fish (Zoecon Corporation 1974b). Uncertainty remains, of course, due to the fact that limited fish species have actually been tested, and most of these tests were conducted in laboratory or other controlled environments not intended to elucidate the interactions of multiple stressors. Nevertheless, the scientific evidence suggests that S-methoprene applied for mosquito control at labeled application rates is very unlikely to directly kill fish, and due to the strength of this evidence the USEPA concluded in 1996 that the statement "do not use in fish-bearing waters" should be removed from the label. This was largely a response to several studies that showed that S-methoprene rarely exceeded concentrations of approximately 2 ppb in the environment, regardless of the formulation applied (e.g., Ross et al. 1994).

Sublethal effects, such as interference with behavior, feeding, or reproduction are of course possible and are generally not as well studied, however the available studies suggest there is a margin of safety for sublethal and chronic effects on fish species, even if this margin of safety is smaller than that for lethality. S-methoprene concentrations at 200 ppb did not affect locomotor activities of mosquito fish (Ellgaard et al. 1979). An early life stage test with newly spawned eggs for fathead minnows (*Pimephales promelas*) continuously exposed for 37 days to S-methoprene at concentrations ranging from 13 to 160 ppb found no observed effects at concentrations of 48 ppb (NOAEC) and a lowest observed effects concentration (LOEC) of 84 ppb (based upon reduction in body length and weight); the estimated maximum acceptable toxicant concentration was 64 ppb S-methoprene (Ross et al. 1994). Thermal tolerance for male mosquitofish (*Gambusia affinis*), was reduced in a 24 hour study where fish were exposed to 50 ppb S-methoprene (Johnson 1977). It is possible there is more literature available than is summarized here, however, we have made our best effort to obtain studies that document deleterious effects to fish species at S-methoprene concentrations ranging up to 100 ppb. All studies we reivewed that showed deleterious effects to fish occurred at concentrations well over those expected during mosquito control activities in natural habitats; these are 1 ppb or less.

5.6.3 Amphibians

Beginning in the late 1990s, increased attention focused on the possible role of retinoids in causing amphibian malformations in nature (e.g., Gardiner and Hoppe 1999; Gardiner et al. 2003). Retinoids are vitamin A derivatives with well-documented tendencies to disrupt development (including limb growth) and pattern formation in vertebrates (Bryant et al. 1987; Bryant and Gardiner 1992; Maden 1993; Gilbert 1997; Gardiner and Hoppe 1999). The teratogenic nature of retinoids stimulated research to determine whether retinoids or retinoid-like compounds occurred in amphibian wetlands. During this period, S-methoprene received attention as a possible agent contributing to amphibian abnormalities (Henrick et al*.* 2002). An S-methoprene derivative, S-methoprene acid, closely resembles the chemical structure of retinoic acid, suggesting that the breakdown of S-methoprene in nature could expose larval amphibians to a teratogenic substance. S-methoprene and its derivatives were initially found to cause developmental problems in *Xenopus* embryos, but at high concentrations (>2,000 ppb) (Dumont et al*.* 1997; Degitz et al*.* 2000). Yet in later experiments, Degitz et al*.* (2003a) found that the concentrations of S-methoprene required to cause developmental toxicity in amphibians were much more likely to cause mortality than developmental malformations (see also Ankley et al*.* 1998). S-methoprene was also not correlated with the occurrence of amphibian malformations in nature (Henrick et al*.* 2002). Degitz et al. (2000, 2003b) arrived at a similar conclusion for the direct exposure of amphibians to exogenous retinoic acid. In experiments with both pulsed and continuous retinoic acid exposure, the authors reported that the conditions necessary to induce limb malformations in native amphibians were unlikely to occur in nature (see Ankley et al*.* 2004). These studies in general used concentrations of S-methoprene several orders of magnitude higher than predicted environmental concentrations when S-methoprene is applied for mosquito control. When S-methoprene was applied at environmentally relevant concentrations, no effects on amphibian development or survival were found in one field study in Maryland (Sparling et al. 2000).

5.6.4 Birds

S-methoprene has been shown to have low toxicity to birds. For mallards, an acute LD_{50} was >2,000 mg/kg methoprene (Zoecon Corporation 1974a). An 8-day dietary LC_{50} for bobwhite quail was found to be >10,000 ppm S-methoprene. For chickens, an 8-day dietary LC_{50} was >4,640 ppm S-methoprene (Kidd and James 1991, Zoecon Corporation 1974a). The reported 5- to 8-day LC_{50} values for Altosid™ are >10,000 ppm S-methoprene for mallards and bobwhite quail; the acute oral LD_{50} for Altosid™ was >2,000 mg/kg S-methoprene for mallards (Zoecon Corporation 1974a). Nonlethal effects that may affect survival of mallards did appear at acute oral doses of 500 mg/kg S-methoprene (Zoecon Corporation 1974a); these effects (e.g., slowness, reluctance to move, sitting, withdrawal) appeared within 2 hours after treatment and persisted for up to 2 days (Hudson et al. 1984). These effects may decrease bird survival by temporarily increasing susceptibility to predation. No effects were observed for reproduction of bobwhite quail and mallards at 30 ppm S-methoprene based upon constant feeding of Altosid™ (Zoecon Corporation 1974a). For mallards, dietary concentrations of 30 ppm S-methoprene caused reproductive impairment, but 3 ppm had no effects (USEPA 1991).

5.6.5 Mammals

S-methoprene is practically nontoxic to mammals evaluated on an acute or chronic basis. It is approved for use in livestock feed to reduce fly production in offal (USEPA 1991). The acute oral LD_{50} of technical S-methoprene for rats and dogs are >10,000 mg/kg and 5,000 to 10,000 mg/kg, respectively. Other oral LD_{50} values for S-methoprene in rats and dogs are >34,600 mg/kg and >5,000 mg/kg, respectively (Kidd and James 1991). An oral LD_{50} for S-methoprene for rats was >5,000 mg/kg (Schindler and Brown 1984).

In a 2-year (chronic) feeding study, rats receiving 0 to 5,000 ppm S-methoprene (86% a.i.) in the diet had no toxic effects (e.g., body weight, behavior, food consumption, blood chemistry). In an 18-month feeding study with Charles River CD-1 mice receiving up to 2,500 ppm S-methoprene in the diet, there was systemic toxicity found at 2,500 ppm (pigmentation on livers), but no toxicological effects at 250 ppm; therefore, the NOEL (no observed effect level) for systemic toxicity was 250 ppm S-methoprene.

S-methoprene is not a developmental toxicant to mice based upon a no observed effects level for developmental effects at 600 mg/kg/day. For rabbits, S-methoprene doses as high as 2,000 mg/kg/day exhibited no developmental toxicity when administered during gestation days 7-18. In a three-generation reproductive study with rats, the NOEL was determined to be 2,500 ppm S-methoprene.

Rats were given Altosid™ in their diet for 6 months at S-methoprene dosage levels of 80 to 10,000 ppm; no toxic effects were noted at 400 ppm in the diet (Nagano et al. 1977). A 90-day study with rats dosed with 0 to 5,000 ppm S-methoprene found 500 ppm was the NOEL for systemic toxicity (e.g., liver weights, kidney weights, renal tubular degradation) and 1,000 ppm was the lowest observed effect level (LOEL). A similar 90-day study with dogs established the NOEL and LOEL at 500 and 5,000 ppm S-methoprene, respectively.

5.7 Summary of indirect effects to non-target organisms

5.7.1 Invertebrates

Several field studies have reported minimal effects to non-target invertebrate species with S-methoprene use. Pinkney and others (2000) investigated the non-target effects of S-methoprene (Altosid Liquid Larvicide™, 5% at 0.011 kg a.i. kg/ha, 0.06 lbs a.i./A) in experimental ponds at the Patuxent Wildlife Research Center, Maryland. Researchers sprayed the ponds three times at 3-week intervals and insect emergence was evaluated before and after spraying. Relative to controls, the emergence data showed only isolated cases of significant non-target insect reductions in the sprayed ponds, and other analyses of the invertebrate community showed no significant difference between the S-methoprene and control ponds. Norland and Mulla (1975) using experimental ponds, exposed caged mayfly nymphs (*Callibaetis pacificus*) to an emulsified concentration of S-methoprene (0.30 kg a.i./ha; 1.56 lbs a.i./A). Emergence was tracked at 4 hours and again at 4 days after treatment. The results showed a decrease in the percentage of mayflies emerging from exposure groups relative to controls. In tidal salt marsh habitats treated concurrently or sequentially with *Bti* and S-methoprene, invertebrate populations recovered quickly after exposure to less persistent formulations of S-methoprene (Russell et al. 2009, Lawler et al. 2000).

Several other studies, however, have suggested that increasing the duration of exposure may increase the likelihood of non-target indirect effects such as depressed food resources. A multiyear study examining non-target effects of S-methoprene and *Bti* to non-target aquatic organisms was conducted in Minnesota by the Metropolitan Mosquito Control District (Hershey et al. 1998). Wetlands in Wright County were sampled for three years (1988-1990) to evaluate natural variability in insect populations, then eight wetlands were treated six times during the spring and the summer at 3-week intervals (1991-1993) with S-methoprene at 0.05-0.058 kg a.i./ha (0.275 – 0.32 lbs a.i./A) based on a 4% a.i. formulation as a 20-d release granule). Nine other sites were treated with *Bti* and nine were left untreated. During the first year of treatment, S-methoprene exposure had minimal effects on non-target insect groups. However, in the second and third years researchers noted a significant reduction in taxa richness of Tipulidae, Ceratopogonidae, and Stratiomyidae. Insect density was reduced by 57–83% and biomass was also reduced by 50–83% during this test period (Niemi et al. 1999). In this study, S-methoprene exposure was essentially continuous throughout the summer months, because the 20-day formulation that was used was re-applied every 3 weeks (Hershey et al. 1998).

5.7.2 Fish

One indirect effect of S-methoprene exposure is bioconcentration, whereby the exposed organism accumulates more of a chemical in its tissues than the ambient concentration in the water. S-methoprene has been shown to bioconcentrate in aquatic organisms, such as fish, aquatic invertebrates, and amphibians (USEPA 1982). The effects of elevated body burdens of S-methoprene for extended time periods are not well researched, but some organisms have been shown to depurate or pass the S-methoprene out of their bodies within a short time after exposure ends. S-methoprene residues were found to accumulate in edible tissues of bluegill sunfish and crayfish at maximum bioconcentration factors of 457 and 75, respectively (USEPA 1991). Under laboratory conditions, the edible tissues of bluegill sunfish accumulated 550 to 950 times the ambient water concentrations of 5 ppb and 310 ppb S-methoprene, respectively. In contrast, non-edible tissues contained residue levels 12 times and 4 times greater than the edible portions associated with the low and high S-methoprene concentrations. After S-methoprene exposure ceased, fish excreted 93–95% of the residue (primarily as unmetabolized parent chemical) within 14 days. The risks from bioconcentration of S-methoprene in fish and aquatic tissues are not well studied, however, bioconcentration is less likely to occur with the less persistent S-methoprene formulations due to a limited exposure period and the documented ability to depurate this chemical relatively quickly. If S-methoprene is applied using ground-based methods to spatially limited mosquito breeding areas, fish exposure in these pools is not anticipated.

5.7.3 Amphibians and Reptiles

Two relatively recent biological opinions resulting from consultations with the USEPA and the USFWS on the Endangered Species Act have determined that S-methoprene use for mosquito control provides an adequate margin of safety for both California Tiger Salamanders (*Ambystoma californiense*) (USEPA 2011) and California Red-legged Frogs (*Rana aurora draytonii*) (2008). S-methoprene was the least toxic chemical tested by Johnson and Prine (1975) who measured thermal tolerance in dehydrated (*Bufo boreas*) toads, and found no effect of S-methoprene at a 30 ppb exposure concentration. Nonetheless, both of these classes of organisms consume invertebrates as adults. Therefore if prolonged use of S-methoprene causes a reduction in invertebrate species required as prey items for amphibians and reptiles, there is potential for negative indirect effects from food-web pathways. Reptiles and amphibians are not likely to be present in the areas of the tidal salt marsh that require mosquito treatment.

5.7.4 Birds

Due to the direct toxicity to birds being relatively low, the primary risk to birds may be through reduction of food resources and food web effects. The Minnesota studies examined evidence for such effects on reproduction of red-winged blackbirds (*Agelaius phoeniceus*) and other breeding birds and found that multiple years of S-methoprene treatment did not have an adverse impact (Hanowski et al. 1997a. 1997b, Niemi et al. 1999).

5.7.5 Mammals

Since bats routinely forage on adult aquatic invertebrates, and therefore indirect effects of S-methoprene treatment are possible for bats through processes similar to those described above (see literature review section for indirect effects to mammals for *Bti*). Given that few other mammals are known to rely extensively on aquatic invertebrates for food, indirect effects to other mammals from S-methoprene seem unlikely.

5.8 Screening level ecological risk assessment for S-methoprene and aquatic species

Risks to different classes of biota from application of S-methoprene as a larvicide to control salt marsh mosquitoes within the Bandon Marsh Refuge can be evaluated using the screening level risk assessment framework established by USEPA (2004). Unlike *Bti* and CocoBear™, for which numerical calculation of risk makes little sense, risk from the active ingredient S-methoprene can be quantified as a function of hazard and exposure. Only the screening level risk assessment was performed as part of this analysis, whereby Risk Quotients for acute and chronic endpoints were calculated and compared to pre-established Levels of Concern (LOCs) for different classes of aquatic organisms. Other qualitative considerations, which may affect either hazard or exposure, and therefore increase or ameliorate risk, are also discussed in sections below.

