Audubon WASHINGTON

November 1, 2017

Washington State Department of Ecology
Water Quality Program
ATTN: Derek Rockett
derek.rockett@ecy.wa.gov
Southwest Regional Office
PO Box 47775
Olympia, WA 98504

RE: Draft Supplemental Environmental Impact Statement – Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington

Dear Mr. Rockett,

This letter concerns the draft *Supplemental Impact Statement for Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington* (SEIS)[1] and associated *Final Environmental Impact Statement Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington* (FEIS; Washington State Department of Ecology; April 9, 2015).[2] These materials are associated with the application by the Willapa-Grays Harbor Oyster Growers Association (WGHOGA) to the Washington State Department of Ecology (Ecology) for a permit under the National Pollutant Discharge Eliminations System (NPDES) for Willapa Bay and Grays Harbor, and Sediment Impact Zone (SIZ) authorizations for Willapa Bay and Grays Harbor. The applicants are requesting authorization to use the neonicotinoid pesticide imidacloprid to treat up to 500 acres annually of commercial shellfish beds: 485 acres in Willapa Bay and 15 acres in Grays Harbor to control native burrowing shrimp (ghost shrimp, *Neotrypaea californiensis* and mud shrimp, *Upogebia pugettensis*).

Audubon Washington is an organization dedicated to the protection of birds and their habitats. We have 25 active chapters here in Washington, representing over 34,000 members. We also have three science and nature centers located in Seattle, Sequim and Tacoma that serve over 35,000 people each year.

Audubon appreciates the long-time presence of the oyster industry in Southwest Washington, its role in providing jobs and revenue to the region, and the industry's production of seafood and contributions to environmental quality. We recognize the challenges that burrowing shrimp pose to the industry in Southwest Washington, and in particular to the family farms of Pacific and Grays Harbor counties. Considerable investment has occurred by growers large and small to limit these native shrimp whose natural burrowing behavior results in siltation and sediment changes that are harmful to oyster production.

Audubon has worked to understand the impacts of chemical pesticide use and the ecological role of burrowing shrimp in coastal estuaries since 2014. We have significant concerns about the use of chemicals to control burrowing shrimp in and around oyster operations, especially in the absence of a greater understanding of the conditions and factors that influence burrowing shrimp distribution and populations. **Audubon especially has strong reservations about this specific pesticide, imidacloprid, which is demonstrably harmful to aquatic invertebrates as well as to birds. As such, WE SUPPORT ADOPTION OF ALTERNATIVE 1, THE NO ACTION ALTERNATIVE.**

Recognizing that the applicants are faced with reduced oyster production while alternative approaches are explored, Audubon encourages consideration of a three-year permit constituting a phase-out period, after which further imidacloprid use will not be considered. As presented here, however, Audubon can only support the "no action" alternative. If a phase-out permitting pathway is possible, it would be critically important to immediately convene and implement a parallel process to bring scientific and technical expertise to the task of transitioning growers to culture methods that can withstand cyclic ghost shrimp population changes and to develop a research program to address key information gaps pertaining to ecosystem-based management in Willapa Bay and Grays Harbor.

Audubon's priorities are to encourage lasting solutions that will help the industry end its long-standing reliance on pesticides and create conditions amenable to ecologically sustainable and economically rewarding shellfish aquaculture. Audubon looks to the considerable scientific, technological and natural resource management expertise in the Pacific Northwest to invest in assessing, understanding and fairly resolving the complex set of issues facing Willapa Bay and Grays Harbor shellfish growers and other coastal stakeholders. We are actively working to secure financial and technical resources to help understand the root causes of ghost shrimp proliferation in shellfish beds and shed light on the ecological role of burrowing shrimp in coastal estuaries. We are eager to work together with shellfish growers and other coastal stakeholders who share an interest in healthy coastal estuaries.

In the sections below we highlight our primary areas of concern regarding the proposed use of pesticides in Willapa Bay and Grays Harbor, including:

- The lack of ecosystem perspective in addressing the role of burrowing shrimp in coastal estuary systems and appropriateness of a long-term chemical control program in the intertidal environment;
- insufficient evaluation of exposure pathways, both on and off-plot, to birds and other non-target species and direct and indirect effects associated with pesticide exposure and foraging habitat degradation;
- the need for a greater level of scientific rigor in field studies associated with burrowing shrimp management and control in Willapa Bay and Grays Harbor.

1.0 Ecosystem considerations

Citing MacGinitie (1934), Horning et al. (1989) note that the ghost shrimp "is one of the most abundant residents of marine sloughs or bay mudflats on the west coast of North America," and go on to conclude that "the ghost and blue mud shrimp appear to be integral part of the nearshore environments."[3] They are commonly found in intertidal areas from southeastern Alaska to Baja Mexico, and are known to occur at high densities in estuaries from Northern California to British Columbia, Canada.[4]

Burrowing shrimp have been described as ecosystem engineers because of how their burrowing activity affects nutrient and carbon fluxes and alters benthic communities. Numerous peer reviewed studies suggest that permeable sediments, such as those formed by inhabitation by ghost shrimp, enhance removal of nitrogenous nutrients and reduce coastal turbidity, thereby improving overall water quality and re-establish healthier intertidal benthic environments.[5,6,7] Burrowing shrimp also exert considerable influence on intertidal food webs; an unpublished estimate of *Neotrypaea* (ghost) shrimp biomass in Willapa Bay in 2006 was close to 20,000 tons (B. Dumbauld, unpublished data). Accordingly, mud and ghost shrimp may represent the largest single contributor to estuary secondary production (i.e., food for consumer organisms) in west coast estuaries.

