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To:	Rockett, Derek (ECY)
Cc:	Jesse DeNike; Billy Plauche
Subject:	Comments on Proposal to Control Burrowing Shrimp using Imidacloprid - Willapa Bay and Grays Harbor
Date:	Monday, December 08, 2014 4:50:30 PM
Attachments:	I.Comment Letter-WGHOGA.Final.pdf

Mr. Rockett:

Attached is a comment letter submitted on behalf of the Willapa-Grays Harbor Oyster Growers Association. If you have any problem opening the PDF, please let me know.

Terri

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Amanda M. Carr

December 8, 2014

Via Email: derek.rockett@ecy.wa.gov
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Olympia, WA 98504

RE: Comments on Proposal to Control Burrowing Shrimp using Imidacloprid on Commercial Shellfish Beds in Willapa Bay and Grays Harbor

Dear Mr. Rockett:

Thank you for the opportunity to comment on the proposal to control burrowing shrimp using imidacloprid on commercial shellfish beds in Willapa Bay and Grays Harbor ("Proposal"). This letter includes comments on the draft individual National Pollutant Discharge Elimination System ("NPDES") permit ("Draft Permit"), the sediment impact zone ("SIZ") applications and public notice letter ("SIZ Letter"), and the draft environmental impact statement ("DEIS") prepared for the Proposal.

We represent the applicant, Willapa-Grays Harbor Oyster Growers Association ("WGHOGA"), and are submitting these comments on the organization's behalf. WGHOGA is a non-profit organization of shellfish growers in Willapa Bay and Grays Harbor. WGHOGA's members range from small farms to companies with hundreds of employees. Most of WGHOGA's member companies are family owned and operated farms stretching back multiple generations. WGHOGA's members and predecessors have been farming shellfish on the coast before Washington statehood and are pillars of the coastal economy, culture, and environment.

I. Background on the Proposal

a. Shellfish aquaculture is critical to the health of the Willapa Bay and Grays Harbor communities

Commercial shellfish aquaculture is critical to the health of the communities and environment of Willapa Bay and Grays Harbor. The DEIS appropriately recognizes that shellfish aquaculture provides extensive benefits to the communities of Pacific County and Grays Harbor County, including the following:

- Willapa Bay is the largest producer of farmed oysters in the United States. It produces approximately 65 percent of the oysters in Washington State and 25 percent of the oysters in the entire United States. It also produces approximately 13 percent of the clams harvested in Washington State. DEIS at 2-16.

- Shellfish aquaculture is the largest private employer in Pacific County and is also a significant employer in Grays Harbor County. The importance of shellfish aquaculture to southwest Washington has increased in recent years following declines in the timber and fishing industries. *Id.*

- Studies from 2010 report that shellfish aquaculture in Pacific County generated more than $90 million in total economic output, over $45 million in labor income and provided 1,580 jobs; shellfish aquaculture in Grays Harbor County generated almost $12 million in total economic output, almost $6 million in labor income and provided 210 jobs. *Id.* at 2-16 – 2-17.[1]

- Shellfish growers pay taxes that generate revenue for State and local governments to fund public services such as police protection, fire protection, emergency medical aid, hospitals, libraries, schools, parks, road improvements, and general governmental services. *Id.* at 2-17. Ensuring shellfish aquaculture remains productive is therefore critical to protecting the well-being of these entire communities, not only the shellfish companies themselves.

Commercial shellfish beds also provide important ecological services that would otherwise require public infrastructure to address, including carbon sequestration, nutrient filtration, and similar services. *Id.* at 2-17. The water quality and nitrogen removal benefits provided by smaller and less productive estuaries have been valued between $77,100 and almost $300,000 per year. In addition, because shellfish cultivation relies on clean water and healthy habitats, shellfish farmers are strong advocates for improving and maintaining the overall health of marine environments. WGHOGA has been especially instrumental in improving Willapa Bay's habitat. The organization was instrumental in successfully eradicating the invasive cord grass, *Spartina*, which at one point dominated over 20,000 acres of Willapa Bay tidelands, and

[1] These statistics do not capture the "upstream" economic benefits generated by commercial shellfish aquaculture, such as jobs created for trucking companies, air freight, wholesalers, retail outlets and restaurants that sell and serve the farmed shellfish.

its members have played key roles in committees established to improve the quality and management of the estuary.

b. Burrowing shrimp threaten to destroy commercial shellfish beds and the overall health of the estuaries

Willapa Bay and Grays Harbor have been impacted by the expansive growth of ghost (*Neotrypaea californiensis*) and mud (*Upogebia pugettensis*) shrimp (collectively, "burrowing shrimp") since the 1940s. While burrowing shrimp populations were once limited, it has recently been estimated that burrowing shrimp-dominated grounds in Willapa Bay alone have skyrocketed to between 15,000 to 20,000 acres.

Burrowing shrimp have devastating impacts to commercial shellfish beds. These shrimp burrow into the marine sediments, causing sediments to be resuspended and softening the substrate. This resuspension and softening of the sediments buries commercial shellfish crops resulting in death. It also makes the farms unsafe to walk upon or operate. Burrowing shrimp have taken an estimated 3,000 acres of shellfish ground out of production in Willapa Bay and Grays Harbor, and the DEIS reports that anywhere between 60 to 90 percent of oyster and clam production will be eliminated in the future absent an effective control tool. DEIS at 2-17.

Burrowing shrimp can also have devastating impacts on the broader environment and health of the estuaries, as documented by voluminous authors. A 2001 Memorandum of Agreement between WGHOGA, several state agencies, and other stakeholders for integrated pest management of burrowing shrimp ("2001 IPM MOA")[2] summarizes these impacts as follows:

> **Whereas** aside from the detrimental impacts to oyster crops, areas dominated by burrowing shrimp exhibit reduced species diversity and altered composition of the benthic invertebrate community. At high densities, thalassinid (burrowing) shrimp are capable of influencing community composition by excluding species that are unable to withstand the disruption of sediment caused by burrowing and turnover of near-surface sediments (Peterson 1977; Brenchley 1981; Bird 1982; Murphy 1985; Posey 1986; Posey et al. 1991; Dumbauld 1994; Tamaki 1994. Bioturbation associated with thalassinid shrimp may interfere with suspension feeding (Rhoads and Young 1970) and surface-deposit feeding (Tamaki 1988), bury newly settled larvae (Swinbanks and Luternauer 1987) and initiate small-scale emigrations (Tamaki 1988). Bioturbation caused by callianassids (ghost shrimp) has been documented by Suchanek (1983) to have a negative effect on seagrass communities. In addition, mud shrimp are predominantly filter feeders (MacGinitie 1930) competing for plankton resources important to bivalves and other estuarine fauna.

In contrast, commercial shellfish beds provide important ecosystem services such as water filtration, resulting in decreased suspended solids, turbidity, and increased denitrification; habitat for epibenthic invertebrates such as crabs; carbon sequestration; and stabilization of

[2] The 2001 IPM MOA is attached as Appendix A.

adjacent habitats and the shoreline (Grabowski and Peterson 2007). They provide habitat for other molluscs, polychaetes, and crustaceans (Lenihan et al. 2001, Rothschild et al. 1994), and refuge habitat for juvenile fish and mobile crustaceans (Coen et al. 1999, Grabowski et al. 2005). Mobile, epibenthic invertebrates (e.g. decapod crustaceans) and fish are found in higher abundances on oyster beds than on sandflats devoid of oysters. Oyster beds provide complex three-dimensional structures, resulting in microhabitats that provide refuge from predation and desiccation. These refuge areas are also important as nursery areas for laying eggs and nesting (Tolley et al. 2005). Oyster beds, especially those that have been undisturbed for more than one year, support diverse communities of benthic invertebrates. These communities are similar in diversity to those found in eelgrass beds, and are much more diverse than those found in areas with large populations of burrowing shrimp (Dumbauld et al. 2009).

c. Willapa Bay and Grays Harbor shellfish growers have a long history of controlling burrowing shrimp, and the Proposal is the culmination of a long effort to find an effective, light-touch control tool

Given the importance of commercial shellfish aquaculture to Willapa Bay and Grays Harbor, together with the dire threat that burrowing shrimp pose to the health of shellfish beds along with the entire ecosystem, there is an acute need to effectively control these pests. In fact, shellfish growers have been searching for effective and environmentally-sound methods for controlling burrowing shrimp ever since the shrimp began rapidly expanding. Growers have effectively controlled burrowing shrimp by applying the pesticide carbaryl to commercial shellfish beds from 1963 until recently. As recognized in the 2001 IPM MOA, "a long term result of controlling burrowing shrimp densities in oyster beds using carbaryl has been the increase in benthic invertebrate species diversity, growth of eelgrass, and increase of Dungeness crab abundance (Doty et al. 1990; Brooks 1995; Dumbauld & Echeverria 1997)."