The USEPA risk assessment methodology (USEPA 2004) uses the following stepwise framework: problem formulation, hazard identification, dose-response relationships, exposure assessment, and risk characterization. These steps allow for the comparison of an estimated environmental exposure with a reference dose associated with a toxic effect. This assessment focused only on the active ingredient, S-methoprene and on exposure to aquatic organisms. No inert ingredients or breakdown products were considered.

Problem formulation
This risk assessment considered exposure and hazards of S-methoprene to aquatic species, due to concerns about some risk of toxicity to listed fish and their prey items. To assess relative risk to aquatic

species, we used the USEPA screening level risk assessment framework, to semi-quantitatively assess risk of lethal and sublethal effects to fish, freshwater invertebrates, and estuarine invertebrates that may utilize the treated mosquito breeding areas at Bandon Marsh Refuge (USEPA 2004). The assessment was limited to mosquito control activities during the mosquito season (spring and summer months) estimating simple screening level risk from exposure to S-methoprene dissolved in marsh waters. Due to low levels of risk to birds, mammals, reptiles, and amphibians described in the literature, we did not pursue a quantitative risk assessment for these classes of animals.

Hazard identification

The ecological risk assessment focused upon the mosquito larvicide, S-methoprene. S-methoprene is registered for application to fresh, salt and tidal marshes where slow-release formulations can result in continuous water-borne exposure that should effectively control multiple generations of mosquito larvae. Based on our literature review, there is concern about potential effects to non-target estuarine invertebrates providing forage for a variety of wildlife, especially migratory birds and fish. Like other units of the National Wildlife Refuge System, the Bandon Marsh Refuge was established primarily to provide habitat for fish and wildlife.

Exposure assessment

For a description of areas of exposure, please refer to sections of the Draft Mosquito Pesticide Plan and Environmental Assessment that describe the Affected Environment. This separate document describes utilization of the salt marsh by different species groups and provides the justification and necessary context for the exposure scenarios presented below.

Risk characterization

USEPA risk assessment approach utilizes the quotient method to compare the level of hazard (estimated from prior studies) to environmental exposure (USEPA 2004). In this approach, a risk quotient (RQ) is calculated by dividing a point estimate of exposure by a point estimate of effects. This ratio is a simple, screening-level estimate that identifies potential high- or low-risk situations, and helps quantify the relative risk of different chemicals to different classes of organisms. This method does not account for duration of exposure for aquatic organisms in any way, therefore it does not account for the persistence of the formulation. Nonetheless, the risk assessment process may provide a useful management tool in some situations, and in that spirit, it is provided here. The Risk Quotient is defined as follows:

$$\mathbf{RQ = EXPOSURE\ /\ TOXICITY}$$

Calculation of RQs is based upon available ecological effects data, pesticide-use data, fate and transport data, and estimates of exposure to the pesticide summarized in the literature review sections above (USEPA 2004). In this method, the estimated environmental concentration (EEC) is compared to an effect level (toxicological endpoint) such as an LC_{50} (the concentration of a pesticide at which 50% of the organisms die in controlled laboratory study).

All ecological risk assessments require the risk assessor to make assumptions (USEPA 2004). This section details the assumptions made for the estimation of risk to aquatic resources. To evaluate effects to aquatic taxa (fish and invertebrates) associated with the application of S-methoprene to the restored salt marsh on the Ni-les'tun Unit, the water-borne EECs of S-methoprene in the different formulations considered were estimated (Table 3).

5.8.1.1 Assumptions used to calculate Environmental Effects Concentrations

Calculations of Estimated Environmental Concentrations (EECs) presented in Table 3 assume the following:

- Continuous water contact for solid and granular formulations (dry periods are likely to extend the longevity of the formulation)
- Degradation rate of S-methoprene is equal to its release rate from the formulation, therefore the concentration of a.i. in the water does not increase over time.
- Liquid formulations release S-methoprene evenly over a 7 day time period
    - An application interval is not specified on these labels
- The products are applied evenly over an acre of water of 6"depth
- The conversion factor from liters to acre feet is 1,233,000 liters of H_20 per acre foot
- The conversion factor is from µg to pounds is 433,600,000 µg/Lb
- Formulated product has dissolved completely (i.e., released all S-methoprene in it) by the lower end of the recommended application interval, so the lower day number listed on the label is used in calculations.
- All labeled application rates were considered, although the high application rates for "polluted" habitats in Table 2 are not appropriate for Bandon Marsh. The guidance regarding application rates from the labels (Altosid Pellets™ as an example) follows:
    - *Use lower application rates when water is shallow, vegetation and/or pollution are minimal, and insect populations are low.*
    - *Use higher rates when water is deep (>2 ft), vegetation, pollution, and/or organic debris or water flow are high, and insect populations are high.*
- Altosid Liquid Larvicide™ uses a conversion factor of 51.3 g/L a.i. and a 7-day extended release time to estimate environmental concentrations (from label).
- Altosid Liquid Larvicide™ Concentrate uses a conversion factor of 205.2 g/L a.i. and a 7-day extended release time to estimate environmental concentrations (from label).
- All products are assumed to have a steady release rate per day over the entire application interval
- The application interval for both Metalarv S-PT™ and Altosid Pellets™ is assumed to be 30 days, even though the application interval for Metalarv S-PT™ recommended on the label is 42 days. Given primary literature we reviewed about the duration of these two products in the field, it is reasonable to assume they may show continued efficacy for far more than 30 days. This assumption of a 30-day release rate for Metalarv S-PT™ results in a higher EEC for this product than would a 42-day interval, however this assumption was slightly more conservative and seemed appropriate, given the similarity of the two formulations (Table 2).

Table 3. Estimated Environmental Concentrations of the different S-methoprene (=a.i.) formulations. Concentrations were estimated using a water depth of 6 inches. "Min", "Max", and "Polluted" refer to the labeled application rates.

Product Name	a.i. (%)	Application Rate Min	Application Rate Max	Application Rate Polluted	EEC Min (ppb)	EEC Max (ppb)	EEC Polluted (ppb)
Solid and granular formulations		*(pounds per acre)*					
Altosid SBG™	0.2	5	10	20	1.4	2.8	5.6
Altosid XR-G™	1.5	5	10	20	2.5	5.0	10.0
MetaLarv S-PT™	4.25	2.5	5	10	2.5	5.0	10.0
Altosid Pellets™	4.25	2.5	5	10	2.5	5.0	10.0
Liquid formulations		*(ounces per acre)*					
Altosid Liquid Larvicide™	5	3	4	Not Listed	1.1	1.4	Not Listed
Altosid Liquid Larvicide Concentrate™	20	0.75	1	Not Listed	1.1	1.4	Not Listed

5.8.1.2 Risk Assumptions and analysis

To calculate risk, we used the lowest toxicity thresholds for non-mosquitoes we could find in the literature including a query of studies listed in the ECOTOX database (http://cfpub.USEPA.gov/ecotox/) using the search term, "methoprene" (n=644 records returned) and the USEPA CAS number "65733-16-6" (n=81 records returned). We sorted this database and used the lowest LC_{50} we could find for aquatic invertebrates that were not mosquitoes, and the lowest sublethal effect that we could vet by reading the original study.

5.8.1.2.1 Acute Risk to Fish

We considered the risk of acute lethality to fish by using the lowest LC_{50} we could find in the literature: an LC_{50} of 760 ppb for Rainbow Trout listed on the Altosid™ material safety data sheet. Using this measure of the hazard of acute lethal effects, and our maximum estimated environmental concentration (EEC, Table 3) of 10 ppb, we calculate a risk of lethality to fish of 0.013 at the highest predicted environmental concentration.

RQ=10/760=**0.013 <0.05=LOC**

We compare this to a level of concern (LOC) for a listed fish species of 0.05 (USEPA 2004). The calculated risk value is below the level of concern by a factor of 4 to 5 indicating a low risk of fish lethality from S-methoprene, even if it is applied at the maximum labeled rates. The environmental S-methoprene concentration would need to exceed 38 ppb to reach the level of concern for listed fish, which is very unlikely, given the bulk of available data (e.g., Ross et al. 1994).

5.8.1.2.2 Chronic Risk to Fish

The lowest endpoint we could find for sublethal and chronic effects to fish was a No Observed Adverse Effects Level (NOAEL) of 48 ppb from an early life stage test with newly spawned eggs for fathead minnows (*Pimephales promelas*) continuously exposed for 37 days to S-methoprene at concentrations ranging from 13 to 160 ppb. Effects measured were reduction in body length and weight (Ross et al. 1994). Based on this endpoint, the risk of fish suffering a reduction in body size under chronic S-methoprene exposure is calculated to be 0.208.

RQ=10/48=**0.208 <1=LOC**

We compare this to a level of concern (LOC) for chronic effects of 1, noting that the risk does not exceed the level of concern in this case. The environmental S-methoprene concentration would need to exceed 48 ppb to reach the level of concern for chronic effects on listed fish, which is very unlikely, given the bulk of available data (e.g., Ross et al. 1994)

5.8.1.2.3 Acute Risk to Freshwater Aquatic Invertebrates

Note that the vast majority of the aquatic habitat that may be treated with larvicides is brackish to hypersaline, and is therefore dominated by estuarine species. We used midges to evaluate acute risk to aquatic invertebrates rather than mosquitoes. We use the lethality endpoint for *Goeldichironomus carus* midges of 13 ppb, an LC_{50} for a 7 day S-methoprene exposure of late third/early fourth instars of *G. carus* (Ali et al. 2008). Using this endpoint of 13 ppb and our maximum EEC of 10 ppb, we calculate the following risk of lethality to freshwater invertebrates:

RQ=10/13=**0.769 >0.5=LOC**

This value exceeds the level of concern of concern of 0.5 for aquatic, non-listed species, indicating risk to some sensitive freshwater invertebrate species from S-methoprene exposure.

5.8.1.2.4 Chronic Risk to Freshwater Aquatic Invertebrates

To calculate the risk of chronic exposure to freshwater aquatic invertebrates, we used a laboratory study that found S-methoprene impaired reproduction of Daphnia at 0.5 ppb S-methoprene (Fortin and Solomon 1988). Using this hazard endpoint of reproductive impairment, we calculate the risk of chronic effects to aquatic invertebrates as follows.

RQ=10/0.5=**20 >1=LOC**

This number is twenty times greater than the level of concern of 1 for chronic effects on non-listed species. This analysis shows that there is a risk of sublethal chronic effects on some freshwater invertebrate species, because these effects seem to occur at concentrations relevant for mosquito control. Factors that influence this risk are discussed below.

5.8.1.2.5 Acute Risk to Estuarine Invertebrates

We used as our measure of acute hazard a value of 55 ppb, given as the concentration that reduced hatching success in 50% of the study population of mud crabs in (EC_{50}=55 ppb in Lee et al. 1999). Using this measure and our EEC of 10 ppb for S-methoprene, we calculate risk of acute effects to estuarine invertebrates as follows:

$$\textbf{RQ}=10/55=\textbf{0.208} < \textbf{0.5=LOC}$$

This risk quotient is lower than the level of concern of 0.5 for acute risk to non-listed aquatic species, showing that there is a reasonable margin of safety for S-methoprene use for mosquito control in terms of acute lethality to estuarine invertebrates.

5.8.1.2.6 Chronic Risk to Estuarine Invertebrates

There are several studies summarized above that demonstrated chronic, sublethal effects to estuarine invertebrates at S-methoprene levels relevant for mosquito control. The value we use here is the lowest observed effects level for reduced hatching in the mysid shrimp, *Neomysis integer*; it is the lowest significant threshold values reported in ppb in the ECOTOX database (1 ppb, Ghekiere et al. 2007) as our lowest observed effects level (LOEL), we calculated risk of chronic effects to some estuarine invertebrates as follows.

$$\textbf{RQ}=10/1=\textbf{10} > \textbf{1=LOC}$$

This number is also over the levels of concern of 1 for chronic risk to non-listed aquatic invertebrates. We therefore reserve some concern about sublethal, chronic effects of S-methoprene to aquatic invertebrate species, such as mysid shrimp.

5.8.1.3 Discussion of risk to aquatic species

To put these values in perspective, however, we discuss here how our conservative assumptions regarding the environmental concentrations and the effects levels chosen to represent exposure hazard influence this analysis. The vast majority of the aquatic habitat that may be treated with larvicides is brackish to hypersaline, and is therefore dominated by estuarine species.

We first note that an estimated concentration of 10 ppb is probably much higher than actual concentrations will be. We obtained this number based on estimates made using the maximum labeled rate of S-methoprene, and this rate is probably inappropriate for use at Bandon Marsh Refuge in a natural habitat, as specified on the label (Table 2). This calculated value (10 ppb) is also at least an order of magnitude higher than values measured in other studies, all of which document that 1 ppb would be a high concentration of S-methoprene in the environment (see discussion above on environmental behavior and differences of formulations). If a value of 1 ppb is used for an estimated environmental concentration, all risk quotients will drop by a factor of 10 (USEPA 2004). Actual concentrations at Bandon Marsh Refuge are predicted to be lower if the lower label application rates are used.

In terms of the acute risk to freshwater invertebrates (RQ=0.769), the Ali and others (2008) paper provides a hazard endpoint that is unclear because the concentrations they list use the “ppm” terminology. When this is used, it is sometimes unclear whether the authors meant the “parts” to be of the active ingredient or the technical formulation. We make the conservative assumption they are discussing ppm of the active ingredient. If they were actually discussing ppm of the technical formulation, this imparts a safety factor of approximately 20-fold on the hazard value (because the product they used was only 4.25% active ingredient). A higher value is consistent with other field and laboratory studies, which tend to document LC_{50}s that are at least several-fold higher than the value found by Ali and others (2008) value (see literature review above and CCME 2007).