Ghost shrimp are prey for large-bodied shorebirds like long-billed curlews and marbled godwits, and red knots may forage in association with shrimp burrows (See Appendix A). Burrowing shrimp are also prey for other species in the marine and estuarine ecosystem, particularly fish. ESA-listed green sturgeon, salmonids, Pacific staghorn sculpin, Dungeness crabs, sea-run cutthroat trout, and leopard sharks are all known to prey on them.[3] A recent study of green sturgeon foraging dynamics in Willapa Bay found that feeding pit density was strongly associated with high densities of ghost shrimp, an important prey item for sturgeon during the summer months.[8] Finally, recreational fishermen use burrowing shrimp as bait and in Washington, Oregon and California they sometimes are harvested commercially for this purpose.

Existing evidence suggests that cyclic changes in shrimp densities over time are to be expected. The SEIS (2-31) states that ghost shrimp recruitment spiked during 2010-2016, following a time of very low recruitment from the mid-1990's to the early 2000's. Unpublished data from Willapa Bay and Yaquina Bay, OR indicate that large fluctuations in ghost and mud shrimp density and recruitment have occurred since the late 1980's when data collection began (B. Dumbauld, unpublished data). Large fluctuations in density and recruitment are also corroborated by earlier accounts of dramatic changes in shrimp densities.[9] Today, mud shrimp are purportedly close to extirpation in Washington and California due to an introduced parasitic isopod that limits reproduction.

The recent uptick in ghost shrimp recruitment and the concurrent decline of mud shrimp have largely been considered through the lens of shellfish aquaculture. There is a pressing need to advance an objective, ecosystem-based evaluation of ghost and mud shrimp population dynamics in relation to both coastal ocean conditions and conditions within Willapa Bay and Grays Harbor. Although significant resources have been expended exploring control methods for burrowing shrimp, much less research and management attention has been given to investigating the role of burrowing shrimp in healthy functioning coastal estuaries. Because of this narrow focus, coastal stakeholders lack the information that would allow them to assess the ghost shrimp/aquaculture conflict from a broader perspective. For example:

- What are the root causes of the apparent burrowing shrimp irruption in Willapa Bay and Grays Harbor? When viewed in the context of past population fluctuations in these estuaries, is there evidence that current densities or spatial extent of occurrence are unusually high?
- Are the current densities of ghost shrimp populations in Willapa Bay and Grays Harbor anomalous compared to other west coast estuaries?
- How does avian and fish use of the estuary differ among shellfish beds, shrimp beds, and other habitat areas? What are the population-level consequences of a decades-long burrowing shrimp control program in Willapa Bay for ESA-listed species like green sturgeon?
- Do ghost shrimp reach high densities in certain sediment types in ways that are predicable? Are there possible alternative culture techniques that could be pursued in these areas during times of high recruitment?
- What are the factors associated with native mud shrimp persistence in remaining population strongholds in Oregon?

2.0 Imidacloprid exposure pathways and potential non-target impacts

In Audubon Washington's December 8, 2014 comments on the draft EIS on Control of Burrowing Shrimp using imidacloprid, we raised a number of general concerns about the potential effects of imidacloprid use on non-target organisms, Grays Harbor and Willapa Bay ecosystems, and about uncertainties surrounding the persistence of imidacloprid in the estuarine environment. In subsequent communications with the Department we have provided specific references and recommendations regarding these concerns, some of which we are pleased to see have been incorporated into the SEIS. Some of these concerns and recommendations are still relevant, however, and are included below.

According to the product label for the granular form of imidacloprid (0.5G), the product “is highly toxic to aquatic invertebrates” Label instructions for use in and around water read as follows: “Do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment wash.” The Environmental Protection Agency (EPA) made a notable exception to these guidelines when it granted permission to Washington state shellfish growers to use imidacloprid in intertidal mudflats. In addition, the EPA failed to fulfill their responsibility under the Endangered Species Act, which requires consultation with the US Fish and Wildlife Service regarding potential listed species impacts.

Given the EPA’s failure to consider potential listed species impacts in granting this unique exception, and with few peer-reviewed studies in the marine environment to draw from, we urge Ecology to note the toxicity of imidacloprid acknowledged in its labeling and adopt a precautionary approach in assessing and managing the use of imidacloprid in Willapa Bay and Grays Harbor. This approach is described here in a 1998 consensus statement:

> …when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.[10]

The four main tenets of this precautionary approach are: 1) take preventive action in the face of uncertainty; 2) shift the burden of proof to the proponents of an activity; 3) explore a wide range of alternatives to possibly harmful actions; and 4) increase public participation in decision making.

2.1 *Persistence of imidacloprid in surface water*. The SEIS (citing CSI 2013) states that laboratory studies of the half-life of imidacloprid at a pH range of 5 – 7 can be greater than one year, while the half-life of imidacloprid at pH 9 is approximately one year (3-11). These studies likely underestimate the half-life of imidacloprid in natural aquatic systems. Main et al. (2014) documented high concentrations of neonicotinoids, including imidacloprid, in wetlands one year after treatment.[11] These wetlands were slightly alkaline, with a pH range (~8.0) similar to that of sea water. Also, contrary to the assumption of rapid photolysis, neonicotinoid concentrations in aquatic systems were not higher in wetlands with surficial plant cover or greater depth, both of which should reduce photolysis relative to shallow, clear wetlands.[12] Though rapid photolysis of imidacloprid occurs in ideal laboratory conditions, in natural environments, such as Willapa Bay and Grays Harbor, such factors as turbidity and low temperatures can lead to prolonged persistence, with measurable and ecotoxicologically relevant concentrations up to a year post-treatment.[13,14,15] Given the low temperatures, turbidity, and depth of the water, as well as frequent cloud cover in the Willapa Bay and Grays Harbor coastal environment, imidacloprid and its degradation products are likely to persist for up to a year and possibility longer in surface waters.