Growers have also performed exhaustive research on alternative mechanical, physical, biological, culturing, and chemical control options. These alternatives are summarized in section 2.8.4 of the DEIS. While the DEIS states that none of these alternatives "has proven to be as effective or practical than chemical application with carbaryl or imidacloprid" at controlling burrowing shrimp, the truth is that none have proven effective at a large scale at all. DEIS, Section 1.5.

WGHOGA has continued to pursue innovative methods for effectively controlling burrowing shrimp while minimizing impacts to non-target species through integrated pest management ("IPM"). The 2001 IPM MOA was executed "to establish a process and time frame for the development of a sustainable, site-specific, environmentally sound and ecologically based pest management plan for the control of burrowing shrimp." 2001 IPM MOA, Section 3. The agreement assigns responsibilities to WGHOGA (principally, to develop an IPM plan), state agencies (including issuance of regulatory approvals and supporting experimental work and other research), and other stakeholders (including supporting research and IPM efforts).

As a result of exhaustive research efforts and the growers' commitment to IPM, WGHOGA has identified imidacloprid as a viable and light-touch alternative for controlling burrowing shrimp. Due to the relatively low toxicity of imidacloprid and application rate

(imidacloprid applications may only be made with up to 0.5 pound of active ingredient per acre, compared to 8 pounds for carbaryl), however, growers need flexibility with this control tool to realize similar efficacy as has been historically achieved with carbaryl.

WGHOGA appreciates the Department of Ecology's ("Ecology's") hard work in reviewing the applications submitted for the Proposal and issuance of the Draft Permit, SIZ Letter, and DEIS. There are, however, many terms and conditions in these documents that will inappropriately and unjustifiably limit WGHOGA's ability to effectively control burrowing shrimp on commercial shellfish beds throughout these two estuaries. These conditions, if adopted in the final permitting documents, will have significant adverse impacts to shellfish growers, the larger economies and communities in which they operate, and the ecology of these estuaries. Therefore, WGHOGA respectfully requests that Ecology adopt the revisions and respond to the concerns set forth below in the final permitting documents for the Proposal.

II. The Draft Permitting Documents for the Proposal Contain Conditions that Will Unjustifiably Impede WGHOGA's Ability to Effectively Control Burrowing Shrimp

a. The SIZ Letter errs in failing to authorize a SIZ in southern Willapa Bay

At Ecology's request, WGHOGA submitted separate SIZ applications for Grays Harbor and Willapa Bay.[3] The SIZ applications requested a SIZ to be established for nearly the entirety of these estuaries to reflect the total extent of commercial shellfish beds and the need to control burrowing shrimp. Ecology's SIZ Letter, however, excludes southern Willapa Bay from the SIZ authorization.

This exclusion is unnecessary, unjustified, and could restrict growers' ability to treat critical shellfish production ground in this area. This, in turn, will have devastating impacts on WGHOGA, the larger communities that depend on commercial shellfish production, and the environment of southern Willapa Bay which will be vulnerable to unlimited burrowing shrimp infestations.

There are approximately 6,800 acres of shellfish beds in the southern exclusion area, and roughly 5,800 of these are owned or operated by WGHOGA members. This represents approximately 27% of the total commercial shellfish ground in Willapa Bay. Hundreds of acres in southern Willapa Bay have been treated within the past several years, and there is an increasing need for treatments given the recent rise in burrowing shrimp populations. Growers estimate that, absent an effective tool to control burrowing shrimp infestations in southern Willapa Bay, approximately 60 to 80 percent of commercial shellfish beds will become overrun with burrowing shrimp and unfarmable. As documented in Northern Economic's aquaculture economic impact analysis, Willapa Bay (Pacific County) is responsible for over $90 million in annual total economic output and 1,580 jobs. *See* Appendix B, p. 18. Assuming each acre lost

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[3] As a point of clarification, the fifth full paragraph on page 13 of the Willapa Bay SIZ application should be revised as follows: "*Tribal Fishing Grounds*. The Shoalwater Bay tribe is located in Willapa Bay and may have~~s~~ usual and accustomed fishing rights in the ~~area~~ boundaries of the reservation. ~~As such, they are entitled to fish all shoreline areas, including privately owned lands, but must have permits in place to harvest shellfish on privately owned lands.~~"

in southern Willapa Bay due to the SIZ exclusion is equivalent to the loss of an average bed in Willapa Bay, an 80 percent loss of beds in this area would result in nearly $20 million in lost economic output each year and the loss of over 340 jobs.

However, these calculations likely underestimate the actual losses that would result if burrowing shrimp could not be controlled in southern Willapa Bay for at least two reasons. First, many of the shellfish beds in southern Willapa Bay produce seed for planting in other areas throughout the Bay. Two WGHOGA members alone have approximately 600 acres of seed ground in the southern exclusion area. Every acre of seed ground lost to production results in a total loss of two acres because it reduces the amount of seed available for planting in the Bay.

Second, several WGHOGA members' farms are concentrated in southern Willapa Bay. If they are not able to treat the vast majority of their beds, they may be forced out of business completely. This will reduce WGHOGA's membership, amount of funding, and ability to pay for the extensive monitoring that is proposed in the Draft Permit. If there are insufficient funds for performing the required monitoring, then the entire permit and control program could be compromised, and WGHOGA could completely lose the ability to control burrowing shrimp in Willapa Bay and Grays Harbor. This will devastate the commercial shellfish industry in Willapa Bay and Grays Harbor, the surrounding communities that rely on aquaculture, and the health of these estuaries. It will also prevent shellfish growers from maintaining beneficial uses of tidelands that were granted under the Bush and Callow Acts for the express purpose of shellfish cultivation.

While precluding treatments in southern Willapa Bay will cause extreme economic and environmental damage, there is also an insufficient scientific basis for this exclusion. Extensive studies have been performed on imidacloprid's impacts to sediments and benthic communities. Most of these studies have been conducted in central and northern Willapa Bay, which share similar sediment characteristics and benthic communities to the southern Willapa Bay. As discussed more fully in the technical memorandum prepared by Hart Crowser attached hereto as Appendix C, Ecology E-MAP data and mapping by Dr. Brett Dumbauld show the varied nature of Willapa Bay sediments. Southern Willapa Bay has areas of high sand concentrations, as well as silt/clay areas, as does the north end of Willapa Bay. Similarly, while there are some areas with higher total organic carbon ("TOC") values in southern Willapa Bay, there are also many areas with low TOC concentrations in southern Willapa Bay. Appendix C, pp. 2-4. Therefore, there is no basis for treating southern Willapa Bay differently from other parts of the bay based on sediment types or TOC values.

There are also broad similarities in invertebrate assemblages found in southern Willapa Bay compared to other parts of the Bay. Dominant taxa observed in 2011 and 2012 imidacloprid field studies were also found in south Willapa Bay according to Ecology's own E-MAP program. Thus, the response to imidacloprid treatments on shellfish beds should be similar with respect to both immediate effects, and subsequent recolonization of treated plots. Appendix C, pp. 4-5.

Imidacloprid will also degrade and dilute to harmless levels in southern Willapa Bay, as in other parts of the Bay. Imidacloprid is photosensitive and breaks down when exposed to light. Imidacloprid will experience photodegradation in water following application, and it will also

break down and become biologically unavailable very rapidly through oxidation and hydrolysis. Appendix C, p. 6.

Concentration of imidacloprid in sediment as well as the incoming tide will be the same regardless of where it is applied, as the application rate is capped at 0.5 pounds of active ingredient per acre. Imidacloprid residence time in water will also not influence its level of impact on non-target organisms, as it dilutes to non-toxic levels throughout Willapa Bay. Imidacloprid will quickly dilute to 0.6 parts per billion ("ppb") or less regardless of where it is applied, and the biological threshold for effects previously recognized by Ecology is 3.7 ppb. Appendix C, pp. 5-6.

Monitoring results from carbaryl treatments confirm these rapid dilution rates, and demonstrate that dilution actually occurs much quicker than theoretically predicted. For example, Dr. Kim Patten calculated the theoretical concentration on the first tidal flushing to range from 0.28 to 2.7 ppb. He also calculated a theoretical maximum 24-48 hours post-treatment, based on an assumption of 25% dilution with each tidal flush. This calculates to a range of 0.21 to 1.49 ppb. Yet actual concentrations measured during carbaryl monitoring and reported in the WGHOGA monitoring reports from 2004 through 2009 range from 0.02 to 0.3 ppb. These values are far below the theoretical values calculated by Dr. Patten and demonstrate chemicals are largely and rapidly diluted in the estuarine environment. Appendix C, pp. 5-8.