One may argue we should have assessed risk to mosquitoes, rather than midges as the freshwater invertebrate, but there is a certain futility in assessing risk to the target invertebrate pest. By definition, pesticide exposure to the target pest *should* be risky. Environmental concentrations of the pesticide are designed to be high enough to kill the target insect, therefore had we used mosquitoes, we would be well over levels of concern in a screening level risk assessment. There is therefore no point in doing one. This is a somewhat circular argument and is therefore a question of policy rather than risk. It is worth noting, however, that S-methoprene—an insect growth regulator and hormone mimic—kills mosquitoes and other insects by a specific mode of action targeted to the end of their aquatic (larval) life cycle. It should have little to no effect on their larval development, and should leave invertebrates in the aquatic system relatively intact as potential prey items to aquatic predators. That said, over time S-methoprene exposure is predicted to negatively affect mosquito populations (in fact, this is the desired result of larvicide treatment) as well as reduce the numbers of adult mosquitoes potentially available as a food source.

5.9 Qualitative comparison of different S-methoprene formulations

Slow release formulations impart more risk to non-target aquatic species because they expose them to S-methoprene for longer periods of time than do the formulations designed to dissipate more quickly. This information is not captured in the numbers reported above for the screening level ecological risk assessment, but is likely to be important when considering the actual risk of S-methoprene to non-target species, especially non-target invertebrates on which S-methoprene may have chronic effects. It is difficult to generate a chronic effect in a short time period (e.g., 10 days). The likelihood of observing a chronic effect of a chemical on a non-target organism increases when the exposure is longer (e.g., 40 days instead of 10, Table 2). The methods for calculating screening level risk to aquatic organisms do not account for this difference in actual risk to the environment caused by the persistence of the formulation, because time is not a component in the Risk Quotient formulas for aquatics (USEPA 2004).

Nonetheless, increased persistence increases exposure duration, which will increase the risk of chronic deleterious effects.

Moreover, in a tidal salt marsh habitat, a more persistent formulation may also increase the spatial extent of chemical exposure, due to the flushing of tidal waters over areas treated with more persistent formulations, which may result in low levels of S-methoprene beyond the treatment area when the tide recedes. It is of course important to consider the effects of dilution when discussing this topic. Due to dilution, it is reasonable to expect the concentration of S-methoprene that would move beyond the treatment area in tidal waters to be much lower than of our predicted EECs. Nonetheless, estuarine organisms may be exposed to these diluted concentrations of S-methoprene. In contrast, by the time treated waters left the estuary and entered the marine environment, dilution would be so great, and the S-methoprene would have degraded due to its short half-life in water, such that marine organisms would not likely be exposed to S-methoprene at levels that could cause harm.

Environmental concentrations measured in published studies are approximately an order of magnitude lower than those EECs in Table 3 (e.g., Ross et al. 1994). Even halving our high predicted EECs results in concentrations below most thresholds for chronic effects for most marine invertebrates, except for those organisms most sensitive to S-methoprene on whom it seems to act at or near the effective concentrations for mosquitoes. For these organisms, the effects were sublethal and often required chronic exposures to elicit. Therefore it is highly unlikely that less persistent formulations of S-methoprene would be harmful to marine invertebrates, given tidal dilution, and a lack of a long term environmental exposure. It is possible that repeated treatments or the use of more persistent formulations of S-methoprene would result in sublethal chronic effects to some sensitive estuarine invertebrates, but tidal dilution does make this scenario less likely if the S-methoprene is applied as directed on the label.

We have made conservative assumptions in this analysis, with the intention of protecting the health of a threatened fish and its prey items in a designated critical habitat. The real risks may actually be lower than those presented here, as shown by several field studies of S-methoprene use in tidal salt marsh habitats (e.g., Lawler et al. 2000, Russell et al. 2009). There are some concerns about chronic and sublethal effects to some invertebrate species. These risks can be minimized by limiting the spatial extent of S-methoprene applications, using less persistent S-methoprene formulations, applying S-methoprene less frequently, and using the lower range of labeled application rates (Table 2).

5.10 Concerns with S-methoprene use at Bandon Marsh Refuge

Two main concerns arise regarding use of S-methoprene at Bandon Marsh Refuge, food web effects and bioconcentration. As with *Bti*, there may be food web effects to non-target animals that prey on adult mosquitoes, such as fish or bats. Nevertheless, if one considers mosquito larvae as prey for aquatic organisms, like fish or insect predators, S-methoprene will keep the mosquito larvae in the system for longer due to the fact that it targets the metamorphic life stage of the insect. Finally, as discussed above, S-methoprene bioconcentrates, whereas *Bti* does not. The effects of bioconcentration of S-methoprene in aquatic species are not particularly well documented (based on our review), but it has been shown to have low mammalian toxicity, approved for use in drinking water cisterns (WHO 1999) and livestock feed (USEPA 1991). Given that fish seem to depurate S-methoprene quickly (within approximately two weeks) after exposure ceases, the less persistent formulations, which limit the duration of non-target exposures, will be more benign in this regard.

6 Comparison of risk to non-targets from *Bti* and S-methoprene.

Brown and others (2000) compared the toxicity and efficacy of different mosquito larvicides to *Culex annulirostris*, an Australian freshwater mosquito and to *Caradina indistincta*, a co-habitating non-target shrimp. They calculated a lethal dose ratio, which was the concentration that killed 95% of the non-target species divided by the concentration that killed 95% of the target species. Therefore a high number indicates a pesticide that was relatively safe for the non-target organism and a low number relatively unsafe. They found *Bti* was the safest for the non-targets, with a lethal dose ratio of 846,000. S-methoprene was also relatively safe with a ratio of 3,300. In contrast, lethal dose ratios for temephos (the active ingredient in Abate) and pirimiphos-methyl were 0.05 and 0.00005, respectively, suggesting a high level of risk for this non-target shrimp from these compounds. Although S-methoprene is obviously more environmentally benign for non-target species than are some of the older organophosphate-based insecticides, the safety profile is better for *Bti* than it is for S-methoprene.

7 Summary of studies evaluating co-application of S-methoprene and *Bti*

Because *Bti* and S-methoprene are commonly used together in mosquito management programs, we review here two studies that evaluated the non-target effects of their co-application in time and/or space. In tidal salt marsh habitats treated concurrently or sequentially with *Bti* and S-methoprene, invertebrate populations recovered quickly after exposure to less persistent formulations of S-methoprene. For example, Russell and others (2009) found S-methoprene and *Bti* to have little effect on aquatic and terrestrial salt marsh invertebrate species; they describe the effects as inconsistent and "short lived (<20 days)" in a salt marsh habitat in Queensland, Australia, treated repeatedly with less persistent formulations of *Bti* and S-methoprene. Lawler and others (2000) did not find evidence of alterations in non-target invertebrate communities when less persistent formulations of *Bti* and S-methoprene were applied together in space and time or Altosid Pellets™ alone were applied in tidal salt marsh habitats in northern California, USA.

8 CocoBear

CocoBear Mosquito Larvicide Oil (CocoBear™, USEPA Registration #8329-93) is a liquid pesticide product applied to the surface of standing water at a rate of 3–5 gallons per surface acre of water to control mosquito larvae and pupae. Sites to which CocoBear™ may be applied include standing water within croplands and pastures, drainage areas, ditches, stagnant pools, swamps, marshes, temporary rain pools, sloughs, log ponds, open sewage basins, settling ponds, catch basins, waste tires, and intermittently flooded areas. CocoBear™ is most often applied with a canister pump sprayer, backpack sprayer, or pressurized hand wand sprayer, but other means can be employed as long as the appropriate application rate is maintained. CocoBear™ can also be applied aerially if large areas of surface water need to be treated, however such use is not anticipated at Bandon Marsh Refuge.

Typically mosquito larvicide oils are utilized in habitats where pupae and late 4th instar mosquito larvae are found. Mosquito larvicide oils kill pupae, while generally most other products do not. As such they provide an important resource to control broods late in development preparing to emerge as adults. Mosquito larvicide oils are also utilized in habitats where the organic content of the water is high. When treating for mosquito larvae, organic matter in water has the potential to reduce the efficacy of other types of products. Mosquito larvicide oils are also used in areas that produce mosquitos for only a short time, such as flooded areas expected to dry in the near future or where the use of longer duration products would not be necessary. However, if longer term control is needed, typically larvicide oils would not be reapplied, but instead, a product would be used which would provide a longer duration of control such as *Bti* or S-Methoprene (USEPA, 2007a).

The CocoBear™ formulation comprises four ingredients. The active ingredient of the product, White Mineral Oil (CAS# 8042-47-5), makes up 10% of the total formulation by weight. The main constituent of Cocobear™, at >75%, is a blend of Methyl Esters of Fatty Acids; however the manufacturer has not disclosed the exact identity of this blend. An undisclosed Alcohol Ethoxylate surfactant is in the formulation at <5%. Another undisclosed component is in the formulation at <1%.

8.1 Mode of action

Mosquito larvae and pupae dwell within water, and during this life cycle stage, most types of mosquitos must periodically surface to breathe air. Normally when surface-breathing types of larvae and pupae come to the surface to breathe, they will penetrate the water surface with their siphon (breathing) tube, and use surface tension to hold in that position as needed. Cocobear™, as with all mosquito larvicide oils, works by killing mosquito larvae and pupae thru physical means. CocoBear™ is an oil-based, hydrophobic product and has a density of 0.868 g/mL; both of these factors allow it to stay on top of the water surface. Surfactant components in the product formulation help CocoBear™ spread across the water surface, leaving a thin layer on top of the water. When larvae and pupae approach the water surface to breathe, most cannot penetrate to the atmosphere because of the layer of CocoBear™ on the water surface, and subsequently are unable to breathe. If they do penetrate the film, the oil's surface tension on the siphon tube is so low that they fall below, and again are unable to breathe. Larvae and pupae can also inhale the oil into their siphon tube and trachea causing asphyxiation. In essence, CocoBear™ kills by the physical means of suffocation.

8.2 History and patterns of use

CocoBear™ is a relatively new, mineral-oil based larvicide. CocoBear™ is a more recent formulation similar to GoldenBear™, which utilized a much higher proportion of petroleum distillates in its formulation. CocoBear™ is intended for use on the Refuge only with ground-based methods in areas where adequate control of mosquitoes has not been attained using other means. CocoBear™ is a single brood product and can be applied as needed. Mosquito larvicide oils kill all immature mosquito stages, including all larval stages and pupae, and therefore the timing of the application is not critical as with other products that require the active ingredient be consumed by feeding larvae, e.g., products containing *Bti*, or during key periods in larval development, e.g., insect growth regulators such as S-Methoprene (USEPA, 2007a).

8.3 Behavior of the active ingredient in the environment and persistence of the formulation

The use of mosquito larvicide oils on water is unique; they are applied to the top of the water surface and the products do not mix with the water. Although some acute aquatic toxicity data is available on Cocobear™'s main components, many organisms would likely experience limited exposure, if any, to these chemicals because the product is designed to remain at the water surface. A United States Environmental Protection Agency Office of Pesticide Programs (USEPA 2007) revised reregistration eligibility decision (RED) for aliphatic solvents suggests, "Due to the characteristics of these mosquito control products, however, it is likely that the oils would not mix within the water column, and that the exposures would be restricted to a much higher concentration at the film layer on the surface of the water. Thus, there would be a higher EEC exposure at the surface, but in a smaller proportion of the entire water body, and a lower EEC throughout the vertical extent of the water body. Thus, any possible adverse effects on the critical components of the aquatic ecosystem would be much lower within the water column."

No environmental fate or persistence data is available at this time for the end use product, Cocobear™. Data on the formulation's two main constituents and surfactant component are available and described below. Regarding mosquito larvicide oils, the 2007(a) USEPA registration documents for aliphatic solvents cites information obtained from the US Centers for Disease Control and Prevention (CDC), which states, "surface films larvicides generally have a shorter environmental persistence (approx. 2-3 days) than most chemical larvicide alternatives" (USEPA, 2007a). Based on the chemical profiles described below, this product is unlikely to dissolve in or contaminate groundwater. Rather, it is likely to sorb to vegetation and other organic matter, and ultimately undergo degradation by microbes.

8.3.1 White Mineral Oil – CAS # 8042-47-5

The USEPA RED for aliphatic solvents describes the behavior of the aliphatic solvents as "...they have low to very low vapor pressures, very low solubility in water, high octanol-water partition coefficients, and high sorption to organic matter. Thus, these chemicals are predicted to exhibit very poor migration, due to their high sorption and low solubility in water, as well as low potential for volatility. Modeling suggests they would remain partitioned to the terrestrial phase, remaining sorbed to soil or the foliar surfaces to which they are applied" (USEPA, 2007a)."

8.3.2 Blend of Methyl Esters of Fatty Acids – CAS # (undisclosed)

The USEPA RED report cites studies showing that the methyl ester that was tested had an aerobic soil metabolism half-life of 9.5 days in soil and an aerobic aquatic degradation half-life of 19 days (USEPA, 2007b). As mentioned above, the USEPA RED for Methyl Esters of Fatty Acids, reports that methyl esters are insoluble in water (USEPA, 2007c).