It is possible that imidacloprid and its degradation products are widely dispersed within Willapa Bay and adjacent coastal waters. This raises the possibility that impacts may occur over a much larger area than the site of application and in ecosystem types that differ from shallow, intertidal oyster beds, none of which are addressed in the SEIS. Potential on-plot impacts to surface waters are discounted because of the expectation that the pesticide would be diluted by incoming tides. However, the cumulative effects of repeated applications to Willapa Bay and the accumulation of imidacloprid in sediments and surface water must be evaluated. Additionally, the potential for dispersion over broad coastal areas increases the possible transport pathways by which imidacloprid and its degradation products could be transported to land ecosystems (and land-based pollinators).

2.2 *Imidacloprid solubility and distribution in sediments*. The SEIS provides reference to field and laboratory studies that indicate that imidacloprid persists longer in sediments that have high levels of organic carbon.[16] Long-term studies assessing imidacloprid persistence in different sediment types are not available, but it's possible that repeated pesticide application could lead to increasing concentrations and cumulative effects in places like the southern portion of the Bay where high amounts of organic carbon exist and tidal exchange is low. Field data on long-term pesticide persistence in a range of hydrologic and sediment conditions are needed.

2.3 *Impacts to non-target organisms*. The SEIS acknowledges that scientific studies to date, including comprehensive reviews by Health Canada[17] and the EPA[18] point to the high toxicity of imidacloprid to freshwater invertebrates, the wide range of toxicity documented for other organisms, and the potential for sub-lethal and indirect effects to animals. Under the preferred alternative (Alternative 4), the SEIS concludes that impacts to non-target organisms, including zooplankton, benthic invertebrates, forage fish and groundfish, birds, pollinators, and threatened and endangered species, would either not occur due to high toxicity thresholds (e.g., fish) or be short-term and localized to treated beds and areas immediately adjacent. The SEIS also acknowledges a high degree of variability and uncertainty regarding the persistence of imidacloprid in the sediment, the extent of potential off-plot and cumulative impacts, and toxicity thresholds for marine invertebrates. The natural variability inherent in the estuarine environment, wide range of biologically relevant toxicity levels to living organisms, and unknown cumulative impacts of intertidal pesticide use all point to a troubling lack of certainty regarding short and long-term impacts to non-target organisms.

2.3.1 *Epibenthic organisms*. The SEIS concludes that impacts to zooplankton and benthic invertebrates are expected to be short term because field studies indicate that benthic invertebrate populations recover within 14 to 28 days following treatment (3-28). The SEIS also acknowledges that invertebrate recovery may be slower in sediments with higher levels of organic carbon. It's important that the public understand how the department of Ecology defines "recovery". Using the Puget Sound Marine Criterion for Sediment Management Standards as a foundation, Ecology previously developed desired endpoints related to the abundance and taxonomic richness of crustaceans, polychaetes, and mollusks. For a treated site to be considered recovered, and thus meet the conditions of the NPDES permit and SIZ authorization, endpoints for these values in a treated site must be at least 50% of the endpoint value in a control or reference site.[2] By this standard, a treated site can be considered "recovered", despite a 50% difference in biotic richness and abundance. It's also notable that the variability in the benthic invertebrate 2014 field trials was high, resulting in low statistical power to detect differences between treated plots and reference sites. In short, we are left with a recovery criterion that is insufficiently protective of benthic life and impractical to apply given the variability in the system.

Zooplankton and ichthyoplankton are vital food sources for fish, including juvenile coho and Chinook salmon.[19] Decapods, including the burrowing shrimp, have much higher tolerances, by 1-2 orders of magnitude, to neonicotinoids, including imidacloprid, than do other crustaceans that contribute to the marine zooplankton and benthic invertebrate faunas, including isopods, amphipods, mysids, and podocopida.[15] Therefore, if imidacloprid is used at concentrations sufficient to kill burrowing shrimp, it is likely to have detrimental effects on the more sensitive marine zooplankton and benthic invertebrates. Together, these organisms constitute a critical food base for marine birds, including shorebirds, waterfowl, and seabirds.

2.3.2 *Pollinators and other insects*. Survival of bees depends on the functioning of complex behaviors within the colony in addition to the survival of individual bees. There is rich, scientific literature reporting that the sensitivity of colony function to pesticides is often orders of magnitude greater (i.e., at lower concentrations) than levels associated with traditional measures of individual survival (i.e., LD-50). For example, Urlacher et al. (2016) reports severe impacts on appetitive olfactory memories at concentrations of chlorpyrifos several orders of magnitude below reported LD-50s.[20] Numerous references in this recent publication point to similar impacts by neonicotinoids in general and imidacloprid specifically.