Accordingly, we respectfully request that Ecology revise the proposed SIZ authorization to extend throughout southern Willapa Bay. There is no clear basis for excluding this area from the SIZ, and even if there were a basis for being concerned about treatments in this area, monitoring results could be used to ensure compliance with regulatory standards.

b. The "conditional" status of the Grays Harbor and northern Willapa Bay SIZ authorizations should be removed

For many of the same reasons, we also respectfully request that the SIZ authorizations for Grays Harbor and northern Willapa Bay be revised to remove the "conditional" classification. Like central and southern Willapa Bay, these areas support highly productive shellfish beds that are critical to sustaining the surrounding communities. While Willapa Bay is the largest source of farmed oysters in the United States, Grays Harbor is also a major producer. According to 2010 data compiled by Northern Economics, Grays Harbor contains almost eight percent of the total shellfish beds in the state, is responsible for nearly $12 million in annual economic output and employs 210 people with approximately $6 million in annual labor income. Appendix B at p. 18. In addition, Grays Harbor oyster beds are characterized by sandy sediments, similar to the sediments in central Willapa Bay that have been extensively studied for imidacloprid impacts (Ferraro and Cole 2011). Therefore, authorizing a SIZ for these areas on a "conditional" basis is unnecessary, particular in light of the monitoring requirements in the Draft Permit, and will result in regulatory and treatment uncertainty for Ecology and the growers alike.

c. The Draft Permit monitoring requirements are unreasonable and must be revised

WGHOGA appreciates that monitoring is commonly required under NPDES permits and recognizes the importance of conducting reasonable and appropriate monitoring for the Proposal. However, the Draft Permit monitoring requirements contained in section S4 must be revised as many are unreasonable, unnecessary, and confusing. According to initial calculations, monitoring is expected to cost well over $1 million over the course of the permit. Further, much of the information sought to be gathered has already been obtained through previous studies and is being requested at much greater frequencies than is warranted or reasonable. Our concerns with the specific monitoring sections, and proposed revisions thereto, are identified below.

i. Water quality monitoring – section S4.A

The water quality monitoring requirements set forth in section S4.A of the Draft Permit are generally reasonable and appropriate. However, the requirement to take samples at 60, 120, 240, and 480 meters from the applications site will not always be possible to comply with because in some cases there is shoreline or major drainage channels less than 480 meters away. Thus, this monitoring requirements should be revised to allow altered sampling locations based on site-specific conditions.

ii. Sediment monitoring schedule – section S4.B

The table in section S4.B of the Draft Permit should be clarified to state that each entry indicates that only a single location will be sampled for each year/area combination. This appears to be the intent of the table, and making this explicitly clear will provide certainty for WGHOGA and Ecology alike.

Further, as explained in Appendix C, consistent and reliable data on sediment concentration levels of imidacloprid has already been gathered through extensive studies. In addition, these studies can be very time and cost-intensive. Thus, the extensive and costly sediment monitoring requirements in the Draft Permit should be revised as follows:

- Sediment sampling should not be required in any location except Grays Harbor, and sampling in this location should be limited to a single sampling location unless sediment results for this location demonstrate results different from those already documented in Willapa Bay.

- No sediment sampling should require collection beyond 28 days.

- An exception to the above is to include monitoring of one location in Willapa Bay that extends in duration beyond 28 days until both sediment pore water and whole sediment concentrations are below the practical quantitation limit ("PQL"). An alternative would be to take sediment samples from an area sprayed with imidacloprid in the prior year. The goal of either effort would be to confirm that imidacloprid falls below detection levels over time, and

therefore that long-term accumulation of imidacloprid in areas that are repeatedly sprayed will not occur.

The basis for these revised monitoring requirements is set forth more fully in Appendix C. In general, the data collected to date in Willapa Bay already answers the questions and concerns voiced by Ecology in Section S4 of the draft NPDES permit, and therefore further extensive monitoring is not scientifically justifiable. See Appendix C, pp. 8-14.

iii. Sediment benthic invertebrate monitoring – section S4.G

Section S4.G of the Draft Permit sets forth an incredibly intense and expensive monitoring program for benthic invertebrates. As discussed more fully in Appendix C, these requirements and procedures must be revised as they are unnecessary, repetitive, and overly burdensome. See Appendix C, pp. 15-16. There has already been extensive analysis of impacts to benthic invertebrates associated with the proposed use of imidacloprid, and repetitive monitoring will not yield additional useful information commensurate with the associated costs. To the extent additional information is determined necessary for purposes of permit monitoring, a much more refined and tailored approach should be adopted as discussed in Appendix C.

d. The maximum biological effects criteria in the Draft Permit are inappropriate and must be revised

Section S3.B of the Draft Permit contains draft maximum biological effects criteria for the proposed use of imidacloprid. WAC 173-204-420 contains maximum criteria for sediment impact zones. Subsection (1)(a) makes clear that the criteria set forth in this section "shall apply to marine sediments within Puget Sound." Subsection (1)(b) states that for non-Puget Sound sediments, Ecology "shall determine on a case-by-case basis the criteria, methods, and procedures necessary to meet the intent of this chapter." Yet the criteria in Section S3.B of the Draft Permit are adopted nearly entirely from the Puget Sound standards. These draft criteria are inappropriate and must be revised to accurately reflect the nature of the Proposal, achieve compliance with Ecology's Sediment Management Standards at chapter 173-204 WAC and the Clean Water Act, and account for the long-term impacts associated with failing to effectively control burrowing shrimp populations.

The criteria in Section S3.B of the Draft Permit are inappropriate because they fail to reflect the nature of the Proposal. The Proposal does not include the typical "discharge" that the NPDES permitting system and Sediment Management Standards were designed to address, such as a pipe that conveys pollutants into the water. The NPDES permitting system and Sediment Management Standards were not drafted to regulate activities such as the Proposal that control aquatic pests in support of beneficial uses. In fact, NPDES permits were not required for the use of pesticides in compliance with FIFRA labels until relatively recently, and there remains significant controversy over precisely when NPDES permits can be required for such uses. Unlike pipes or other outfalls that discharge pollutants into waters on a continual or regular basis, the Proposal only calls for a single application per year of imidacloprid. Therefore, the Proposal will have a much more limited temporal impact on sediments than typical projects that require a NPDES permit, and is outside of the Puget Sound area that the criteria in WAC 173-204-420

were designed to address. Accordingly, the Puget Sound criteria are inappropriate for regulating the Proposal and should not be used in any form.

Moreover, the maximum biological effects criteria in the Draft Permit fail to meet the intent of the Sediment Management Standards and the Clean Water Act. In particular, the criterion that no ecological metric listed in S3.B.1 can be reduced by more than 50 percent, 14 days after imidacloprid applications is inappropriate and must be stricken or revised. This criterion is extremely rigid and focused only on short-term impacts to a narrow class of benthic organisms. The 14-day timeline is not based on any regulatory standard or the biology of benthic organisms. It is also inconsistent with some proposed monitoring conditions requiring benthic invertebrate samples to be taken up to 56 days after treatment. This rigid and artificial limit may restrain growers' flexibility to apply imidacloprid during times and conditions to achieve required efficacy, thereby compromising the continued viability of commercial shellfish beds, which are beneficial uses of Willapa Bay and Grays Harbor. This is an unacceptable result under the Sediment Management Standards and Clean Water Act. WAC 173-204-210 states "[t]he policy of the department and the purpose of this chapter shall be to manage waste discharges and sediment quality so as to protect existing beneficial uses and move towards attainment of designated beneficial uses as specified in section 101 (a)(2) of the federal Clean Water Act (33 U.S.C. 1251, et seq.) and chapter 173-201 WAC, the Water quality standards for surface waters of the state of Washington." Both the Clean Water Act and Ecology's guidelines at chapter 173-201A WAC specifically identify the propagation and protection of shellfish as beneficial and protected uses. 33 U.S.C. § 1251(a)(1); WAC 173-201A-010(1). The Ninth Circuit Court of Appeals has also confirmed that, in enacting the Clean Water Act, "Congress plainly and explicitly listed the "protection and propagation of . . . .shellfish" as one of the goals of reduced pollution and clean water." *Association to Protect Hammersley, Eld, and Totten Inlets v. Taylor Resources, Inc.*, 299 F.3d 1007, 1016 (9th Cir. 2002) (quoting 33 U.S.C. § 1251(a)(2) and citing 33 U.S.C. §§ 1312(a), 1314(a)(2)).