8.3.3 Alcohol Ethoxylate surfactant – CAS # (undisclosed)

Information regarding the Alcohol Ethoxylate class of chemicals is described below, however no specific information regarding the surfactant used in CocoBear™ was disclosed. A 2009 Human & Environmental Risk Assessment on Ingredients of European Household Cleaning Products (HERA) on alcohol ethoxylates reported that, "Alcohol ethoxylates are not expected to undergo hydrolysis under normal environmental conditions (pH range 4 to 9). Photolysis in the atmosphere, in water, or when adsorbed to solid surfaces such as soil and sediment surfaces is also not expected to occur, due to the chemical structure of the AE homologues" (HERA, 2009). The report goes on discuss aerobic degradation of alcohol ethoxylates, stating "As a class, alcohol ethoxylates undergo rapid primary and ultimate biodegradation under both laboratory and field conditions," "AE with a typical alkyl chain (e.g., C12 to C15) will normally reach more than 60% ultimate degradation in standardized tests for ready biodegradability....Currently available data … shows that C16 and C18 homologues with up to 30 EO units should pass the current ready test (OECD 2006) (HERA, 2009)". The report also states that alcohol ethoxylates are biodegradable through anaerobic processes (HER, 2009). Therefore, microbial degradation is the most likely primary breakdown process for this chemical.

8.4 Target specificity and summary of direct effects to non-target organisms

No ecological data is available at this time for the ecological effects of the end use product, Cocobear™. Data on the formulation's two main constituents are available and described below.

8.4.1 White Mineral Oil – CAS # 8042-47-5

The USEPA OPP revised RED for aliphatic solvents, which includes white mineral oil, provides a general overview of the ecological toxicity for these solvents. The report states, "The results of toxicity testing with fish, both estuarine/marine and freshwater species, have shown virtually no toxic effects, and there were no toxic effects in testing with estuarine/marine mysid shrimp. There is a study showing adverse effects on oyster shell deposition (EC_{50} = 6 mg/L), but this might be due to the mineral oils coating the surfaces of the food sources for the oysters, impairing their ability to digest their food....In the most recently submitted study with daphnia, the effects observed included immobilization in the water column and/or floating on the surface, but visual observations with a microscope revealed the daphnia hearts were still beating. Thus, while immobilization and floating effects were observed even at the lowest test concentration (EC_{50} = < 0.9 mg/L), the study reported that "the test compound, VHVI-4, was not lethal to Daphnia magna at the highest test concentration (14 mg/L) after 48 hours exposure."" Effects on the daphnia were observed, however the report does not clarify the identity test compound "VHVI-4." Although aquatic toxicity endpoints were reported for the aliphatic solvents in this USEPA RED, the report also states that these exhibit very low water solubility (USEPA, 2007a). It is unknown whether an effective concentration level can be reached due to the low water solubility of white mineral oil. A LD_{50} of >2250 mg/kg-bw was reported for birds along with the following statement, "There was essentially no lethality observed in any of the tests conducted with fish species (in freshwater or estuarine/ marine species), mammals (rats or mice), or birds (in either acute, oral, single-dose or sub-chronic dietary feeding tests)" (USEPA, 2007a).

8.4.2 Blend of Methyl Esters of Fatty Acids – CAS # (undisclosed)

Limited information was found regarding this component. A USEPA OPP Environmental Fate and Effects Division (EFED) revised ecological risk assessment for methyl esters of fatty acids, provided summary data for study conducted with technical test substance (Methyl esters of fatty acids, CAS# 67762-39-4) on the test species Bluegill Sunfish, *Lepomis macrochirus*. The 96-hour LC_{50} was reported at >100 mg a.i./L (USEPA, 2007b). Note that the identity of the blend of methyl esters in the CocoBear™ was not disclosed.

It should be noted that methyl esters are not likely to be soluble in water. Although an aquatic toxicity study was conducted and reported on, a USEPA RED for Methyl Esters of Fatty Acids reports that the water solubility at 20°C of methyl esters of fatty acids (CAS# 67762-39-4) is "Zero gm/100 ml," (USEPA, 2007c). A search of MSDS's of various methyl esters indicates that chemicals in this class are insoluble in water.

8.5 Summary of potential effects to non-target organisms

8.5.1 Invertebrates

Surficial oils like CocoBear™ are predicted to suffocate other non-target insects that reside on the water surface or must surface to breathe. The mode of action of the surficial oil is not specific, and thus it is predicted to kill surfacing insects somewhat non-selectively by the same mode of action that it kills mosquito pupae. For this reason, its use should be limited spatially and it should be applied only to species-poor habitats.

8.5.2 Fish

Due to its environmental behavior (floating on the water surface, adhering to soil and vegetation, relatively rapid breakdown), CocoBear™ is unlikely to dissolve into the water column at high concentrations. Because fish do not generally rise to the water surface to breathe, this compound is unlikely to affect fish through the primary suffocation pathway. Nonetheless, due to the newness of this product and the limited information on its toxicity to fish in the combined formulation, and the conservation objectives of Bandon Marsh Refuge, the precautionary principle would encourage avoiding habitats containing fish when using this product. This does not present a problem, since the target mosquitoes generally do not breed in pools with fish.

8.5.3 Amphibians and Reptiles

Amphibian tadpoles do need to surface to breathe, in particular at later larval stages as they are transitioning from gills to lungs as they approach metamorphosis. During metamorphosis, they often sit in vegetation at the water surface. Some types of surfactants have been shown to be lethal to amphibians, which have permeable skin (e.g., Relyea 2005a-c). It is therefore predicted (in the absence of data showing otherwise) that this mosquito larvicide may cause substantial harm to either adult or larval amphibians. Adult and larval amphibians and their breeding habitats should be avoided during use. At Bandon Marsh, the target mosquitoes use brackish, highly ephemeral pools that do not support amphibians, so larvicide application will not expose larval amphibians.

Mineral oil spirits also seem to interfere with the development of eggs and other instances of calcium-based shell development (e.g., mineral oil spirits have been shown to terminate embryonic development in chickens and gulls, when applied to the eggs; Morris and Siderius 1990). In a similar manner, they may affect eggs of reptiles, therefore care should be taken to avoid their burrows. This product is not licensed for application to terrestrial habitats, therefore this should not be a problem, but may be considered by field applicators nonetheless.

8.5.4 Birds

As noted for reptiles above, mineral oil spirits have been shown to disrupt avian embryonic development (Morris and Siderius 1990). Therefore, care should be taken during applications to avoid bird nests when using this product. Moreover, because CocoBear™ is a surface oil, it may coat the feathers of birds that land in treated areas, causing oiling of eggs that bird may be incubating or matting of feathers and loss of ability to thermoregulate.

8.5.5 Mammals

Acute mammalian toxicity summary data for CocoBear™ are provided in the table below along with its corresponding USEPA Toxicity category. Toxicity information was obtained from the product's registrant and manufacturer, Clarke Mosquito Control Products, Inc., and was originally submitted to USEPA Office of Pesticide Programs as a requirement of registration. The USEPA Toxicity Category below is defined by federal law (40 CFR 156.62). Category IV is the least toxic category.

Table 4. Acute mammalian toxicity data for CocoBear™

Study Type	Endpoint / Result	USEPA Toxicity Category
Acute Oral Toxicity	> 5000 mg/kg	IV
Acute Dermal Toxicity	> 5050 mg/kg	IV
Acute Inhalation Toxicity	> 2.16 mg/L	IV
Acute Eye Irritation	Not an eye irritant; Minimal effects, if any, clearing in 24 hours	IV
Acute Dermal Irritation	Not a dermal irritant; PII = 0.3 Slightly irritating but clearing in 72 hours	IV

8.6 Inability to calculate screening level risk for Cocobear™

Like with *Bti*, it did not make sense to calculate screening level risk for CocoBear™ for several reasons. The first is that surface oils are designed to sit atop the water surface, not dissolve into the water, making an estimate of water concentration difficult without a fairly extensive modeling exercise. Moreover, CocoBear™ utilizes 10% mineral oil spirits (by weight) as the ostensible active ingredient in the formulation, however, its mode of action is not toxicity; rather it is suffocation. It is likely that the other 90% of the ingredients assist with the mode of action of the product, while enabling the formulation to comprise ingredients less toxic to aquatic life than mineral oil spirits.

8.7 Concerns with Cocobear™ use at Bandon Marsh

It is anticipated that at Bandon Marsh Refuge, all applications of CocoBear™ will be ground based and limited in spatial extent. Projected use at Bandon Marsh Refuge is that CocoBear™ will only be applied to small, brackish to hypersaline, and species-poor water bodies containing predominantly late-stage mosquitoes. Effort should be made to visually assess the habitat for non-target invertebrate, fish, or amphibian species (terrestrial or aquatic stages) and to refrain from application in these areas. There may be risk to birds or reptiles if eggs are sprayed or incubated by an oiled adult and to birds if feathers are coated and matted down due to direct overspray or to landing on treated water surfaces, post application. CocoBear™ is dispersed using a surfactant of undisclosed identity. Some surfactants, while often having multiple uses including as ingredients in food products, can exert some level of aquatic toxicity. Based on a qualitative assessment of the toxicity of Cocobear™, we recommend limited use of this product in time and space.

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Appendix D. Mosquito Biology

The following information was provided courtesy of the author, Wesley A. Maffei, and excerpted from:

Baylands Ecosystem Species and Community Profiles: Life histories and environmental requirements of key plants, fish and wildlife. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. 2000. P.R. Olofson, editor. San Francisco Bay Regional Water Quality Control Board, Oakland, CA. 408 pp.

This list includes some species that have been identified at Bandon Marsh NWR, but all have the potential to occur, and *Aedes dorsalis* is the current target of management due to its recent abundance and use of breeding pools that were inadvertently created by salt marsh restoration activity at Ni-les'tun.

Contents:

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Summer Salt Marsh Mosquito

Aedes dorsalis (Meigen)

Wesley A. Maffei

Description and Systematic Position

The summer salt marsh mosquito, *Aedes dorsalis*, is a medium sized mosquito measuring approximately 5-6 mm in length. Freshly emerged adults are one of the most brightly colored marsh mosquitoes found within the San Francisco Estuary. These insects are brilliant gold in color, have a dorsal white band running the length of the abdomen and have broad white bands on the tarsal segments of the legs. Older specimens may be yellow or yellowish-brown in color and the markings on the abdomen may be incomplete if the scales have been rubbed off. The immature stages can be identified by insertion of the siphon tuft at or beyond the middle of the siphon tube, a broadly incomplete anal saddle, presence of a weak saddle hair and moderate to short anal papillae. The presence of single upper and lower head hairs has been used as an additional diagnostic feature but this can be inconsistent, especially in later instar larvae.

The similarity of this mosquito to *Aedes melanimon* Dyar has resulted in some confusion with early efforts to identify both adults and larvae. Detailed studies of different populations of both of these mosquitoes have helped to clarify and verify the systematic position of both of these insects (Bohart 1956, Chapman and Grodhaus 1963).

Distribution

This mosquito can be found throughout most of the United States, southern Canada, Europe and Asia (Carpenter and LaCasse 1955, Darsie and Ward 1981). Within California, this mosquito can be found in coastal salt marshes and the brackish waters of the Sacramento and San Joaquin Delta (Bohart 1956, Bohart and Washino 1978).

Suitable Habitat

Larvae are found in a variety of brackish and freshwater habitats throughout their world range (Carpenter and LaCasse 1955). Within San Francisco Bay *A. dorsalis* are usually encountered in temporarily flooded tidal marsh pannes, heavily vegetated ditches and brackish seasonal wetlands. Adults prefer open habitats such as grasslands, open salt marsh and the edges of woodlands.

Biology

Adults are aggressive day biting mosquitoes that have been found capable of traveling distances of more than 30 miles (Rees and Nielsen 1947). Flights of adults in Alameda County have been known to disperse distances of more than five miles from their larval source (Maffei, unpub.). Garcia and Voigt (1994) studied the flight potential of this mosquito in the lab and found that the adults exhibited strong flight characteristics which they believed helped them to adapt to the strong winds encountered in their preferred open habitats. Females are readily attracted to green, grassy fields and will rest there waiting for available hosts (Maffei, unpub.).

Host studies have shown that large mammals are preferred, especially cattle and horses (Edman and Downes 1964, Gunstream et al. 1971, Shemanchuk et al. 1963, Tempelis et al. 1967). The effects of adult feeding activity on livestock can be severe resulting in reduced feeding and in some instances injury to animals attempting to evade severe attacks. Recent adult activity within the San Francisco Estuary has impacted outdoor school activities, businesses and residents, resulting in at least two instances where medical attention was required for people reacting to multiple bites (Maffei, unpub.).

Eggs are deposited individually on the mud along the edges of tidal pools or the receding water line of brackish seasonal wetlands. Winter is passed in the egg stage and hatching occurs with the first warm weather of spring. Additional hatches occur with subsequent refloodings of the larval habitat. Eggs can remain viable for many years with only part of any given brood hatching during any single flooding event.

The larval stage can last from four to fourteen days with duration being primarily dependent on temperature. Other factors that can regulate rate of larval development include competition for space and quality and availability of nutrients. Rees and Nielsen (1947) found larvae that completed their development in saline pools of the Great Salt Lake with salt concentrations as high as 120 ‰. Washino and Jensen (1990) reared larvae, from Contra Costa County salt marshes, in solutions simulating 0, 10, 50 and 100% concentrations of seawater and found that survivorship improved as salt content approached that of seawater.

Total developmental time, from egg to adult, has been observed to occur in less than one week (Maffei, unpub.).

Reproduction

Male mating swarms have been observed occurring over low growing bushes, prominent objects and open fields (Dyar 1917, Garcia et al. 1992). Both observations noted that swarming activity began at sunset and that the swarms were not more than two to three meters above the ground. Swarming and mating usually occurs on the marsh within a few days of adult emergence and is followed by random dispersal of host seeking adults.