The proposed rate of application of 0.5 lb/acre is equivalent to 560 g/ha, which is more than 50 times over the lowest “maximum application rate” investigated by the European Food Safety Authority, which was found to produce a HQ value of 123, over double the trigger value indicating high risk to bees.[21] Moreover the U.S. Environmental Protection Agency’s (EPA 2016) new imidacloprid risk assessment for bees identifies a risk level of 25 ppb (0.025 mg/kg), over 100 times lower than the proposed application concentration of 3.34 mg/kg.[22] Imidacloprid is highly toxic to bees at very low concentrations, with an LD50 contact of 0.081 µg/bee and an LD50 oral of 0.0037 µg/bee.[23] Consequently, applications at the rates proposed here are likely to be acutely toxic to any bees that come into contact with the insecticide. As honeybees regularly forage several kilometers from their nest, bees in colonies 0.5 miles from the shellfish beds are well within foraging range and may be exposed to imidacloprid, which is frequently transported by wind, soil water or waterways (up to 95% of active ingredients on treated seeds[24]) and could be taken up by nearby plants.

2.3.3 *Fish*. Though imidacloprid’s direct toxicity to fish is limited, it has been shown to have sub-lethal effects on fish at environmentally relevant concentrations, including physiological stress, damage to DNA, and reduced growth rates.[25,26] Toxicity to ichthyoplankton should be addressed.

2.3.4 *Birds*. The SEIS concludes that on-plot impacts to birds are expected to be minor due to the expected short-term reductions in prey species, limited pathways for direct consumption, limited toxicity to birds and the relatively small amount of the Bay/Harbor that would be subject to impacts.

Imidacloprid is toxic to birds in acute doses with concentrations as low as 13.9 mg/kg.[15] Furthermore, sub-lethal (chronic) effects on reproduction (testicular anomalies and reduced embryo length) and genetic material (increased breakage of DNA) have been observed in Japanese Quail at concentrations as low as 1 mg/kg, one-third of the proposed application levels.[27] House Sparrows experience loss of coordination and inability to fly at concentrations as low as 6 mg/kg.[28] Indeed, Gibbons et al. (2015) reports the results of numerous studies showing direct harm to birds.[26] The Gibbons study also cites one instance where young robins appear to have been poisoned by grubs emerging from a lawn treatment.

The SEIS minimizes the likelihood of shorebirds consuming granular insecticides or pesticide-laden prey. Shorebirds often quickly return to foraging sites immediately after human disturbance has ceased. Hence, shorebirds could easily come into contact with and consume insecticide granules that remain along the shoreline or in shallow waters prior to hydrolysis. Birds often consume small pebbles and it is not unusual for seeds to be recorded among the gut contents of feeding shorebirds,[29] so it is not unreasonable to assume that they could consume these clay and insecticide pellets. In addition, anecdotal references in the SEIS and other imidacloprid field study reports describe direct consumption of imidacloprid-laden prey by birds. Supplemental information on the avifauna of Willapa Bay and Grays Harbor and their foraging dynamics is included in Appendix A.

The SEIS has focused overwhelmingly on direct acute toxicity (i.e., mortality) to birds (3-24 – 3-25). The possibility for sub-lethal and chronic effects is mentioned in the final paragraph on potential impacts to birds, but never fully addressed. Even if pesticides don’t directly and immediately kill birds, they can have population-level effects by reducing survival and reproductive success. For species like the red knot, which has a significant proportion of its Pacific population stopping over in Willapa Bay and Grays Harbor during spring migration,[30] this could have population-level effects.

2.3.5 *Mammals.* Though imidacloprid's direct toxicity to mammals is low, as with fish and birds, sub-lethal effects to reproduction, immune response, growth, and plasma biochemistry occur at concentrations as low as 0.21-5 mg/kg in a variety of mammal species including cows, mice, and rats (numerous studies reviewed in Gibbons et al. 2015).[26]

2.3.6 *Indirect effects.* The SEIS review of potential effects on threatened, endangered and protected species focuses on direct toxicity, ignoring the sub-lethal and chronic effects discussed above. Indeed, salmonids may come into direct contact with imidacloprid, including potential consumption, during application. Similarly, the proposed application rate produces concentrations over three times that known to cause detrimental sub-lethal effects to birds, as cited above. Birds such as the federally threatened/state endangered Pacific coast population of snowy plovers could face reproductive, genetic, and physiological harm if they consume imidacloprid, particularly in the granular form.

3.0 Issues and recommendations related to 2014 experimental trials for imidacloprid use in Willapa Bay

We noted a number of issues upon review of the 2014 experimental field trials that compromise the validity of the results. These issues fall into four categories:

- Sampling design and statistical issues
- Timing of sampling
- Metrics assessed
- Adherence to sampling framework

Should additional monitoring be conducted, we raise the following concerns and recommendations for consideration.

3.1 *Sampling design and statistical issues*

- The use of three or more treatment sites for different measures complicates interpretation of the results. It was not clear why the Cedar River site was not used as the treatment site for all measures.
- The size of the control sites was not described.
- The lack of pre-treatment sediment samples from the treatment sites, and post-treatment samples from a control site, make comparisons problematic.
- T-tests are highly sensitive to violations of assumptions, such as that the data are normally distributed and that the variances of the two groups (treatment and control) are similar (aka homogeneity of variances). Data such as these (particularly invertebrate abundance) rarely meet these assumptions and, therefore, t-tests are recommended only if used following a transformation that produces data that meet all assumptions. T-tests also fail to account for the fact that samples that are physically close to one another are more likely to have similar values (i.e., lack of independence).
- As it stands, given the violation of assumptions (independence, homogeneity, and normality) and the sensitivity of t-tests to these violations, the results of these statistical analyses are not reliable. Although the authors used alternative techniques when their data violated one of the assumptions (normality), there is no discussion of methods to evaluate or account for violations of the other,

equally-important assumptions. Moreover non-parametric tests are conservative and thus less likely to detect differences between control and treatment sites.