Finally, restricting growers' ability to effectively control burrowing shrimp will also conflict with the intent of the Sediment Management Standards and the Clean Water Act because the quality of marine sediments and the overall health of the estuaries will be significantly harmed if burrowing shrimp are allowed to infest and dominate thousands of acres of shellfish beds. As discussed above, burrowing shrimp-dominated areas exhibit reduced species diversity and altered composition of the benthic invertebrate community. *Supra* at p. 3. In contrast, shellfish beds benefit the marine ecosystem by providing a variety of ecosystem services, including: water filtration, resulting in decreased suspended solids, turbidity, and increased denitrification; habitat for crabs, molluscs, polychaetes, crustaceans mobile invertebrates, and fish; carbon sequestration; and stabilization of adjacent habitats and the shoreline. *Id.* at 3-4. The communities supported by shellfish beds are similar in diversity to those found in eelgrass beds, and are much more diverse than those found in areas with large populations of burrowing shrimp. *Id.* If growers are not able to effectively control burrowing shrimp, as expected, due to the narrow and myopic maximum effects criteria in the Draft Permit, then burrowing shrimp will dominate thousands of shellfish bed acres resulting in extensive harm to the overall health of both estuaries. This unacceptable impact directly conflicts with the goals of the Sediment Management Standards and Clean Water Act and must be avoided.

In order to meet the intent of the Sediment Management Standards and Clean Water Act, Ecology must develop alternative maximum biological effects criteria that take into account the precise nature and location of the Proposal, focus on a broader suite of organisms, take a long-term perspective, and consider the significant harm that will be caused to the estuaries if burrowing shrimp are allowed to infest and dominate thousands of acres of productive shellfish beds. Ecology has, in fact, previously recognized the importance of taking a longer-term perspective when regulating WGHOGA's use of pesticides to control burrowing shrimp. As discussed above, the 2001 IPM MOA emphasized the "long term result of controlling burrowing shrimp densities in oyster beds using carbaryl has been the increase in benthic invertebrate species diversity, growth of eelgrass, and increase of Dungeness crab abundance." Imidacloprid has the potential to effectively control burrowing shrimp similar to carbaryl but at reduced toxicities and application rates. Ecology should be attempting to facilitate the growers' transition to this control tool, rather than imposing artificial conditions that are not based on any regulatory standard and will lead to the long-term degradation of the marine environment.

Accordingly, WGHOGA respectfully requests that Ecology revise the maximum biological effects criteria in section S3.B of the Draft Permit. Ecology's heavy reliance on, and broad-scale adoption of, the Puget Sound criteria is inappropriate for regulating the Proposal and must be removed. At the very least, the 14-day time period must be removed and replaced with a more reasonable and appropriate time period that takes into account the long-term impacts associated with the use of imidacloprid, burrowing shrimp infestations, and the ecological services provided by shellfish beds. This focus should be over the term of the five-year permit or one year after applications to account for time and seasonal variations along with the life stages of potentially affected organisms. In no case should the time period be less than 56 days consistent with the proposed SIZ closure plan monitoring requirements.

e. Annual Operations Plan

Section S6.A of the Draft Permit requires an annual operations plan ("AOP") to be submitted by March 1 of each year. This may be impossible during the first year of the permit, since it is unclear the Final Permit will be issued before that date. In addition, some years treatments may not occur until several weeks to months after March 1, and growers may not know which beds they intend to treat by March 1. Therefore, WGHOGA respectfully requests that this provision be revised to require AOPs to be submitted at least 14 days prior to the first treatment of the year. This revision will provide adequate notice and review time for Ecology, while granting growers needed flexibility.

In addition, WGHOGA respectfully requests that the GPS coordinates provided in the AOP be of the treated bed, not the precise area to be treated. While growers may know which beds they intend to treat two weeks ahead of time, the precise area treated will depend on site specific conditions of the bed at the time of treatment. This is particularly true with imidacloprid, which requires a more "hands on" application approach.

III. Conclusion

WGHOGA appreciates Ecology's hard work in developing the Proposal's draft permit documents. In order for WGHOGA to effectively control burrowing shrimp for the benefit of its members, the surrounding communities that they support, and the environment, shellfish growers need a flexible, reasonable, and predictable control tool. Adopting the revisions and responding to the concerns set forth in this letter will be critical to achieving that goal.

Very truly yours,

Jesse DeNike

JGD:tat
Attachments

References

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Appendix A

BURROWING SHRIMP
INTEGRATED PEST MANAGEMENT

MEMORANDUM OF AGREEMENT

BETWEEN

WASHINGTON DEPARTMENT OF ECOLOGY

WASHINGTON DEPARTMENT OF AGRICULTURE

WASHINGTON STATE COMMISSION ON PESTICIDE REGISTRATION

WASHINGTON DEPARTMENT OF FISH & WILDLIFE

THE WILLAPA/GRAYS HARBOR OYSTER GROWERS ASSOCIATION

PACIFIC COAST SHELLFISH GROWERS ASSOCIATION

PACIFIC SHELLFISH INSTITUTE

1. INTRODUCTION

This MEMORANDUM OF AGREEMENT (hereafter referred to as "MOA") is entered into by and between the Washington State Department of Ecology (hereafter referred to as "Ecology"), Washington State Department of Agriculture (WDOA), the Washington State Commission on Pesticide Registration (WSCPR), the Washington Department of Fish and Wildlife (WDFW), the Willapa/Grays Harbor Oyster Growers Association (hereafter referred to as the Growers Association), the Pacific Coast Shellfish Growers Association (PCSGA), and the Pacific Shellfish Institute (PSI), with reference to the following:

2. RECITALS

2.1 **Whereas** there are 45,000 acres of tidelands in Willapa Bay and 34,460 in Grays Harbor. Of these, approximately 9,000 acres (20%) in Willapa and 900 acres (3%) in Grays Harbor are farmed for oysters. Members of the Growers Association own the vast majority of this acreage, which is being farmed. (WDF/WDOE 1992)

2.2 **Whereas** since the 1940's Willapa Bay and Grays Harbor have experienced expansive growth in populations of burrowing ghost (*Neotrypaea californiensis*) and mud (*Upogebia pugettensis*) shrimp. In Willapa Bay it is estimated that 15,000 to 20,000 acres are dominated by burrowing shrimp. (Dumbauld and Tufts, 2000)

2.3 **Whereas** burrowing shrimp cause major economic harm to shellfish growers by resuspending sediments and softening the substrate resulting in oysters sinking or being buried, inhibiting growth or killing the crop. It is estimated that nearly 3,000 acres of oyster grounds (i.e. ~30% of the currently farmed acreage) in both estuaries combined could be reclaimed for oyster production if the burrowing shrimp were controlled (Burrowing Shrimp Control Committee [BSCC] 1992).

2.4 **Whereas** aside from the detrimental impacts to oyster crops, areas dominated by burrowing shrimp exhibit reduced species diversity and altered composition of the benthic invertebrate community. At high densities, thalassinid (burrowing) shrimp are capable of influencing community composition by excluding species that are unable to withstand the disruption of sediment caused by burrowing and turnover of near-surface sediments (Peterson 1977; Brenchley 1981; Bird 1982; Murphy 1985; Posey 1986; Posey et al. 1991; Dumbauld 1994; Tamaki 1994. Bioturbation associated with thalassinid shrimp may interfere with suspension feeding (Rhoads and Young 1970) and surface-deposit feeding (Tamaki 1988), bury newly settled larvae (Swinbanks and Luternauer 1987) and initiate small-scale emigrations (Tamaki 1988). Bioturbation caused by callianassids (ghost shrimp) has been documented by Suchanek (1983) to have a negative effect on seagrass communities. In addition, mud shrimp are predominantly filter feeders (MacGinitie 1930) competing for plankton resources important to bivalves and other estuarine fauna.

2.5 **Whereas** carbaryl is toxic to juvenile salmonids, Dungeness crab and polychaetes (WDF/WDOE, 1992). Application of carbaryl is managed so as to minimize impacts to these species.

2.6 **Whereas** the control of burrowing shrimp is essential to maintain viable commercial shellfish beds. The majority of oyster ground has been treated with carbaryl on a periodic basis since 1963 and would not be in use today were it not for control of the burrowing shrimp through some management intervention.

2.7 **Whereas** Ecology has authorized in accordance with Chapter 90.48 Revised Code of Washington (RCW) the application of carbaryl to shellfish beds for the control of burrowing shrimp. Ecology has issued growers Temporary Water Quality Modification Orders for spraying which modified water quality criteria specified in Chapter 173-201A-110(1) Washington Administrative Code (WAC) and required compliance with the State Environmental Policy Act (SEPA). The use of carbaryl for burrowing shrimp control currently complies with the provisions of Washington State Local Needs Pesticide Registration No. WA-900013 issued by EPA through the Washington Department of Agriculture under authority of section 24(c) of the Amended Federal Insecticide, Fungicide, and Rodenticide Act.