The number of gonotrophic cycles and eggs produced per female remains unclear for San Francisco Bay populations. Early work by Telford (1958) found that 12 broods and approximately eight generations occurred during one breeding season at Bolinas in Marin County. The number of generations per year does vary with respect to weather and tidal conditions.

Significance to Other Wetlands Taxa

This species of mosquito is commonly found in association with the tidal pool brine fly *Ephydra millbrae* and the water boatman *Trichocorixa reticulata*. Both the brine fly and the water boatman have been identified as food sources for shorebirds and waterfowl (Anderson 1970; Feeney and Maffei 1991; Howard 1983; Maffei, unpub.; Martin and Uhler 1939). The larvae of this mosquito may also be a food source for these birds and adults may be a food source for swallows.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be taken when altering or restoring seasonal or tidal wetlands. Sites that drain poorly will create habitat that can readily produce very large numbers of aggressive biting adults. Plans for long term maintenance of seasonal and tidal wetlands should include resources for mosquito control as the need arises. The dynamic nature of these types of habitats coupled with human activities can easily convert a non-breeding site into a major mosquito producing source.

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lar, with additional sites having been identified along the shoreline of the East Bay.

Winter Salt Marsh Mosquito

Aedes squamiger (Coquillett)

Wesley A. Maffei

Description and Systematic Position

Aedes squamiger is a medium-sized to large mosquito, measuring approximately 6-9mm in length, that belongs to the fly family Culicidae (**Figure 3.13**). Adults have a distinctive black and white speckled appearance and large, flat scales along the wing veins which separates this fly from other San Francisco Bay mosquitoes. Larvae can be identified by the presence of an incomplete anal saddle, a siphon tuft distal to the pecten row, an anal saddle hair as long or longer than the anal saddle, and upper and lower head hairs that are usually branched (**Figure 3.14**).

This mosquito was described as a new taxon by Coquillett in 1902 from specimens collected from the cities of Palo Alto and San Lorenzo, California. Bohart (1948) differentiated the larvae and pupae of *Aedes dorsalis* and *Aedes squamiger* thereby providing a means of separating the immature stages of these two species which are very similar in appearance. In 1954, Bohart described and provided keys to the first stage larvae of California *Aedes* and further clarified the differences between these two mosquitoes.

Distribution

This mosquito is found along the Pacific Coast region from Marin and Sonoma counties, California, south to Baja California, Mexico (Bohart and Washino 1978, Carpenter and LaCasse 1955, Darsie and Ward 1981, Freeborn and Bohart 1951). **Figure 3.15** shows the distribution of *Aedes squamiger* in 1950. The current distribution within the San Francisco Bay area is very similar, with additional sites having been identified along the shoreline of the East Bay.

Suitable Habitat

Preferred habitat consists primarily of coastal pickle weed tidal and diked marshes, especially salt marsh pools that are diluted by winter and early spring rains. Cracked ground of diked wetlands and old dredge disposal sites are also a favorite habitat for deposition of eggs and development of larvae. This mosquito prefers brackish or saline habitats and has not been found in truly fresh water marshes. Bohart, et. al. (1953) found larvae of various stages in pools with salinities ranging from 1.2 ‰ to 35 ‰. Studies by Garcia and coworkers (1992, 1991) indicated that optimal larval development occurred at salinities between 5 ‰ and 15 ‰.

Biology

Eggs hatch as early as late September and can continue to hatch with the accumulation of rainfall from each successive storm event. Maffei (unpub.) found larvae that hatched from the incidental flooding of a marsh by a duck club as early as late September. Bohart, et. al. (1953) states that three to six major hatches of eggs occur during the fall months. It is believed that only part of the eggs laid during the prior spring season hatch with a decreasing percentage of the remaining eggs hatching during successive years. Garcia, et al. (1991) found that as many as four floodings were necessary to hatch all of the eggs from field collected samples. Bohart and Washino (1978) state that the eggs are usually dormant from April through September and that this obligatory diapause is terminated by the decreasing fall temperatures that fall below 7°C. Garcia et al. (1991) found that hatching does not occur until the eggs have been exposed to temperatures that are less than 10°C. Voigt (pers comm.) believes that once the eggs have been thermally

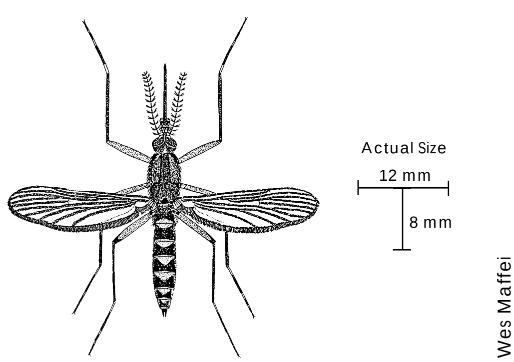

Figure 3.13 Adult Winter Salt Marsh Mosquito – *Aedes squamiger*

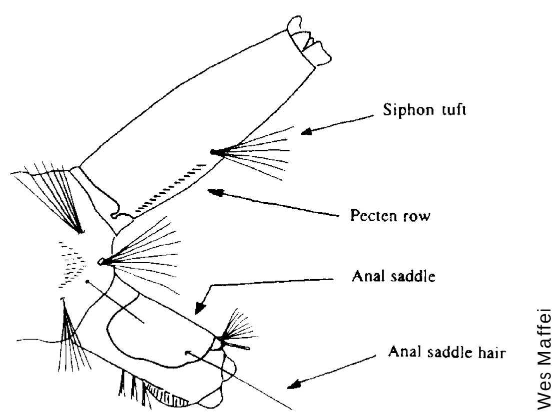

Figure 3.14 Terminal Abdominal Segment of a Fourth Instar Larva

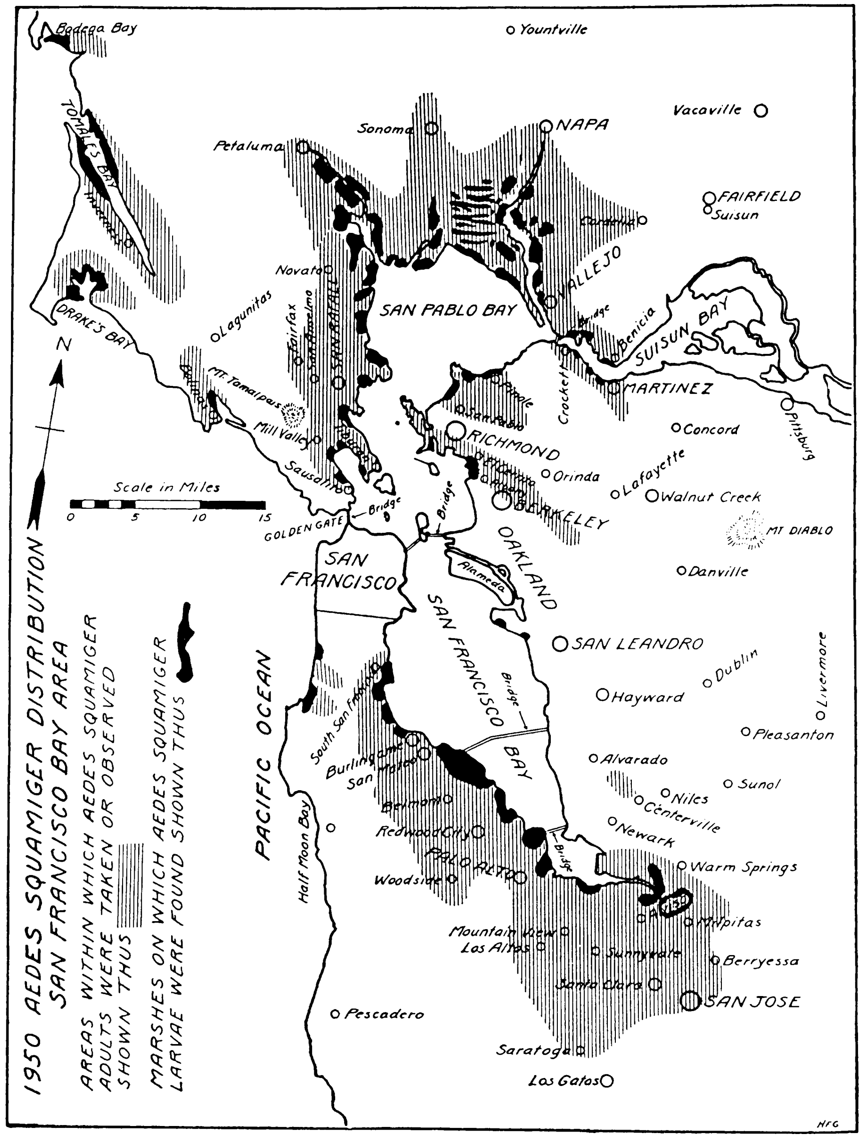

Figure 3.15 *Aedes Squamiger* Distribution in the San Francisco Bay Area, 1950

From Aarons, 1954

conditioned that hatching can then occur anytime in the future following submersion. This may possibly help to explain summer hatches following flooding of sites by inadvertant human activity (Maffei, unpub.).

Larvae are principally found in salt marsh pools that are diluted by fall and winter rainfall. Bohart and coworkers (1953) found that a minimum of 48 days were required for the development of the aquatic stages before adult emergence, with the first pupae having been found during the first week of February. Under "normal" conditions pupae are usually found from the last two weeks of February through the beginning of March. Estimates of the number of larvae per acre vary from 1.65 million to 1.45 billion depending on environmental factors (Aarons 1954, Aarons et al 1951, Lowe 1932). Larvae are capable of remaining submerged for extended periods of time where they browse on vegetation and mud. Garcia, et al (1990) calculated the minimum developmental threshold for development of larvae to the adult stage to be 4.4°C. Additional studies by Garcia and coworkers (1991) found that first and second instar larvae had developmental thresholds that were 2-4°C lower than the later instars. From these data , they concluded that the lower developmental thresholds of the earlier instars allowed larvae from later hatching installments to emerge as adults in closer synchrony with those larvae that hatched earlier in the season. They also noted that larvae and pupae could survive in the mud at sites that underwent periodic draw-down of the water. Garcia, et al. (1990) also studied the diapause habit of the last instar larvae and concluded that this interesting trait probably contributed in some degree to the partial synchronous emergence of the adults.

Adults usually emerge during the last week of February through the end of March. Emergence of adults in April has occurred from unusually heavy late winter and early spring rains that have caused late egg hatches with rapid larval development. Adults usually fly to areas away from their breeding sites, using ravines and natural or man made waterways from the marshes to the local hills as passageways. From these passageways the adults spread laterally into the wind protected areas of the surrounding community (Freeborn 1926). It is believed that at these protected sites adults mate and and seek blood meals (Telford 1958). Gray (1936) noted that this mosquito flew the longest distance of any California mosquito from its larval source. Aarons (1954) noted that adults were found in Saratoga, some 10 miles from the nearest known larval source. Other workers have found that adults of this mosquito are capable of traversing distances of more than 15 miles from any possible larval site (Aarons, et. al. 1951, Krimgold and Herms 1934, Lowe 1932, Stover 1931, Stover 1926). Biting activity begins in April and usually ends by early June. Rabbit baited traps in the east bay have collected adults from 16 March to 28 June (Garcia et al. 1983). Adults are known to be aggressive day and early dusk biting mosquitoes. This species along with the Summer Salt Marsh Mosquito, *Aedes dorsalis*, were the first mosquitoes to become the primary focus of organized mosquito control efforts in California. The first mosquito control campaigns were undertaken at San Rafael in 1903 and also at Burlingame in 1904. The earliest written record of what is believed to be the attacks of *Aedes squamiger* and *Aedes dorsalis* on humans was in a diary entry of Father Juan Crespi in April of 1772 (Bolton 1927). In his diary he describes the vicious attacks of mosquitoes that sorely afflicted his party while traveling along the eastern side of San Francisco Bay. Aarons, et al. (1951) states that there is reason to believe that the salt marsh mosquitoes made certain times of the year almost unbearable for the early Indians.

Females oviposit in those parts of the marshes that are not under water. Eggs are laid on plants and along the muddy margins of ponds close to the water line. Most of the eggs are located in these higher areas of the marshes and will therefore not hatch without a combination of tides and rainfall. For diked marshes, at least a few inches of rainfall must occur to inundate the eggs and stimulate hatching. Maffei (unpub.) has found that the runoff of as little as one inch of rainfall from city streets into marshes used as flood control basins can flood a marsh sufficiently to hatch eggs and produce larvae. Females that oviposit in late spring will deposit eggs in the lower portions of the marshes and it is these eggs that hatch first with tidal activity only or ponding of early rain water runoff.

Reproduction

Observations on mating swarms have shown that *Aedes squamiger* tends to swarm approximately one hour before to one-half hour after sunset (Garcia et. al. 1992). Swarms can consist of a few to several thousand individuals that hover over prominent objects such as trees or large bushes and can occur at heights ranging from six to approximately 50 feet (Bohart and Washino 1978, Garcia et. al. 1992). Garcia et al. (1992, 1983) found that adults traveled back and forth to the marshes quite readily producing a new batch of eggs with each trip. He also found that the highest parous condition observed was seven, with average parity rates ranging between 3 and 5.4. Garcia, et al. (1992) found a direct correlation between wing length and the number of eggs produced with larger females producing more eggs. The maximum number of eggs produced per female was less than 250. Garcia, et al. (1990) also found that temperature played an important role in longevity, ovarian development and oviposition. Females held at 15°C were still alive 50 days after their last blood meal and average longevity was about 35 days when kept at 20°C. The minimum temperature threshold for ovarian development or oviposition was found to be about 15°C.