***Recommendation*:** This experimental design is perfectly suited for a Before-After-Control-Impact (BACI) analysis, which would also account for potential pre-treatment differences between treatment and control site measures. Moreover random effects should be incorporated to account for the lack of independence among survey points. A BACI analysis in a general linear mixed modeling framework would resolve these issues, and would present results of a single, coherent analysis, avoiding the complex and confusing pathways used.

3.2 *Timing of sampling*

- It is problematic that the first invertebrate samples did not occur until two weeks post-treatment. Samples should have been conducted within one to two days to document immediate population-level effects. Such a delay likely minimizes the apparent effects of imidacloprid by allowing time for immigration of invertebrates to the site.

***Recommendations*:**
- We highly recommend conducting the first invertebrate sampling within one to two days of treatment.
- Due to the temporal variability in invertebrate abundance and richness, sampling frequency should also be increased to account for stochastic variation. A power analysis may be appropriate to determine what level of sampling is required to detect change.

3.3 Metrics sampled

- Biomass is an ecologically-relevant measure of invertebrate availability to predators such as shorebirds. This is especially relevant given that imidacloprid has been shown in studies to reduce growth rates in many organisms (see comments above).

***Recommendations*:** We recommend any future invertebrate studies include measurements of biomass and that thresholds for this metric are developed for under a new Sediment Impact Zone authorization if Alternative 4 is approved.

3.4 Adherence to sampling framework

Presumably, the sampling framework developed in collaboration between Ecology and industry representatives represents a compromise between the ideal study design and the realities of field work in a tidal system. However, the 2014 Field Study report and Ecology's own review of the field report indicates problematic deviations from the sampling framework that may bias the results.

***Recommendations*:**
- A process in which deviations from the sampling framework are communicated and approved by Ecology during the field season would be preferable to the current practice of after-the-fact reporting. In reviewing proposed deviations from the proposed sampling scheme, Ecology would need to consider whether the deviations would compromise the scientific validity of the results.
- The lead field investigator for the imidacloprid field trials is widely perceived to hold a bias towards the use of pesticides. To repair public trust in the Ecology permitting process, we recommend that a small peer-review panel of technical experts is convened to review and evaluate any further

imidacloprid field testing scenarios. Panel members should be entirely independent of Ecology or the industry, but could include appropriately qualified individuals from other agencies, academic institutions, unrelated industries, etc.

Summary and recommendations

Despite the importance of Willapa Bay and Grays Harbor for migratory birds and fish, shellfish production, and other natural resource economies, Washington State has invested very little in the rigorous scientific assessment, management and stewardship of these vital places. The consequences of over half a century of pesticide use on nutrient and carbon fluxes, food web dynamics, intertidal sediments, vegetation, and secondary consumers, including shorebirds and waterfowl in Willapa Bay and Grays Harbor are almost entirely unknown. Coastal stakeholders lack information on ecosystem condition, species status, distribution and population dynamics, ecological relationships and management alternatives that are necessary to understand and make informed decisions about burrowing shrimp management.

The SEIS incorporates a number of new studies and describes a considerable range of potential direct and indirect impacts to living organisms that may result under Alternative 4, the preferred alternative. The best available science tells us that at a minimum, imidacloprid use will have immediate effects on the benthic invertebrate and zooplankton communities within the treated plots, with drastic reductions in invertebrate prey for consumers. “Recovery” of these biotic communities after treatment is set at an unacceptably low level; when treated areas have at least half the benthic invertebrate abundance and richness as untreated reference areas. There is considerable uncertainty regarding how long and to what extent imidacloprid will persist in the different types of sediment and hydrological conditions found throughout the Bay and Harbor, whether or not benthic communities are actually recovered at the 50% criteria, the nature of sub-lethal effects on bird and fish populations, and the potential indirect effects on birds and fish through degradation of foraging habitat.

Our priorities are to encourage lasting solutions that will help the industry end its long-standing reliance on pesticides and create conditions amenable to ecologically and economically sustainable shellfish aquaculture. Audubon looks to the considerable scientific, technological and natural resource management expertise in the Pacific Northwest to invest in assessing, understanding and fairly resolving the complex set of issues facing Willapa Bay and Grays Harbor shellfish growers and other coastal stakeholders. We are actively working to secure financial and technical resources to help understand the root causes of the apparent ghost shrimp proliferation in shellfish beds and shed light on the ecological role of burrowing shrimp in coastal estuaries. We are eager to work together with shellfish growers and other coastal stakeholders who share an interest in healthy coastal estuaries.

Thank you for considering our issues and concerns. Please don’t hesitate to contact us with any questions or concerns.