2.8 **Whereas** in 1999, Ecology provided detailed oversight of the Orders issued to the oyster growers and determined that compliance with the conditions of the Orders was achieved.

2.9 **Whereas** over 250 studies reviewing the various aspects associated with the control of burrowing shrimp on oyster beds have been conducted. These studies include the related social, economic, biological and physical impacts with the majority focusing on the use of carbaryl in the aquatic environment of Willapa Bay. An Environmental Impact Statement was completed in 1985 with over 120 citations related to burrowing shrimp control. A Supplemental Environmental Impact Statement was completed in 1992 with an additional 75 citations on studies completed between 1984 and 1989. Since 1990 approximately 75 additional studies have been published or are in completed manuscript form (Dewitt et al, 1997). More studies are currently underway or are being planned, and may or may not change the conclusions drawn to date.

2.10 **Whereas** the preferred alternative of the 1992 SEIS referenced above/, was that burrowing shrimp be managed through an Integrated Pest Management Plan.

2.11 **Whereas** carbaryl has significant short-term impacts on the abundance and diversity of benthic invertebrates (Dumbauld 1994; Brooks 1995). However, recolonization of treated beds by many invertebrates begins within 24 hours.

2.12 **Whereas** no long-term adverse effects to estuarine communities (including benthic invertebrate communities) have been clearly attributed to carbaryl application, with the exception of the eradication of burrowing shrimp (WDF/WDOE 1992; Brooks 1995; Simenstad and Fresh 1995, Simenstad 1989). No studies specifically assessing potential long-term adverse or potentially beneficial effects have been undertaken.

2.13 **Whereas** a long term result of controlling burrowing shrimp densities in oyster beds using carbaryl has been the increase in benthic invertebrate species diversity, growth of eelgrass, and increase of Dungeness crab abundance (Doty et al. 1990; Brooks 1995; Dumbauld & Echeverria 1997).

2.14 **Whereas** Dungeness crabs, which are highly susceptible to carbaryl, may not recolonize treated oyster beds for up to 2 weeks, but afterward can attain higher abundances than on tide flats with high burrowing shrimp densities (Feldman et al. 2000, Doty et al. 1990).

2.15 **Whereas** mammals and birds show no sensitivity to carbaryl at several orders of magnitude above the range of toxicity to fish and invertebrates. No adverse effects have been observed to birds feeding on dead shrimp in carbaryl treated areas (DeWitt 1997; WDF/WDOE 1992).

2.16 **Whereas** carbamates are not known to bioaccumulate in the food chain (WDF/WDOE 1992).

2.17 **Whereas** the U.S. Environmental Protection Agency's established residue tolerance for carbaryl in oysters is 0.25 ppm. While growers may not treat beds that are within a year of being harvested, tidal movement of carbaryl from treated beds to adjacent harvest areas is a concern. Repeated testing by the Washington State Department of Agriculture immediately following bed treatment has never detected carbaryl levels in excess of EPA's established residue tolerance on treated or adjacent beds (Merkel, 2001).

2.18 **Whereas** oyster growers have investigated various alternative mechanical and chemical control measures over the past 40 years. While these efforts are on-going, none as yet has proven to be as economical, reliable, effective, or more species specific than carbaryl.

2.19 **Whereas** today, carbaryl remains the most commonly used means of reducing burrowing shrimp abundance in oyster beds in Willapa and Grays Harbors. The use of carbaryl for burrowing shrimp is presently and has historically been limited to these two estuaries. Currently carbaryl is applied annually on 600 acres (1.3% of total intertidal acres) in Willapa Bay and 200 acres (0.58% of total intertidal acres) in Grays Harbor. Carbaryl is applied predominantly by helicopters during 1 or 2 extreme low tide series in July or August.

2.20 **Whereas** carbaryl and its breakdown product, 1-naphthol, have been shown to have been transported up to 700 feet offsite application sites. Depending on environmental conditions, carbaryl and 1-naphthol persist for a few days (in water) to several weeks (in sediments) at levels near the lower limits of detection. A study conducted by Ecology's Environmental Assessment Program (EAP) in 1998 (Stonick, 1999) determined that carbaryl and 1-naphthol persist longer than previously understood. This same EAP study identifies~~d~~ future recommendations and research necessary to more fully evaluate the environmental impacts associated with the use of carbaryl.

2.21 **Whereas** Ecology conducted a study in 2000 to: 1) determine if there is a carbaryl background that persists in Willapa Bay water beyond the July/August spray period, 2) analyze carbaryl in other potential sources to Willapa Bay, 3) achieve detection limits for carbaryl sufficiently low for comparison with the NAS 0.06 ug/L recommendation, and 4) review the literature on carbaryl's effects to marine organisms and evaluate the Appropriateness of the NAS criterion for Willapa Bay. (Johnson, A. 2000)

2.22 **Whereas** a two year process culminating in an August 1997 report by Batelle (DeWitt et al. 1997), evaluated the feasibility of using Integrated Pest Management (IPM) to control burrowing shrimp. This report resulted in a framework for future research and work to be done in the development of an IPM.

2.23 **Whereas** an IPM Plan would provide a framework for controlling pests based on the ecology of the pest, economics of farming oysters and managing shrimp damage, the integration of control tactics, and protection of other beneficial uses of the harbors. **And,**

2.24 **Whereas** the Pacific Coast Shellfish Growers Association is developing an Environmental Code of Practice for the entire west coast shellfish industry in an effort to identify and minimize negative environmental impacts associated with the production of shellfish. It is the intent of the industry to include burrowing shrimp IPM in the Code of Practice and ultimately use an IPM approach for all pest and predator control.

NOW, THEREFORE, in consideration of the RECITALS here in above stated and by the authority of Ecology, Washington Department of Agriculture, Washington Department of Fish and Wildlife, the Washington Commission on Pesticide Registration, and Growers Association, the Pacific Coast Shellfish Growers Association and the Pacific Shellfish Institute, it is hereby agreed as follows:

3. PURPOSE

The purpose of this MOA is to establish a process and time frame for the development of a sustainable, site-specific, environmentally sound and ecologically based pest management plan for the control of burrowing shrimp. This Integrated Pest Management Plan shall integrate knowledge of the life history and ecology of both species of burrowing shrimp, their natural predators and competitors, chemical, biological, and physical control tactics, cultivation practices, and all other suitable techniques to maintain populations of burrowing shrimp at population densities below economically injurious levels (as defined in Section 5. IPM Plan Development).

This MOA further defines the responsibilities of each party under the current carbaryl spray program until such time that it has evolved into an approved IPM Plan (as outlined in Section 5. IPM Plan Development).

4. DEFINITIONS

For the purpose of this MOA, Integrated Pest Management is defined as per the Revised Code of Washington (RCW) 17.15.010.

4.1 **"Integrated Pest Management"** means a coordinated decision-making and action process that uses the most appropriate pest control methods and strategy in an environmentally and economically sound manner to meet agency programmatic pest management objectives. The elements of integrated pest management include:

A. Preventing pest problems;

B. Monitoring for the presence of pests and pest damage;

C. Establishing the density of the pest population, that may be set at zero, that can be tolerated or correlated with a damage level sufficient to warrant treatment of the problem based on health, public safety, economic, or aesthetic thresholds;

D. Treating pest problems to reduce populations below those levels established by damage thresholds using strategies that may include biological, cultural, mechanical, and chemical control methods and that must consider human health, ecological impact, feasibility, and cost-effectiveness; and

E. Evaluating the effects and efficacy of pest treatments.

5. INTEGRATED PEST MANAGEMENT (IPM) PLAN DEVELOPMENT AND CARBARYL SPRAY PROGRAM RESPONSIBILITIES

5.1 Growers Association

A. IPM Plan Development

1. Establish an Integrated Pest Management Committee. This committee would oversee the implementation of this MOA as well as the development and implementation of the IPM plan, prioritizing Growers Association efforts accordingly. The IPM Committee shall consist at a minimum of a representative of each signatory party to this MOA.

   Timeframe – Organize, appoint and charter this committee by February 28, 2001.

2. Identify an IPM plan Coordinator. This individual will coordinate the development and implementation of the IPM plan. Duties will include convening meetings of the IPM Committee or other groups as necessary, coordinating the IPM research strategy, keeping abreast of research and grant opportunities for IPM-related topics and preparing an annual report on the status of the IPM plan.

   Timeframe – Identify and appoint an IPM plan coordinator by February 28, 2001.