Significance to Other Wetlands Taxa

Aedes squamiger larvae are frequently found in association with larvae of the Summer Salt Marsh Mosquito, *Aedes dorsalis*, and the Winter Marsh Mosquito, *Culiseta inornata*. The adults of these mosquitoes may be a possible food source for swallows and the larvae may be a food source for waterfowl.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be taken when altering or restoring seasonal or tidal wetlands. Sites that drain poorly will create habitat that can readily produce very large numbers of aggressive biting adults. Plans for long term maintenance of seasonal and tidal wetlands should include resources for mosquito control as the need arises. The dynamic nature of these types of habitats coupled with human activities can easily convert a non-breeding site into a major mosquito producing source.

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Washino's Mosquito

Aedes washinoi Lansaro and Eldridge

Wesley A. Maffei

Description and Systematic Position

Aedes washinoi was described as a new taxon by Lanzaro and Eldridge in 1992 and was determined to be a sibling species of *Aedes clivis* and *Aedes increpitus*. Prior to 1992, all three species of mosquitoes were known as *Aedes increpitus*. Adults of this mosquito are almost impossible to separate from its sibling species, when using morphological features, and can also sometimes be confused with *Aedes squamiger*. The easiest way to distinguish *Ae. squamiger* and *Ae. washinoi* is to examine the wing scales. *Aedes squamiger* has very broad, flat, plate-like scales on the wings whereas *Ae. washinoi* will have the usual thin, pointed wing scales. The wings of *Ae. washinoi* will also tend to be uniformly dark with a concentration of pale scales on the anterior wing veins. In all other respects, both *Ae. squamiger* and *Ae. washinoi* share a similar black and white speckled appearance. The larvae of this mosquito can be difficult to separate but Darsie (1995) has provided additions to Darsie and Wards 1981 keys to facilitate identification.

Distribution

This mosquito is found from Portland, Oregon south to Santa Barbara, California and eastward into the lower Sierra Nevada mountains. Populations of this mosquito have also been found along the eastern Sierra Nevada Range at Honey Lake.

Suitable Habitat

Within the San Francisco Estuary the preferred habitat is shallow ground pools and upland fresh to slightly brackish water sites that are next to salt marshes or in riparian corridors. These habitats also tend to be dominated by willow or cotton wood trees and/or black berry vines.

Biology

Larvae usually hatch during early winter after a series of successive storm events has filled ground depressions with water. Additional hatches of larvae can occur if late winter and early spring rains refill drying larval sites. Larvae of this mosquito also exhibit a late fourth instar diapause and partial synchronous adult emergence similar to that observed in *Aedes squamiger*. Adults emerge during late winter and early spring and can persist through early June, depending on weather conditions.

Females are aggressive day biting mosquitoes that tend not to travel far from their larval sources. Maffei (unpub.) found that adult mosquitoes traveled a maximum distance of one and one-half miles from their larval habitat and that local, man made canals were used as a passageway into the surrounding community.

Eggs are deposited in the muddy margins adjacent to the receding water line of the larval habitat and hatch the following winter when reflooded.

Reproduction

Adults have been observed swarming under or near the tree canopy of their larval habitat (Garcia, et al. 1992).

Significance to Other Wetlands Taxa

Unknown.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be taken when altering or restoring seasonal wetlands or riparian corridors. Sites that have shallow ground pools and willow or cotton wood trees or blackberry vines will create habitat that can readily produce very large numbers of aggressive biting adults. The restoration of historical willow groves should not occur if homes are within two miles of the project site.

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Western Encephalitis Mosquito

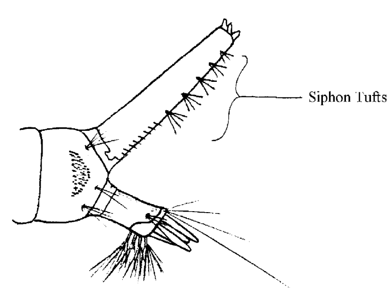
Culex tarsalis Coquillett

Wesley A. Maffei

Description and Systematic Position

The western encephalitis mosquito is a medium sized mosquito measuring approximately 5-6 mm in length. This fly was described in 1896 as a new taxon by Coquillett from specimens gathered in the Argus Mountains of Inyo County, California (Belkin et al. 1966).

Adults can be identified by using the following morphological features: legs with bands of pale scales overlapping the tarsal joints; femur and tibia of the hind legs with a pale stripe or row of pale spots on the outer surface; proboscis with a complete median pale band; ventral abdominal segments with v-shaped patches of darkened scales; and the inner surface of the basal antennal segment with patches of pale scales. The larvae can be recognized by the four to five pairs of ventrally located siphon tufts that are nearly in line with each other (**Figure 3.16**) and the 3-branched lateral abdominal hairs found on segments III to VI.



Wes Maffei

Figure 3.16 Terminal Abdominal Segment of *C. tarsalis larva*

Distribution

This mosquito has been found in central, western and southwestern United States, southwestern Canada and northwestern Mexico (Carpenter and LaCasse 1955, Darsie and Ward 1981). Within California, this fly has been found in every county from elevations below sea level to almost 10,000 feet (Bohart and Washino 1978, Meyer and Durso 1993).

Suitable Habitat

The immature stages are found in all types of fresh water habitats except treeholes. Poorly drained pastures, rice fields, seepages, marshes and duck club ponds are especially favored as breeding habitat for this mosquito. Telford (1958) found larvae in salt marsh pools with salinities up to 10 ‰. Urban sources include poorly maintained swimming pools, ornamental ponds, storm drains, flood control canals, ditches, waste water ponds and most man made containers (Beadle and Harmston 1958, Bohart and Washino 1978, Harmston et al. 1956, Meyer and Durso 1993, Sjogren 1968).

Adults rest by day in shaded or darkened areas such as mammal burrows, tree holes, hollow logs, under bridges, in caves, in eves and entry ways of residences, brush piles and in dense vegetation (Mortenson 1953, Loomis and Green 1955, Harwood and Halfill 1960, Price et al. 1960, Rykman and Arakawa 1952).

Biology

Adult females of this species usually feed at night. Precipitin tests indicate a wide variety of hosts consisting of various birds and mammals with an occasional reptile or amphibian (Anderson et al. 1967, Edman and Downe 1964, Gunstream et al. 1971, Hayes et al. 1973, Reeves and Hammon 1944, Rush and Tempelis 1967, Shemanchuk et al. 1963, Tempelis 1975, Tempelis et al. 1967, Tempelis et al. 1965, Tempelis and Washino 1967). Reeves (1971) states that host availability and season are probably the most important considerations in the adult host feeding pattern. The availability of nesting birds during spring and early summer may account for the preponderance of identified, early season, avian blood meals. With the progression of the summer season, availability and behaviour of bird hosts varies and a switch to mammal hosts occurs (Hammon et al. 1945, Hayes et al. 1973, Reeves and Hammon 1944, Reeves et al. 1963, Tempelis et al. 1967, Tempelis and Washino 1967). Adults pass the winter months in facultative diapause which is triggered by short day length and low ambient temperatures. In the warmer parts of southern California adults are active year round while in San Francisco Bay populations inactivity usually occurs from December through February. Additional periods of low temperatures or unseasonably warm winters can vary the time spent in diapause.

Flight range studies indicate that this mosquito will readily disperse from its larval source. Reeves et al. (1948) found that adults generally dispersed two miles or less, although prevailing winds helped to distribute marked females up to three miles. Bailey et al. (1965) studied the dispersal patterns of Yolo County, California populations and found that prevailing winds were important to adult dispersal with significant numbers of adults having traveled seven miles within two nights. The maximum distance traveled was recorded at 15.75 miles. From their studies they concluded that the likely dispersal distance of Sacramento Valley populations was probably about 20-25 miles. It was further concluded that most locally controlled mosquito sources are repeatedly reinfested during the summer because these mosquitoes travel so readily with the wind.

The larval stages feed on a wide variety of microorganisms, unicellular algae and microscopic particulate matter. The amount of time required to complete development from egg to adult varies depending on water temperature, availability of food and crowding. Bailey and Gieke (1968) found that water temperatures of 69°F to 86°F were optimal for larval development. Beyond 86°F, the larval stage lasted about eight days but mortality was very high. Mead and Conner (1987) found the average developmental rates from egg to adult to be 18.7 days at 67°F and 7.4 days at 88°F.

Reproduction

Male mating swarms occur shortly before to just after sunset. Harwood (1964) found that initiation of the mating swarm was related to changes in the light intensity and that light levels of approximately 7 foot candles would initiate crepuscular flight activity. He further found that lab colonized males could be induced to swarm when abrupt changes in light intensity occurred.

Lewis and Christenson (1970) studied female ovipositional behaviour and found that the initial search for oviposition sites by females occurs close to the lowest available surface. Groups of eggs, also known as egg rafts, are deposited directly onto the water with the average number of eggs per raft varying between 143 to 438 (Bock and Milby 1981, Buth et al. 1990, Reisen et al. 1984). Environmental factors such as water temperature, crowding and availability of food have been found to affect development of the immature stages, which in turn, affects the size of the female mosquito and ultimately the number of eggs and egg rafts produced. Logan and Harwood (1965) studied the effects of photoperiod on ovipositional behaviour of a Washington strain of *Culex tarsalis* and found that peak oviposition occurred within the first hour of darkness and light.

Autogeny, or the development of eggs without a blood meal, does occur with this mosquito. Moore (1963) found that autogenous *Culex tarsalis*, from Sacramento Valley, California, produced an average of 116 eggs per female with an observed maximum of 220. He also found that the level of autogeny decreased from spring to summer. Spadoni et al. (1974) also studied autogeny in *Culex tarsalis* populations from the same region finding similar results and detecting autogeny as early as April. They further found that no autogenous egg development was observed in overwintering females from November through February and that the mean number of eggs produced per autogenous female was 144.

Significance to Other Wetlands Taxa

This mosquito is the primary vector of Western Equine Encephalitis (WEE) and Saint Louis Encephalitis (SLE) viruses for most of the western United States (Brown and Work 1973, Longshore et al. 1960, Reeves and Hammon 1962, Work et al. 1974). Rosen and Reeves (1954) have also determined that this fly is an important vector of avian malaria.

Larvae of the Winter Marsh Mosquito, *Culiseta inornata*, are frequently found with the immature stages of this mosquito during fall and spring. The larvae of this insect may be a possible food source for waterfowl.

Conservation Needs and Limiting Factors

Sound water management practices should include consultations with local public health and mosquito or vector control agencies to prevent or at least minimize the production of this mosquito from managed, restored or newly created wetlands. Adequate resources need to be provided in all short and long term management plans to help protect humans and horses from the encephalitis viruses that can be vectored by this mosquito.

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Winter Marsh Mosquito

Culiseta inornata (Williston)

Wesley A. Maffei

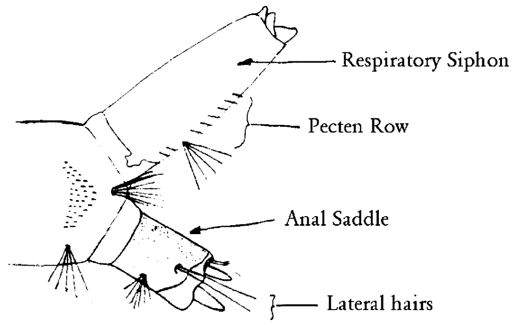

Figure 3.18 Terminal Abdominal Segment of a Fourth Instar Larva

Description and Systematic Position

The winter marsh mosquito was described from specimens collected in the Argus Mountains, Inyo County, California, in 1893 (Belkin, et al 1966). This insect is one of California's largest mosquitoes, measuring approximately 8-10 mm in length. Adults are generally light brown to reddish-brown in color and lack any unusual or distinctive markings. Diagnostic features of the imagines include: tip of the abdomen bluntly rounded; wings with the radial and medial cross veins nearly in line with each other; anterior wing veins with intermixed light and dark scales; and wings without distinct patches of dark scales (**Figure 3.17**). Larvae can be identified by the presence of only one tuft of hairs inserted near the base of the pecten row on the siphon and by having the lateral hairs of the anal saddle distinctly longer than the anal saddle (**Figure 3.18**).

Distribution

This mosquito can be found throughout the United States, southern Canada and northern Mexico over a wide range of elevations and habitats (Carpenter and LaCasse 1955). Populations of the winter marsh mosquito have been found throughout California except in Mariposa County (Meyer and Durso 1993).

Suitable Habitat

The immature stages can be found in a wide variety of habitats ranging from duck club ponds, ditches, seepages, rainwater pools, salt marshes and manmade containers. Telford (1958) found larvae in Marin County marshes with salinities ranging from 8 ‰ to 26 ‰.

Adults are usually found resting near their larval habitats during their breeding season while summer aestivating adults are presumed to utilize animal burrows in upper marshes and adjacent uplands (Barnard and Mulla 1977, Shemanchuk 1965).

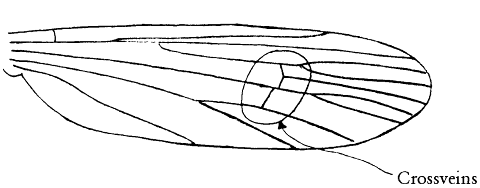

Figure 3.17 Wing of an Adult *Cs. inornata*

Biology

Adults are present fall, winter and spring and enter facultative diapuase in the summer as a means of surviving the hot, dry California summers. Aestivating females are thought to emerge from mammalian burrows and shelters in the fall following decreased temperatures and the first fall rains. Meyer, et al. (1982a, 1982b) found that optimal flight activity occurred between temperatures of 48°F and 64°F, with a sharp decrease below 43°F and above 64°F. Washino, et al. (1962) studied populations of this mosquito in Kern County, California and found that small numbers of adult females persisted throughout the summer period.