Sincerely,

Trina Bayard, Ph.D.
Director of Bird Conservation

Sam Merrill, Conservation Chair
Black Hills Audubon Society

Diane Bachen, President
Kitsap Audubon Society

Judy Hallisey, President
Kittitas Audubon Society

Jim Castle, President
Lower Columbia Basin Audubon Society

Pam Borso, President
North Cascades Audubon Society

Bob Phreaner, President
Olympic Peninsula Audubon Society

Cindy Easterson, President
Pilchuck Audubon Society

Heather Gibson, President
Rainier Audubon Society

John Brosnan, Executive Director
Seattle Audubon Society

Timothy Manns,
Conservation Chair
Skagit Audubon Society

Tom Light, President
Spokane Audubon Society

Julie Burman, President
Vashon-Maury Island Audubon Society

Sharon Gauthier, President
Whidbey Audubon Society

Larry Brandt, President
Willapa Hills Audubon Society

Appendix A: Avifauna of Willapa Bay and Grays Harbor

Willapa Bay and Grays Harbor are sites of regional and hemispheric importance for shorebirds and waterfowl, supporting ten Important Bird Areas (IBAs) and two Western Hemisphere Shorebird Reserve Network sites; one of hemispheric importance at Grays Harbor and one of international importance at Willapa Bay. As the fourth largest estuary on the U.S. West Coast, Grays Harbor supports a diverse array of birds and marine wildlife, including exceptional numbers of migratory shorebirds and waterfowl. Willapa Bay is one of ten major flyway stopover points on the West Coast, and is a vital wintering area for waterfowl and shorebirds and the last remaining breeding area for Western Snowy Plovers in Washington State.

1.1 Shorebird conservation status. Grays Harbor and Willapa Bay support around two dozen species of shorebirds (WHSRN.org). Of these, 19 species regularly occur (e.g., Dunlin), and for some species (e.g., Western Sandpipers) large proportions of their populations use the two estuaries.[31] Eleven species are considered species of national conservation concern[32] and all but two species are considered of moderate to high regional concern (Table 1): The Red Knot is a species of high conservation concern nationally, and virtually the entire Pacific population (*Calidris canutus roselaari*) stops in Willapa Bay or Grays Harbor during migration.[30] These estuaries are also highly important for Marbled Godwits, some of which are from the small Alaska Peninsula breeding population, ca. 2000 individuals. These godwits are recognized as a unique subspecies (*Limosa fedoa beringiae*) and migrate through or overwinter at the two estuaries.[33] Finally, Long-billed Curlew, which prey on burrowing shrimp, presently are found in relatively small numbers in Willapa Bay, though historical use of the estuary is unknown.

1.2 *Habitat use.* Shorebird use of estuarine habitats varies throughout the year in response to the underlying substrate and associated prey availability, tide status, weather, and behavioral interactions with predators and competitors. Some species defend feeding territories in the non-breeding season (e.g., plovers) while most others feed in flocks.[34] Shorebirds do not feed across all intertidal habitats, rather they aggregate in patches according to prey availability.[35] Prey availability in turn, is driven by physical factors such as sediment grain size, tidal action and salinity. Sediment plays a fundamental role in supporting aquatic food webs; sediment grain size influences the distribution of benthic fauna and vegetation, which in turn influences foraging opportunities for shorebirds, as well as salmon and other fish. Not surprisingly, fish and birds are known to cue in on different sediment sizes while foraging. For example, Dunlin favor substrates with higher mud content[36] and Chinook salmon favor sand flats.[37]

The tidally-driven and seasonal nature of shorebird distributions makes delineating and prioritizing discrete habitat areas for conservation or protection a challenge. In their 2014 study, Frazier et al. found that shorebird use of intertidal habitats in an Oregon estuary is greatest as the tide approaches and recedes and that areas of low marsh, including *Zostera japonica* beds, *Neotrypaea*/sand dominated tideflats, and *Upogebia*/mud dominated tideflats, had comparable densities of birds, whereas *Zostera marina* beds had significantly lower shorebird densities.[38] No comparable study has been conducted at Willapa Bay or Grays Harbor, though Buchanan observed Red Knots foraging for bivalves in a variety of habitat types, ranging from the mudflat-saltmarsh interface to open mudflats more than 150 m from shore.[39]

1.3 *Diet and foraging preferences.* Shorebirds are opportunists in their food habits, and their preferred prey vary by location, year, season, and substrate. Documented intertidal prey include amphipods, cumaceans, bivalves (especially *Macoma* sp.), insects and polychaetes. Nevertheless, species-specific bill morphology and foraging behaviors are adapted to specific prey types, which can constrain foraging choices.[40] Small species, such as Western Sandpipers, take a wide variety of invertebrate prey (e.g., Senner et al. 1989[41]), while the much larger Red Knots are specialists on bivalves, such as *Macoma balthica*. Recent studies have also documented the importance of biofilm, a diatom-dominated microorganism community that forms on the surface of intertidal flats as a food source for some *Calidris* species, such as Dunlin and Western Sandpipers.[42] Larger bodied species such as Long-billed Curlews are known to eat large prey, including ghost shrimp.[43] In fact, it has been proposed that this species' long, decurved beak has evolved specifically to prey on ghost shrimp. Marbled godwits also prey on ghost shrimp.[44] In addition, Red Knots have been observed to prey on the spat of bivalves which have a commensal relationship with ghost shrimp and their burrows.[39]

Table 1. Conservation status of shorebird species regularly occurring in Willapa Bay and Grays Harbor.[31] ESA – listed under the U.S. Endangered Species Act; IM – requires immediate conservation action, meets criteria for the Birds of Conservation Concern (BCC); MA – needs management attention, meets BCC criteria; WL – meets Watch List 2014 criteria as a global species, USA/Canada population, or a taxa below these levels; N. Pacific – regional scores from the N. Pacific Shorebird Plan[3]. Category codes: 5 = Highly imperiled, including species listed as threatened or endangered; 4 = High concern; 3 = Moderate concern; 2 = Low concern; 1 = No risk; WA ESA – listed under Washington State Endangered Species Act; SGCN – Washington Department of Fish and Wildlife Species of Greatest Conservation Need.[45]