3. Develop and apply accurate, reliable, rapid and cost-effective techniques to monitor populations of both ghost shrimp and mud shrimp in oyster beds. Accurate estimates of the population densities of ghost and mud shrimp are fundamental to all aspects of decision making in the burrowing shrimp IPM plan. The two species of burrowing shrimp have different life cycles (Feldman et al. 2000), which need to be taken into account when controlling them. This monitoring program will:

   a. Improve upon problems associated with current burrow count methodology;

   b. Incorporate Young of the Year (YOY) sampling to assess recruitment;

   c. Assess efficacy of prior treatment.

   Timeframe – Year 2001 application, to be continued in subsequent years.

4. Quantify the relationship between the density of burrowing shrimp populations and damage to oyster yield. This "damage/density" function is a mathematical formula that describes the relationship between the abundance of the pest and the reduction to the yield of the crop. To determine damage/density functions, studies will be undertaken to measure the survival, growth, and harvest yield of oysters on beds with different densities of both species of burrowing shrimp, taking into account the effects of habitat, season, culture technique, and other environmental variables. Initial efforts will focus on developing damage/density functions for the cultural practices suffering the greatest economic loss from burrowing shrimp.

a. Develop draft Damage Density model

Timeframe – May 1, 2001.

b. Collect data to apply to the Damage Density model

Timeframe - Commencing with 2001 spray season and continuing through entire crop cycle (~ four years to accurately establish the damage/density relationship).

5. Develop objective decision making criteria to determine when and where to deploy control tactics. Economic injury level (EIL) and economic threshold (ET) models underlie the formal decision-making process for IPM. The Growers Association will develop EIL and ET models which include provisions for multi-year, multi-season crop production cycle, seasonal changes in the damage caused by the shrimp, and the effects of other environmental factors on the physiology and growth of oysters and shrimp. These models will build upon the damage/density model developed under §5.1.A.4

a. Develop draft Economic Injury Level (EIL) and Economic Threshold (ET) models.

Timeframe – May 1, 2001.

b. Collect data to apply to EIL and ET models

Timeframe - Commencing with 2001 spray season and continuing through entire crop cycle (~ four years to accurately establish the damage/density relationship).

6. Investigate alternative methods and timing for the delivery of carbaryl. Attempts have been made in the past to find alternative methods to apply carbaryl, however growers have been restricted by label requirements specifying methodology and Washington Department of Fish & Wildlife timing requirements. Using the joint Ecology/WSDA Experimental Use Permit (EUP) application process to seek and secure approval to test and evaluate other technologies and treatments, the Growers Association will:

a. Investigate alternative methods to more precisely deliver carbaryl to the burrows in an effort to reduce the amount of pesticide that is applied on each bed thereby also reducing offsite impacts.

Timeframe – Immediate and on-going.

b. Undertake studies to determine whether application of carbaryl at seasons other than mid-summer would be 1) more effective at controlling shrimp, and 2) environmentally acceptable.

Timeframe - As funding is available.

7. Encourage investigation into the underlying reasons for increasing burrowing shrimp populations. Long-term reduction of the impact of burrowing shrimp on oysters will require knowledge of, and the ability to change, the factors that led to the expansion

of burrowing shrimp populations in Willapa Bay and Grays Harbor. Studies should start by searching historical archives for physical evidence of changes in burrowing shrimp distributions and changes in environmental conditions (i.e. El Nino/La Nina salinity changes due to damming the Columbia River) within Willapa Bay, Grays Harbor and other Pacific Northwest estuaries. Ways in which these environmental changes as well as anthropogenic effects may have altered predator/prey relationships favoring proliferation of burrowing shrimp populations should also be investigated. Sediment cores and dating techniques could provide additional evidence of historical changes in patterns of burrowing shrimp bioturbation in different parts of the estuary. Oral histories of burrowing shrimp distributions and estuarine conditions should be constructed from interviews with oyster growers and local biologists. Using these sources of information and/or others will help identify when the shrimp populations expanded and what environmental and anthropogenic conditions might have accompanied (or precipitated) that event. Experiments should then be conducted to measure the responses of burrowing shrimp to these factors, from which the cause of population increase might be identified.

The Growers Association and the other parties recognize that an understanding of the ecological changes, which resulted in the increased shrimp populations, is crucial to effectively control them. Recognizing hat the shrimp are impacting multiple grower and public resources in the estuary, the parties agree to work cooperatively with resource management agencies to understand these underlying ecological changes.

Timeframe – As funding is available.

8. Continue to seek alternative physical, biological or chemical control methods that could be more species specific, economical, reliable and environmentally responsible. The Growers Association and the other parties put a high priority on seeking non-chemical alternatives.

   Timeframe – Immediate and ongoing.

9. Develop and implement an Integrated Pest Management plan for burrowing shrimp control. IPM plans have traditionally been developed for terrestrial, not marine pests. As is acknowledged by the Batelle IPM feasibility study, more information needs to be gathered before an effective IPM plan can be implemented. Recognizing further, that an IPM plan is a living document, constantly evolving as control technologies change, the Growers Association will have all of the necessary components complete and an effective IPM plan developed by March 29, 2002.

   Timeframe – A) IPM plan completed by the Growers Association by March 29, 2002 B) an approved IPM plan will be a requirement prior to permit issuance in 2002, and be implemented in the 2002 season.

B. <u>The Carbaryl Spray Program</u>

1. Growers Association Responsibilities are to provide an Annual Spray Coordinator whose responsibilities include:

   a. Notify growers of impending spray season and provide them with an Application for Chemical Pest Control Permit no later than March 1.

b. Inspect oyster beds to ascertain whether they meet the necessary criteria to qualify for spraying. No oyster bed may be treated with carbaryl if it contains oysters, which are within one (1) year of harvest. No oyster bed may be treated with carbaryl unless the mean burrow count exceeds ten (10) burrows/m^2 unless a report is filed with Ecology at least one (1) week before the application date with the following information, and is supported by the economic threshold described in §5.1.A.5:

   1) A substrate condition evaluation;

   2) Species of burrowing shrimp present;

   3) The anticipated use of the bed following treatment.

c. Prepare, document and submit precise mapping of bed and spray locations through the use of GPS, DGPS, or other accurate means.

d. Prepare a summary of applications, inspections, environmental checklist (SEPA), and Temporary Water Quality Modification Permit applications for submission to Ecology by May 15.

e. Acquire and maintain WSDA Pesticide Applicators License with Aquatics Endorsement. Assure compliance with all permit conditions issued by Ecology to the individual growers as specified to allow temporary modification of state water quality standards (see Attachment A: 2000 permit conditions).

f. Assure compliance with all label (24(c) Supplemental Label) requirements for the use of carbaryl in Willapa Bay and Grays Harbor (see Attachment B: current carbaryl label).

g. Oversee all carbaryl treatments that are hand-sprayed unless the grower intending to spray has acquired a WSDA Pesticide Applicators License with Aquatics Endorsement.

h. Oversee all carbaryl treatments that are aerially sprayed.

i. Provide Ecology a post spray report summarizing the results of treatment within a month of the last treatment of carbaryl. A copy of this report shall be provided to the Department of Fish and Wildlife. At a minimum, the report must include:

   1) All of the information provided in §5.1.B.1.

   2) All pertinent observations.

   3) Documentation of the actual areas treated, to the extent that any boundary revisions were made to the "applied for parcels" to accommodate tidal variations on spray day.

5.2 Ecology

A. Support the Growers Association in their efforts to develop and implement an IPM plan for burrowing shrimp control. Control of burrowing shrimp, particularly as it relates to the use of carbaryl, has attracted the concerns of state and federal resource agencies, tribes, citizen's group and shellfish growers. So long as the Growers Association is meeting its obligations under this MOA, and completes an IPM plan, which is subsequently approved by Ecology, Ecology agrees to support the process and the growers' efforts to control shrimp, and agrees to use the IPM as the vehicle for burrowing shrimp control. When appropriate, assist the Growers Association with identifying research funding opportunities, preparation of grant proposals and assisting with IPM related research.

   Timeframe – immediate and ongoing for the duration of this agreement.

B. Process permit applications for the application of carbaryl to shellfish beds for the control of burrowing shrimp in accordance with Chapter 90.48 Revised Code of Washington (RCW). Issue, condition or deny growers Temporary Water Quality Modification Orders for spraying (modification of water quality criteria specified in Chapter 173-201A-030 WAC). Assure the carbaryl spray program and future controls employed under IPM are in compliance with the State Environmental Policy Act (SEPA). Using the joint Ecology/WSDA Experimental Use Permit (EUP) application process, issue, condition or deny approval to test and evaluate other technologies and treatments.