Adult female mosquitoes feed primarily on large domestic mammals although populations associated with brackish marshes have been significantly pestiferous to humans within the San Francisco Estuary (Bohart and Washino 1978; Maffei, unpub.). Precipitin tests have shown that the primary hosts are cattle, sheep, horses and pigs (Bohart and Washino 1978, Edman and Downe 1964, Edman et al. 1972, Gunstream et al. 1971, Reeves and Hammon 1944, Shemanchuk et al. 1963, Tempelis 1975, Tempelis et al. 1967, Tempelis and Washino 1967, and Washino et al. 1962).

Flight range studies have found that the maximum distance traveled was 14 miles (Clarke 1943). Adults of San Francisco Bay populations tend to stay close to their larval source, usually traveling less than two miles for a blood meal. Wind and proximity of available hosts are probably important factors affecting adult dispersal and may help account for the variability observed between different populations of this mosquito.

Adults can be attracted to lights. Bay area mosquito abatement Districts monitor adult populations of this mosquito by using New Jersey light traps. Barnard and Mulla (1977) found that the trapping efficiency of New Jersey light traps could be improved by incresing the intensity of the incandescent light bulbs used from 25W to 100W.

Studies of lab colonized females by Owen (1942) found that the average life expectancy for adults was about 97 days with a maximum of 145 days. Weather conditions, specifically temperature and humidity, and availability of nutrients will affect adult longevity.

Total developmental time from egg to adult has been studied by Shelton (1973) and Mead and Conner (1987) and both found that water temperatures above 78°F were lethal to larval development. Average developmental times ranged from 48 days at 51°F to 13 days at 74°F. Shelton (1973) also noted that as water temperature increased beyond 68°F, average body weight and adult survivorship decreased markedly.

Reproduction

Rees and Onishi (1951) found that adults usually do not swarm and that freshly emerged females are mated by waiting males. Copulation usually occurs end to end vertically, with the female above the male, and is completed in about 3.5 to 6.5 hours.

Groups of eggs, also known as egg rafts, are deposited directly on the water. Buxton and Breland (1952) studied the effects of temporary dessication and found that eggs were still viable after three to four days exposure in damp leaves at various temperatures. They also found that the eggs tolerated exposure to temperatures as low as 17.6°F and had a hatch rate as high as 98%. The survival of larvae hatched from eggs exposed at 17.6°F was low varying from 50% to 100% mortality following 24 and 48 hours exposure respectively.

Significance to Other Wetlands Taxa

Winter Marsh Mosquito larvae are frequently found in association with larvae of *Aedes squamiger* and the Encephalitis Mosquito, *Culex tarsalis*. The larvae of this mosquito may be a possible food source for waterfowl.

Conservation Needs and Limiting Factors

This mosquito, like other species of mosquitoes, is extremely opportunistic. Care must be exercised when managing, altering or restoring seasonal wetlands. Sites that pond water will produce very large numbers of adults. Care must be exercised when manipulating water levels in diked marshes. The fall flooding of these types of wetlands for waterfowl management can produce enormous numbers of adults. The proximity of human habitation or recreational facilities can be seriously affected by the biting activity of these mosquitoes.

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Brine Flies

Diptera: Ephydridae

Wesley A. Maffei

Description and Systematic Position

There are numerous species of brine flies (Diptera: Ephydridae) that can be found within the confines of the San Francisco Bay region. Three are exceptionally numerous within the bay's tidal and diked seasonal wetlands. These are: *Ephydra cinerea, Ephydra millbrae* (**Figure 3.19**), and *Lipochaeta slossonae* (**Figure 3.20**). Adults can readily be recognized by the following features: head—lacking oral vibrissae, having a swollen protruding face, and having small diverging postvertical setae; wings -with the costa broken near the subcosta and humeral crossvein, and lacking an anal cell.

Adult flies are small in size (*E. cinerea* 2-3 mm in length, *E. millbrae* 4-5 mm in length, and *L. slossonae* 2-3 mm in length) and have unpatterned wings. The coloration for each is as follows: *E. cinerea*—opaque bluish-grey with a greenish tinge and legs with knees and most tarsal segments yellow; *E. millbrae*- brownish grey with brown legs; and *L. slossonae*—whitish grey with a black-brown thoracic dorsum and legs having yellow tarsal segments.

The immature stages are small yellowish-white larvae bearing eight pairs of ventral prolegs with two or three rows of hooks. The last pair of prolegs are enlarged and have opposable hooks and the last abdominal segment bears elongate respiratory tubes with terminal spiracles. The puparium is similar in shape to the last larval stage and is generally dark yellow to brown in color (**Figure 3.21**).

Distribution

Ephydra millbrae is found throughout the San Francisco Bay Area in mid to upper marsh tidal pools that are infrequently affected by the tides. *E. cinerea*

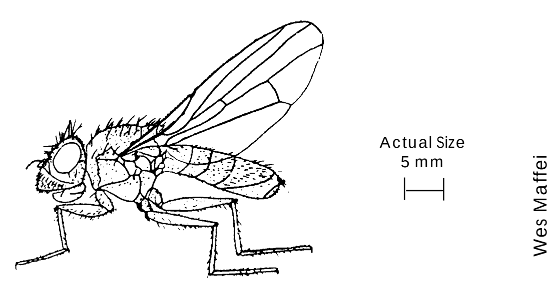

Figure 3.19 Adult *Ephydra millbrae* (Adapted from Jones (1906) and Usinger (1956))

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Appendix E. State of Oregon West Nile Virus Summary Report 2012

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State of Oregon
West Nile Virus Summary Report
2012

3/11/13

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2012 Program Highlights

Some of the principal findings and accomplishments of Oregon's surveillance, education, and planning programs for West Nile virus (WNV) in 2012 include the following:

- Continued statewide surveillance of mosquitoes, humans, birds, sentinel chickens, and horses.
- 12 human cases of WNV reported.
- No cases of WNV positive birds.

Figure 1. Number of positive WNV tests, Oregon, 2012.

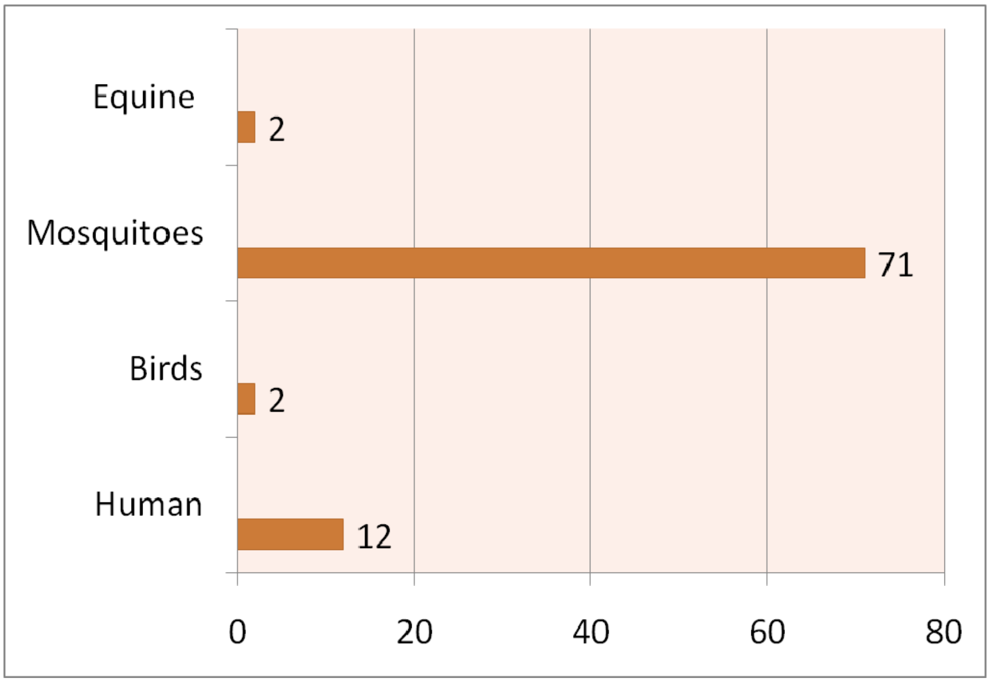


Table 1. Confirmed WNV infections in Oregon, 2004–2012.

Group	2004	2005	2006	2007	2008	2009	2010	2011	2012
Human	5	8	73	27	16	12	0	0	12
Horses	32	46	35	16	0	5	0	2	2
Birds	23	15	25	52	2	16	0	0	2
Mosquito Pools	0	11	22	28	16	262	4	3	71
Sentinel Chickens	0	15	0	11	0	0	0	0	0

Introduction

Oregon's surveillance program for WNV was launched in 2001. West Nile Virus (WNV) first appeared in Oregon in 2004 when the first human, avian, and equine WNV cases were diagnosed.

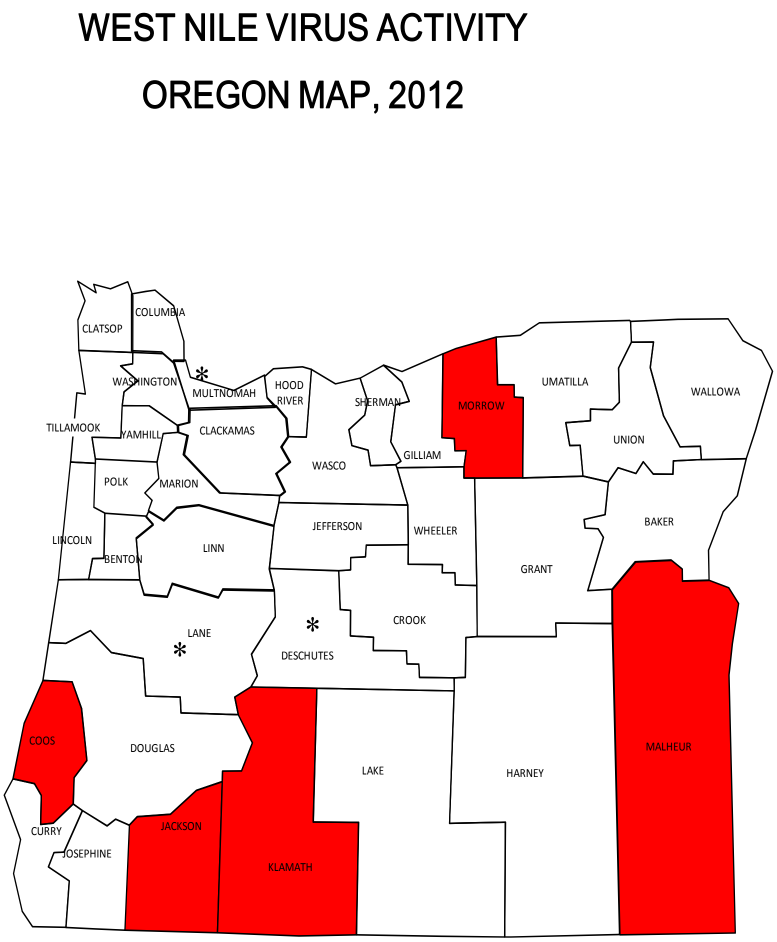
In 2012, 12 Oregonians, 2 birds, 2 horses and 71 mosquito pools were diagnosed with WNV.

Twelve Vector Control Districts (VCDs) and one county health department perform mosquito surveillance in Oregon (Figure 4). One sentinel chicken surveillance flock is located in Jackson County (southern Oregon).

The VCDs collect mosquitoes and dead birds, identify them, and prepare them for testing. Some VCDs conduct initial WNV tests for mosquito pools and dead birds using RAMP (Rapid Analyte Measurement Platform). In counties without VCDs, this work may be conducted by the local health department or the Oregon Department of Fish and Wildlife (ODFW). Confirmatory testing of WNV for humans is performed by the Oregon State Public Health Laboratory (OSPHL). Oregon State University's (OSU's) Veterinary Diagnostic Laboratory performs WNV testing of mosquitoes, dead birds, horses, and other mammals.

The Oregon WNV surveillance findings for humans, horses, birds, and mosquitoes in 2012 are summarized in the sections that follow.

Figure 2. Map of Oregon with shaded counties reporting WNV, 2012.



County	Human	Chicken	Birds/Raptor	Horses	Mosquitoes
Coos	1	0	0	0	0
Deschutes	1*	0	0	0	0
Jackson	0	0	1	0	1
Klamath	0	0	0	2	0
Lane	1*	0	0	0	0
Malheur	8	0	1	0	68
Morrow	0	0	0	0	2
Multnomah	1*	0	0	0	0
Total	**12**	**0**	**2**	**2**	**71**

* Human infections acquired out-of-state

Updated: November 1, 2012

WNV Surveillance and Related Activities

Human Surveillance

In 2012, 12 Oregon residents tested positive for WNV by IgM antibody.

Table 2. Trend data for Oregon residents who contracted WNV in Oregon, 2004–2012

Year	All Cases	Neuroinvasive	Deaths
2004	5	0	0
2005	8	1	0
2006	73	13	1
2007	27	7	1
2008	15	3	0
2009	8	0	0
2010	0	0	0
2011	0	0	0
2012	12	1	0

Veterinary Surveillance

Surveillance for WNV in Oregon's equine population resulted in 2 positive tests while 14 other equine tests were negative for WNV. Positive test results for Oregon counties in 2012 are summarized in Table 3. No other mammals tested positive for WNV in 2012.

Table 3. Positive Equine WNV test results, Oregon 2012.