Common name	**Scientific name**	**Conservation Status**						
		ESA	**IM**	**MA**	**WL**	**N. Pacific**	**WA ESA**	**WA SGCN**
Black-bellied Plover	*Pluvialis squatarola*					4		
Snowy Plover	*Charadrius nivosus*	X			X	5	X	
Semipalmated Plover	*Charadrius semipalmatus*					3		
Black Oystercatcher	*Haematopus bachmani*				X	4		X
Greater Yellowlegs	*Tringa melanoleuca*					4		
Lesser Yellowlegs	*Tringa flavipes*			X		2		
Whimbrel	*Numenius phaeopus*		X		X	4		
Long-billed Curlew	*Numenius americanus*			X	X	2		
Marbled Godwit	*Limosa fedoa*			X	X	4		X
Ruddy Turnstone	*Arenaria interpres*					4		
Black Turnstone	*Arenaria melancephala*				X	4		
Red Knot	*Calidris canutus*		X		X	4		X
Surfbird	*Calidris virgata*					4		
Sanderling	*Calidris alba*			X		4		
Dunlin	*Calidris alpina*				X	4		
Least Sandpiper	*Calidris minutilla*					3		
Western Sandpiper	*Calidris mauri*					4		
Short-billed Dowitcher	*Linmodromus griseus*				X	4		
Long-billed Dowitcher	*Limnodromus scolopaceus*					3		

References Cited

[1] GeoEngineers 2017. Supplemental Environmental Impact Statement for Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, WA. – Draft. Prepared for WA Dept. Ecology. Pub. No. 17-10-027.
[2] Hart Crowser 2015. Final Environmental Impact Statement for Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, WA. Prepared for WA Dept. Ecology. Pub. No. 15-10-013.
[3] Hornig, S., A. Sterling, and S.D. Smith. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) – ghost shrimp and mud shrimp. U.S. Fish and Willidfe Service Biology Rep. 82(11.93). U.S. Army Corps of Engineers, TREL-82-4. 14 pp.
[4] DeWitt, T.H., A.F. D'Andrea, C.A. Brown, B.D. Griffen, and P.M. Eldridge. 2004. Impact of burrowing shrimp populations on nitrogen cycling and water quality in western North American temperate estuaries. In Symposium on "Ecology of large bioturbators in tidal flats and shallow sublittoral sediments-from individual behavior to their role as 628 ecosystem engineers", ed. A. Tamaki, 107-118. Nagasaki, Japan: Nagasaki University.
[5] Boudreau et al. 2001. EOS. Vol. 82: No.11. p. 133-140.
[6] D'Andrea, A.F. and T.H. DeWitt. 2009. Geochemical ecosystem engineering by the mud shrimp *Upogebia pugettensis* (Crustacea: Thalassinaidae) in Yaquina Bay, Oregon: Density-dependent effects on organic matter remineralization and nutrient cycling. Limnology and Oceanography 54: 1911-1932.
[7] Laverock, B., et al. 2011. Bioturbation: impact on the marine nitrogen cycle. Biochemical Society Transactions 39:315-320.
[8] Borin, J.M., Moser, M.L., Hansen, A.G. et al. 2017. Energetic requirements of green sturgeon (*Acipenser medirostris*) feeding on burrowing shrimp (*Neotrypaea californiensis*) in estuaries: importance of temperature, reproductive investment, and residence time. Environmental Biology of Fishes. Pp 1-13.
[9] Bird, E.M., 1982. Population dynamics of thalassinidean shrimps and community effects through sediment modification. Ph.D. dissertation, University of Maryland, College Park, Maryland, 150 p., unpublished.
[10] Raffensperger C, Tickner J, eds. Protecting Public Health and the Environment: Implementing the Precautionary Principle. Washington, DC, Island Press, 1999
[11] Main, A., et al. 2014. Widespread use and frequent detection of neonicotinoid insecticides in wetlands of Canada's Prairie Pothole Region. PLoS ONE 9(3):e9821.
[12] Main, A., et al. 2015. Ecological and landscape effects on neonicotinoid insecticide presence and concentration in Canada's Prairie wetlands. Environmental Science & Technology 49:8367-8376.
[13] Guzsvany, V., J. Csanádi, F. Gaal. 2006. NMR study of the influence of pH on the persistence of some neonicotinoids in water. Acta Chimica Slovenica 53:52–57.
[14] Kanrar, B., et al. 2006. Degradation dynamics and persistence of imidacloprid in a rice ecosystem under west Bengal climatic conditions. Bulletin of Environmental Contamination and Toxicology 77:631–637.
[15] Morrissey, C.A., P. Mineau, J.H. Devries, F. Sanchez-Bayo, M. Liess, M.C. Cavallaro, K. Liber. 2015. Neonicotinoid contamination of global surface waters and associated risk to aquatic invertebrates: a review. Environment International 74:291-303.
[16] Grue, C.E. and J.M. Grassley. 2013. Environmental fate and persistence of imidacloprid following experimental applications to control burrowing shrimp in Willipa Bay, Washington. Washington Cooperative Fish and Wildlife Research Unit, University of Washington. Seattle, WA 91 pp.
[17] Health Canada. 2016. Proposed re-evaluation decision, imidacloprid. Document PRVD2016-20. Health Canada Pest Management Regulatory Agency. Ottawa, ON. Canada.
[18] U.S. Environmental Protection Agency (USEPA). 2017. Preliminary aquatic risk assessment to support the registration review of imidacloprid. PC Code 129099. DP Barcode 429937. USEPA, Office of Chemical Safety and Pollution Prevention, Washington D.C. Prepared by USEPA Office of Pesticide Programs, Environmental Fate and Effects Division, Washington D.C.