   Timeframe – Immediate and ongoing.

C. Provide support in obtaining experimental use permits and/or label exceptions to allow studies that will explore alternative treatment timing and methodology if environmental risks are low, and with WDFW and WDOA concurrence, thereby assisting growers to achieve their responsibilities in §5.1.A.6.

   Timeframe – Immediate and ongoing.

D. Support growers in pursuing an investigation into the underlying reasons for increased burrowing shrimp populations (§ 5.1.A.7).

   Timeframe – As funding is available.

E. Approve, condition or disapprove the IPM plan developed by the OGA and submitted to Ecology. Ecology will make its decision on whether to approve the IPM plan within 30 days of submittal.

   Timeframe – Within 30 days after receipt of an IPM Plan.

5.3 Washington Department of Agriculture

Support Washington State Local Needs Pesticide Registration No. WA-900013 issued by EPA through the Washington Department of Agriculture under authority of section 24(c) of the Amended Federal Insecticide, Fungicide, and Rodenticide Act.

Timeframe - Immediate and ongoing.

5.4 Washington State Commission on Pesticide Registration

The Washington State Commission on Pesticide Registrations (WSCPR) was formed for the purpose of funding minor use pesticide registrations and development of improved pest management programs in the state of Washington. The primary means for the Commission to support minor use pest management needs is through the competitive disbursement of funds. The need to support the use of carbaryl and alternative tactics and products for control of burrowing shrimp on oyster beds qualifies for funding by the WSCPR. The WSCPR has funded two years of research on development of reduced risk alternatives to carbaryl and for two subsequent years on the more recent IPM program. The WSCPR would be willing to provide future support to the oyster growers association after a review and consideration of a favorably competitive proposal.

Timeframe - Immediate and ongoing.

5.5 Pacific Shellfish Institute

Assist the Growers Association with prioritizing research, identifying funding opportunities, preparation of grant proposals and assisting when appropriate in IPM related research.

Timeframe – Immediate and ongoing.

5.6 Pacific Coast Shellfish Growers Association (PCSGA)

Participate in the IPM development and review process, incorporating the resulting IPM plan into the PCSGA's Environmental Management System. Disseminate the burrowing shrimp IPM information for the benefit of other coastal growers plagued with similar infestations. Promote integrated pest management for pest and predator control of species other than burrowing shrimp.

Timeframe – Immediate and ongoing.

5.7 Washington Department of Fish & Wildlife

A. Provide substantive and timely response, decisions, and resources as available to § 5.2.A, B, C and D. and other sections as related to WDFW authority and expertise.

   Timeframe – Immediate and ongoing.

B. Consider experimental work on state oyster reserves as part of IPM development and implementation.

   Timeframe – Immediate and ongoing.

6. FUNDING FOR IMPLEMENTATION OF THIS AGREEMENT

6.1 Growers Association

A. The Growers Association will administer and manage an annual assessment/treated acre with individual growers to cover the Grower's Association's cost of administering this agreement.

B. The Growers Association will fund the IPM Coordinator, development of the IPM plan as well as research and monitoring needs identified by the IPM Committee.

6.2 Pacific Shellfish Institute

PSI agrees to assist the Growers Association in obtaining grant funding for research priorities.

6.3 Ecology

A. Ecology agrees to seek or maintain adequate funding in its budget to fulfill its obligations under this MOA.

B. Ecology agrees to assist the Growers Association in identifying and supporting opportunities to obtain funds for the research and monitoring necessary to develop and implement an effective IPM plan for burrowing shrimp.

6.4 Washington Commission on Pesticide Registration

When funding is available, support the Growers Association efforts to achieve the research and monitoring necessary to develop and implement an effective IPM plan for burrowing shrimp, through the consideration and approval of favorably competitive grant request(s) submitted by the Growers Association in accordance with Commission procedures and requirements.

7. COMMUNICATIONS

7.1 Annual Meeting

At least once a year, within the months of January or February, the Growers Association will sponsor and facilitate a meeting of (but not limited to) the signatories of this MOA.

The agenda for these annual meetings shall include:

- Review of past year's data.
- Previous year's issues.
- Previous year's IPM development actions.
- Recommendations for management changes.
- Status and evaluation of the MOA milestones.
- Prioritization of MOA actions described as "immediate and ongoing" for the coming year's activities.
- Recommendations for Agreement (MOA) Amendments.
- Evaluation of IPM effectiveness.
- Recommendations for IPM revisions.

Notes will be prepared for each meeting which document meeting notice, attendance, discussion, positions, and decisions. Notes will be provided to all parties for signatures of concurrence or attachment of alternate language.

7.2 Special Meetings

Any party may request a special meeting at any time. Meetings will be arranged as soon as possible, but within 30 days of the request. However, meetings requested by Ecology relative to regulatory action, must be held within seven days of the request.

7.3 Points of Contact

A. Permit and Process

1. Ecology:

   Janet Boyd
   PO Box 47775, Olympia, WA 98504-7775
   Phone (360) 407-0245
   FAX (360) 407-6305

   Email: jboy461@ecy.wa.gov

2. Growers Association:

   Dennis Tufts
   PO Box 236
   Ocean Park, WA 98640
   Phone (360) 665-4577
   FAX (360) 665-6064

   Email: mobydick@willapabay.org

3. Routine and Administrative Matters:

   a. Ecology:

      Mark Bentley
      PO Box 47775, Olympia, WA 98504-7775
      Phone (360) 407-7269
      FAX (360) 407-6305

      Email: mabe461@ecy.wa.gov

   b. Growers Association:

      Bill Dewey
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      130 SE Lynch Road, Shelton, WA 98584
      Phone (360) 426-6178
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8. AMENDMENTS

From time to time, changes in this agreement may be necessary to reflect an adaptive management approach to the use of carbaryl, permit conditions, points of contact, label changes, environmental conditions, economic conditions, or regulatory changes. Any party may develop proposed amendments consistent with the purpose of this Agreement for the consideration of all parties. Such amendments should be proposed for discussion and possible adoption at the annual meeting.

This agreement may be amended by adding new parties and new dates for those parties at any time upon written invitation by Ecology and the Growers Association through their contact persons in § 7.3.A.. New parties and their duties may be added through attachment of an appendix to this agreement, signed by the new parties, Ecology and the Growers Association. No original party shall be liable or responsible for any additional duties or an expansion of original duties without the written consent of the original party.

9. ENFORCEMENT

Development of an approved IPM is intended to provide substantial compliance with Chapter 90.48 RCW and the water quality criteria for Willapa Harbor and Grays Harbor. This MOA does not affect Ecology's regulatory authority under Chapter 90.48 RCW.

10. DURATION AND TERMINATION

This Agreement shall be in effect from the date of signature by all parties, and shall continue to be in effect until such time as the Growers Association or Ecology terminates pursuant to the termination process described below.

The Growers Association or Ecology may terminate this Agreement by submitting written notice of termination to the other parties at least 90 days in advance. Any other party may withdraw from this agreement on 30 days notice to the other parties, and this agreement shall continue in affect for the remaining parties.

11. SIGNATURES

Burrowing Shrimp
INTEGRATED PEST MANAGEMENT
Memorandum of Agreement

_____ _____
Kelly Susewind, SWRO Water Quality Section Manager Date
Washington Department of Ecology

_____ _____
Doug Muse, Chairman Date
Washington Commission on Pesticide Registration

_____ _____
Jim Jesernig, Director Date
Washington Department of Agriculture

_____ _____
Brian Sheldon, President Date
Willapa/Grays Harbor Oyster Growers Assoc.

_____ _____
Brett Bishop, President Date
Pacific Coast Shellfish Growers Assoc.

_____ _____
Bill Dewey, President Date
Pacific Shellfish Institute

_____ _____
Jeff Koenings, Director Date
Washington State Department of Fish and Wildlife

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Attachment A: Year 2000 Permit Conditions

Attachment B: Current Carbaryl Label

Appendix B

The Economic Impact of Shellfish Aquaculture in Washington, Oregon and California

Prepared for

Pacific Shellfish Institute

April 2013

Prepared by

Northern Economics

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Abbreviations

CDFW	California Department of Fish and Wildlife
I-O	Input-Output
NSSP	National Shellfish Sanitation Program
PSI	Pacific Shellfish Institute
WDFW	Washington Department of Fish and Wildlife

Executive Summary

The objective of this analysis was to assess the economic impact of shellfish aquaculture production in the states of Washington, Oregon and California. Our intent was to explicitly identify the production function of the industry through detailed interviews with key informants and a general survey of producers. The motivation for doing this research was to develop reliable economic information for policy makers managing local marine resources and global issues such as eutrophication of estuaries and effects of ocean acidification. The species covered include Pacific, Kumamoto, Eastern, European Flats, and Olympia Oysters, Manila, littleneck and geoduck clams, and Blue and Mediterranean mussels. These species are grown out on the ground, on the ground in bags or racked bags, and long line culture and are harvested using methods that include high pressure hoses, hand picking, and dredging.