County	Number of Positive Test Results
Klamath	2
Total	**2**

Avian Surveillance

Surveillance for WNV in Oregon's avian population resulted in two positive test results out of 35 birds tested by OSU's Veterinary Diagnostic Laboratory and the VCDs. Of the 35 birds that were collected, 20 were of the family Corvidae (a.k.a. corvids) while the remaining 15 were American species other than corvid. Table 4 shows the avian species collection totals in Oregon by county for 2012. Trend data for avian WNV testing and positive test results for Oregon counties for the years 2004–2012 are presented in Table 5.

Table 4. Avian WNV test results for Oregon Counties, 2012.

Avian Species Collection Totals by County			
County	**Total Corvid Tested**	**Total Other Species Tested**	**Total Positives**
Baker	0	1	0
Benton	1	9	0
Clatsop	1	0	0
Harney	1	1	0
Jackson	2	0	1
Klamath	0	1	0
Lake	0	1	0
Lane	4	0	0
Malheur	1	0	1
Morrow	1	0	0
Multnomah	8	1	0
Umatilla	1	0	0
Union	0	1	0
TOTAL	20	15	2

Table 5. Avian WNV tests and trend of positive test results for Oregon counties, 2004–2012.

Year	Number Tested	Number Positive	% Positive
2004	448	23	5%
2005	298	15	5%
2006	212	25	12%
2007	246	55	22%
2008	117	2	2%
2009	90	16	18%
2010	24	0	0%
2011	20	0	0%
2012	35	2	6%

Sentinel Chicken Surveillance

The only sentinel chicken flock for 2012 was located in Jackson County. None of the sentinel chickens were diagnosed with WNV in 2012. Additionally, United States Department of Agriculture collected blood samples from chickens showed at several county fairs including Jefferson, Crook, Wasco and Deschutes counties. None of the samples tested positive for WNV.

Mosquito Surveillance

In 2012, the VCDs conducted surveillance for WNV in Oregon's mosquito population. Figure 3 indicates the efficiency of vector transmission for various mosquito species (information obtained from the Centers for Disease Control and Prevention). Figure 4 (page 12) shows the counties with participating VCDs and their activities. Statewide, 179,754 individual female mosquitoes were collected and tested for WNV. The mosquitoes submitted represent 14 mosquito species. PCR testing for WNV was conducted by OSPHL and RAMP was performed by some VCDs. Table 6 displays the number of mosquito pools per species that tested positive for WNV in Oregon in 2012 only. Table 7 displays the mosquito species and the number of individual female mosquitoes that VCDs collected for testing in Oregon in 2012. Table 8 displays the mosquito species in Oregon between 2004 through 2012 found positive for WNV.

Table 6. WNV Positive Mosquito Pools, Oregon 2012.

VCD	Mosquito Species	Number of Positive Mosquito Pools	Collection Date
Jackson	*Culex tarsalis*	1	8/10
Malheur	*Culex tarsalis*	1	7/26
Malheur	*Culex pipiens*	52	7/26 – 9/7
Malheur	*Culex* sp.	15	7/12 - 8/31
Morrow	*Culex tarsalis*	1	8/15
Morrow	*Culex pipiens*	1	8/15

Table 7. Female mosquitoes collected for testing by Oregon VCDs, 2012.

County	*Aedes cinereus*	*Aedes dorsalis*	*Aedes increpitus*	*Aedes sticticus*	*Aedes vexans*	*Anopheles freeborni*	*Anopheles punctipennis*	*Coquillettidia perturbans*	*Culex erythrothorax*	*Culex pipiens*	*Culex sp.*	*Culex tarsalis*	*Culiseta inornata*	*Other Species/Unkown*	
Baker	0	0	0	0	0	0	61	0	0	0	0	4,569	11	0	
Clackamas	0	0	0	6	8	52	100	4	0	1,445	0	65	1	449	
Columbia	0	0	2	927	378	0	720	968	0	3,645	0	519	3	19	
Crook	0	0	0	0	0	125	0	0	0	0	0	911	40	88	
Deschutes	0	0	0	0	22,129	348	0	0	0	80	0	260	428	929	
Jackson	0	6	6,055	34	4,393	527	878	5,562	20,479	3,446	106	6,616	223	916	
Klamath	0	0	0	0	966	1,104	0	0	0	86	50	4,266	2,004	1,905	
Lane	0	0	0	0	1,089	0	0	0	0	618	0	381	0	42	
Malheur	0	0	0	0	0	0	0	0	0	32	563	2,786	0	301	
Morrow	0	23	522	0	1,387	1,159	20	43	0	8,778	0	8,599	1,391	0	
Multnomah	21	0	697	3,980	9,802	34	906	211	0	4,760	9	4,860	215	868	
Umatilla	0	0	0	0	0	0	0	0	0	8,055	262	2,621	0	11	
Union	0	0	0	0	0	0	0	0	0	1,548	0	1,548	0	0	
Washington	2	0	0	0	3,661	28	540	39	0	2,859	694	1,118	13	3,746	
Total	23	29	7,276	4,947	43,813	3,377	3,225	6,827	20,479	35,352	1,684	39,119	4,329	9,274	total 179,754

Table 8. Trend data, WNV Positive Mosquito Pools, Oregon 2004–2012.

Year	Mosquito Species	Number of Positives
2004	-	-
2005	*Culex tarsalis* *Culex stigmatosoma* *Culex pipiens*	11 pools*
2006	*Culex tarsalis*	22 pools
2007	*Aedes vexans* *Culex pipiens* *Culex tarsalis*	8 pools 2 pools 23 pools
2008	*Aedes vexans* *Culex pipiens* *Culex tarsalis*	5 pools 3 pools 8 pools
2009	*Aedes vexans* *Anopheles freeborni* *Anopheles punctipennis* *Coquillettidia perturbans* *Culex pipiens* *Culex tarsalis* *Culex* sp.	1 pool 1 pool 1 pool 1 pool 75 pools 131 pools 52 pools
2010	*Culex pipiens* *Culex tarsalis* Culex sp.	1 pool 2 pools 1 pool
2011	*Culex* sp.	3 pools
2012	*Culex pipiens* *Culex tarsalis* *Culex* sp.	53 pools 3 pools 15 pools

*1 pool ≈ 50 mosquitoes

Figure 3. Potential Oregon vectors of WNV based on laboratory vector competence studies.[1] ***Posted with permission.***

Table 3. Potential for selected North American mosquitoes to transmit WNV based on bionomics, vector competence, virus isolations, and involvement with other arboviruses

Species	Association with other viruses[a]	Host preference	Activity time	Flight range	Vector competence for WNV[b]	Field isolations of WNV[c]	Potential to serve as a	
							Enzootic vector[d]	Bridge vector[e]
Ae. aegypti		Mammals	Crepuscular/day	200 m	+++, 3	+	0	+
Ae. albopictus	EEE	Opportunistic	Crepuscular/day	200 m	++++, 3, 6	+	+	++++
Ae. vexans	EEE, WEE, SLE	Mammals	Crepuscular/night	>25 km	++ 1, 5, 8	+++	0	++
Cq. perturbans	EEE	Opportunistic	Crepuscular/night	5 km	+, 4	+	+	+
Cs. melanura	EEE	Birds	Crepuscular/night	9 km	+, 8	++	++	0
Cs. inornata	WEE	Mammals	Crepuscular/night	2 km	+++, 5	+	+	++
Cx. stigmatosoma	SLE	Birds	Night	1 km	+++, 5	0	+++	+
Cx. erythrothorax	WEE	Opportunistic	Crepuscular/day	<2 km	++++, 5	0	++	+++
Cx. nigripalpus	EEE, SLE	Opportunistic[f]	Crepuscular	5 km	++, 4	+++	+++	++
Cx. pipiens	SLE	Birds	Crepuscular/night	2 km	+++, 1, 3, 5	++++	+++++	++
Cx quinquefasciatus	SLE	Birds	Crepuscular/night	2 km	+++, 4, 5	0	++++	++
Cx. restuans	SLE	Birds	Crepuscular/night	2 km	++++, 4	+++	+++++	++
Cx. salinarius	EEE, SLE	Opportunistic	Crepuscular/night	10 km	++++, 4	+++	+++	++++
Cx. tarsalis	WEE, SLE	Opportunistic[f]	Crepuscular/night	>6 km	++++, 5, 7	++++	++++	+++
Oc. atropalpus		Mammals	Day and night	1 km	++++, 3	+	+	++
Oc. canadensis	EEE	Mammals	Day	2 km	++, 8	+	0	++
Oc. cantator	EEE	Mammals	Day	>10 km	++, 8	+	0	++
Oc. dorsalis	WEE	Mammals	Day and night	5 km	+++, 5	+	0	++
Oc. japonicus	JE?	Mammals	Crepuscular/day	unk	++++, 2, 3	+++	+	++++
Oc. melanimon	WEE	Mammals	Day and night	>10 km	+++, 5	0	0	++
Oc. sierrensis		Mammals	Crepuscular/day	1 km	+, 5	0	0	+
Oc. sollicitans	EEE	Mammals	Crepuscular/night	>25 km	++, 1, 3	+	0	+
Oc. taeniorhynchus	EEE	Mammals	Day and night	>25 km	+, 1, 3	+	0	+
Oc. triseriatus		Mammals	Day	200 m	+++, 8	++	0	+++
Ps. ferox	SLE	Mammals	Day	2 km	0, 8	+	0	0

Distribution and bionomics based on and generalized from information in Carpenter and LaCasse (1955), Darsie and Ward (1981), and Moore et al. (1993).

[a] Known association with other viruses with a similar transmission cycle. EEE, eastern equine encephalomyelitis virus; JE; Japanese encephalitis virus; SLE; St. Louis encephalitis virus; WEE; western equine encephalomyelitis virus. Based on Karabatsos (1985).

[b] Efficiency with which this species is able to transmit WNV in the laboratory. 0, incompetent; +, inefficient; ++++, extremely efficient vector. Based on 1 (Turell et al. 2000), 2 (Sardelis and Turell 2001), 3 (Turell et al. 2001), 4 (Sardelis et al. 2001), 5 (Goddard et al. 2002), 6 (Sardelis et al. 2002), 7 (Turell et al. 2003), or 8 (present study).

[c] Relative number of WNV-positive pools detected. 0, none; +, few; ++++, many.

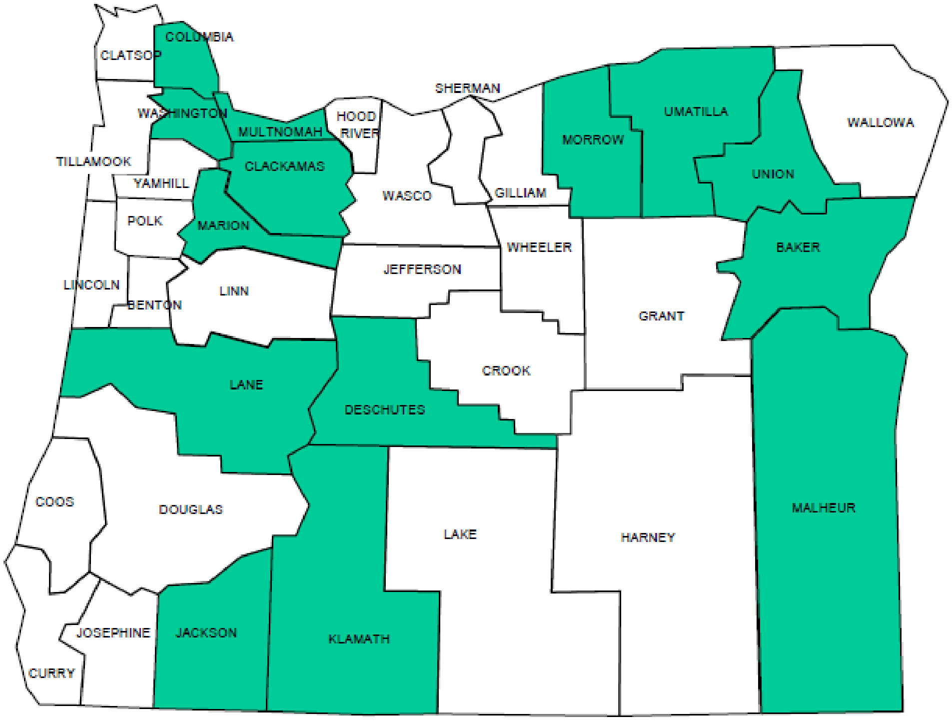
[d] Potential for this species to be an enzootic or maintenance vector based on virus isolations from the field, vector competence, feeding behavior, etc. 0, little to no risk; +++++, this species may play a major role.

[e] Potential for this species to be an epizootic or bridge vector based on virus isolations from the field, vector competence, feeding behavior, etc. 0, little to no risk; +++++, this species may play a major role.

[f] Feeds primarily on avian hosts in spring and early summer and mixed between avian and mammalian hosts in late summer and fall.

Vector Control Districts

Figure 4. Oregon counties with participating vector control districts (VCDs) and their activities.



District/county	Mosquito collection	Mosquito fish	Sentinel Chickens	Bird collection	Larvaciding	Adulticiding
Columbia	*			*	*	*
Deschutes	*			*	*	*
Jackson	*			*	*	*
Klamath	*	*		*		*
Lane	*			*		
Malheur				*		
Marion	*			*	*	*
Morrow	*			*	*	*
Multnomah	*	*		*	*	*
Umatilla	*	*		*	*	*
Union	*	*		*	*	*
Washington	*	*		*	*	*

References

1. Turell, MD, et al. "An Update on the Potential of North American Mosquitoes (*Diptera: Culicidae*) to Transmit West Nile Virus. J. Med. Entomol. 42(1): 57-62 (2005).

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