[19] Daly, E. A., Auth, T. D., Brodeur, R. D., and W. T. Peterson. 2013. Winter ichthyoplankton biomass as a predictor of early summer prey fields and survival of juvenile salmon in the northern California Current. Marine Ecology Progress Series 484: 203-217.
[20] Ulracher, E. et al. 2016. Measurements of chlorpyrifos levels in forage bees and comparison with levels that disrupt honey bee odor-mediated learning under laboratory conditions. J. Chemical Ecology 42:127-138.
[21] European Food Safety Authority, 2015. The 2013 European Union report on pesticide residues in food. EFSA Journal 2015 13(3):4038, 169 pp. doi:10.2903/j.efsa.2015.4038.
[22] http://www.epa.gov/pesticides/epa-releases-first-four-preliminary-risk-assessments-insecticides-potentially-harmful
[23] EFSA (European Food Safety Authority). 2013. Conclusion on the peer review of the pesticide risk assessment for bees of the active substance imidacloprid. EFSA Scientific Report 1(1):3068.
[24] Goulson, D. 2014. Ecology: p*esticides linked to bird declines.* Nature 511: p. 295-296.
[25] Hayasaka, D. et al. 2012. Cumulative ecological impacts of two successive annual treatments of imidacloprid and fipronil on aquatic communities of paddy mesocosms. Ecotoxicology and Environmental Safety 80:355–362
[26] Gibbons, D., C. Morrissey, P. Mineau. 2015. A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. Environmental Science and Pollution Research 22:103-118.
[27] Tokumoto, J., et al. 2013. Effects of exposure to clothianidin on the reproductive system of male quails. Journal of Veterinary Medical Science 75:755–760,
[28] Cox, C. 2001. Insecticide factsheet: imidacloprid. Journal of Pesticide Reform 21:15-21.
[29] Senner, S.E. 1977. The ecology of western sandpipers and dunlins during spring migration through the Copper-Bering River Delta system, Alaska. M.Sc. thesis, University of Alaska, Fairbanks, AK. 108 pp.
[30] Buchanan, J. B., J. E. Lyons, L. J. Salzer, R. Carmona, N. Arce, G. J. Wiles, K. Brady, G.E. Hayes, S. M. Desimone, G. Schirato, and W. Michaelis. 2012. Among-year site fidelity of red knots during migration in Washington. Journal Field Ornithology 83:282-289.
[31] Drut, M.S., and Buchanan, J.B. 2000. U.S. national shorebird conservation plan: Northern Pacific Coast Working Group regional management plan. Unpublished report submitted to Manomet Center for Conservation Sciences, Manomet, MA.
[32] U.S. Shorebird Conservation Plan Partnership. 2015. U.S. Shorebirds of Conservation Concern – 2015. Available at: http://www.shorebirdplan.org/science/assessment-conservation-status-shorebirds
[33] Gibson, D.D. and B.Kessel. 1989. Geographic variation in the marbled godwit and description of an Alaska subspecies. Condor 91: 436-443
[34] Goss-Custard, J.D. 1985. Foraging behavior of wading birds and the carrying capacity of estuaries. Pp. 169-188 in Sibly, R.M. and R.H. Smith (eds.). Behavioural Ecology, Blackwell Science, Oxford.
[35] Colwell, M.A. 2010. Shorebird ecology, conservation, and management. University of California Press, Berkeley, California.
[36] Granadeiro, J.P. et al. 2004. Modelling the distribution of shorebirds in estuarine areas using generalized additive models. Journal of Sea Research 52: 227-240.
[37] Simenstad, C.A. et al. 1991. Estuarine Habitat Assessment Protocol. EPA 910/9-91-037. 201 pp.
[38] Frazier, M.R., J.O. Lamberson, W.G. Nelson. 2014. Intertidal habitat utilization patterns of birds in a Northeast Pacific estuary. Wetlands Ecology and Management 22:451-466.
[39] Buchanan, J.B. 2008. The spring 2008 survey of Red Knots *Calidris canutus* at Grays Harbor and Willapa Bay, Washington. Wader Study Group Bull. 115(3): 177–181.
[40] Baker M. C. 1979. Morphological correlates of habitat selection in a community of shorebirds (Charadriiformes) Oikos. 33:121–126.
[41] Senner, S.E., D.W. Norton, and G.C. West. 1989. Feeding ecology of western sandpipers, *Calidris mauri*, and Dunlins, *C. alpina*, during splring migration at Hartney Bay, Alaska. Canadian Field-Naturalist 103:372-379.

[42] Kuwae, T. et al. 2008. Biofilm grazing in a higher vertebrate: the Western Sandpiper, *Calidris mauri*. Ecology 89:599-606.
[43] Dugger, Bruce D. and Katie M. Dugger. 2002. Long-billed Curlew (*Numenius americanus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/628
[44] Gratto-Trevor, Cheri L. 2000. Marbled Godwit (*Limosa fedoa*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/492
[45] WDFW. 2015. State Wildlife Action Plan – Comprehensive Wildlife Conservation Strategy – CWCS. Washington Department of Fish and Wildlife. Olympia, WA. Available at: http://wdfw.wa.gov/conservation/cwcs/