To assess the economic impact of shellfish aquaculture in Washington, Oregon and California, Northern Economics implemented a survey of shellfish growers and conducted an Input-Output (I-O) analysis. I-O analysis is a modeling tool used to measure the economic effects of a project or industry using a matrix that tracks the flow of money between the industries within a specified economic region of interest. For the purpose of our analysis, the regions of interest were the states of Washington, Oregon and California. The model measures how many times a dollar is re-spent in, or "ripples" through, each of these states' economies before it leaks out. Indirect impacts quantify the effect of spending within the study region on supplies, services, labor, and taxes. Induced impacts measure the money re-spent in the study area as a result of spending by labor. Direct, indirect, and induced impacts sum to the total economic impacts of a project or industry. This analysis presents total impacts as economic output, jobs created, and labor income generated within the study area.

The study team used IMPLAN™ software to estimate economic impacts to the Washington, Oregon and California economies. IMPLAN is a software tool which uses information sourced from local and census sources to produce region-specific economic impact models. IMPLAN uses specific data on what inputs are needed to produce the goods or services for over 440 economic sectors, and county-specific data on what industries are available locally from which to purchase those inputs. This analysis used IMPLAN 2010 data. The limitation to most (not all) of the shellfish economic impact studies reviewed in the literature is that estimates are based on data which are not refined enough to develop an actual production function for the industry or use multipliers not directly reflective of the shellfish industry's' spending patterns. This study attempts to account for these limitations by collecting detailed expenditure data by type and location of each business. Table ES-1 outlines the summary statistics used to generate final results.

Table ES-1. Summary Statistics

	WA	CA	OR
Acres Reported	22,502	6,201	3043
Farmed Acres Reported (%)	62%	12%	32%
Total State Acres	29,663	6,201	5,011
Employment	1,266	204	0
Revenues/Sales ($)	90,296,206	25,856,668	9,313,300

Expenditures/Acre ($)	4,880	1,912	n/a
Reported Production (lbs)	19,009,588	1,792,795	n/a

n/a = not available

The study team estimates that the shellfish aquaculture industry in Washington spent approximately $101.4 million in the Washington economy in 2010, which in turn generated $184 million, or 1.8 times the activity. Shellfish farmers were responsible for approximately 1,900 direct jobs in 2010. They also generated an additional 810 jobs through indirect and induced activity, for a total of 2,710 jobs. Finally, shellfish farmers paid approximately $37 million in wages in 2010. Their economic activity generated additional labor income of $39.9 million, for a total of $77.1 million in labor income in the state of Washington.

The California shellfish aquaculture industry spent approximately $11.9 million in that state's economy in 2010, which in turn generated $23.3 million or 1.9 times the activity. Shellfish farmers were responsible for approximately 200 direct jobs in 2010. They also generated an additional 80 jobs through indirect and induced activity, for a total of 280 jobs. And, finally, shellfish farmers paid approximately $5.4 million in wages in 2010. Their economic activity generated additional labor income of $4.6 million, for a total of $10 million in labor income.

The study was unable to assess the complete range of economic impacts for Oregon due to data limitations. For Washington State and California, we were able to estimate direct, indirect, and induced impacts as well as identify related multipliers. The study team calculated the economic impacts differently for Washington and California, however, again due to different levels of detailed expenditure data collected. Since the team was able to collect detailed expenditure data for Washington, we were able to calculate the expenditures going to each supporting industry and whether those expenditures remained in the study area. The expenditure data reported through the general survey implemented in California demonstrated a pattern similar to that of Washington. As a result, the study team assumed the spending in the "other" category of expense was the same as in Washington and that expenditures remained in the study area. Because of the diverse nature of the data sets for each state, comparison of economic impacts between states is not meaningful. However, in general, the statistics generated in this study enhance our knowledge about the west coast shellfish aquaculture industry and can be used to inform management and policy decision making.

As noted in the study the results of our analysis apply specifically to commercial shellfish growers. Our analysis is not representative of the entire shellfish industry as wild and tribal harvest and shellfish bed restoration are not included. The study team believes tribal growers and harvesters, wild harvesters, and shellfish restoration activities have unique production and expenditure patterns and warrant further investigation. Finally, our study focuses on the economic impacts of the production of cultured shellfish only and did not include sales trends and demand factors. Another area of potential future research is the economic impacts of shellfish consumption. Residents and tourists of west coast communities all enjoy and benefit from the supply of fresh shellfish provided by the aquaculture industry. People purchase shellfish through retail markets, consume shellfish in restaurants, and enjoy local seafood fare at fundraisers and events. An investigation into the revenue generated through these types of shellfish sales could serve as a means to quantify additional economic impacts of the shellfish aquaculture industry.

1 Introduction

As the shellfish aquaculture industry grows on the west coast of the United States and around the world, growers and policymakers strive for a deeper understanding of the industry's economic impact on local regions. Assessing an industry's economic impact is a way to gain a deeper understanding of the role that industry plays in the local economy, thereby helping industry representatives and local policy makers to make informed decisions. This analysis of shellfish aquaculture extends from basic statistics such as total revenue and employment to more detailed information such as tax payments and employee wage rates. Even more telling is the industry's connection to the other industries that supply it with inputs. This last area of analysis helps explain shellfish aquaculture's broader impacts on other industries.

Several studies have attempted to estimate the economic impact of shellfish aquaculture in the United States. A study from the NOAA Fisheries Office of Habitat Conservation used an input-output model, to estimate that oysters worth $1 million in dockside value in Chesapeake Bay generate an estimated $36.4 million in total sales, $21.8 million in income, and 932 person-years of employment (NOAA undated). Gardner Pinfold Consulting Economists Ltd. (2003) and O'Hara et al. (2003) estimated the economic impacts of shellfish aquaculture in Maine, while Philippakos et al. (2001) utilized an input-output methodology to estimate the direct, indirect, and induced economic impacts of the cultured clam industry in Florida. Burrage et al. (1990) examined the regional economic impacts of a project intended to revitalize the northern Gulf Coast oyster industry by relaying oysters (moving oysters from leases under compromised water quality to leases in cleaner, approved waters before final harvest). Adams et al. (2009) report on the significant growth in economic impact of commercial cultured clams in Florida linked to strong demand for cultured shellfish, support by relevant agencies, and continued supply of high quality coastal water within the region. They estimated the economic impact to the Florida economy in 2007 to be $52 million. Note that these authors do not report where or how they derived the multipliers they used in their analyses. Koeger (2012) reports the economic impacts from two reef construction projects in Alabama and associated activities (reef monitoring and community workforce training) to be $8.4 million in local output, $2.8 million in earnings and 88 jobs created. The study estimates that these reef construction projects will inject $4.3 million into two local counties.

In Washington State, an early study by Bonacker and Cheney (1988) measured the direct economic impacts of shellfish culture in Willapa Bay. The study examined expenditure patterns of industry employees but did not calculate multiplier effects. According to a 1987 study of Washington's aquaculture industry conducted by the Washington State Department of Trade and Economic Development (Inveen 1987), the ratio of total jobs to direct jobs for the oyster industry was 1.17. That is to say, for every one job directly related to the industry, 0.17 additional indirect jobs were generated in other industries throughout the state. An economic impact analysis conducted in the early 1990s by Conway (1991) suggested that, on average, each job in Washington's oyster industry supported 1.13 additional jobs elsewhere in the state economy—this constitutes an employment multiplier for the oyster industry equal to 2.13. Wolf et al. (1987) of the Economic Development Council of Mason County estimated the economic impact of the County's oyster industry using the employment multiplier of 1.17 from the Washington State Department of Trade and Economic Development's 1987 study. The analysis was updated in

2002 using the same employment multiplier (Economic Development Council of Mason County 2002).

The limitation to most (not all) of the studies reviewed is that they estimate the economic impacts of projects related to shellfish aquaculture and restoration without gathering detailed expenditure data or with use of a multiplier not directly related to shellfish production. That is, much of the previous work did not collect the data necessary to generate a production function specific to shellfish aquaculture. This study attempts to account for these limitations.[1] The goal of this study was to collect the missing information needed to understand the economic impacts of the west coast shellfish aquaculture industry by gathering data directly from shellfish aquaculture growers. To that end, the study team surveyed growers in Washington, Oregon and California on their revenue, expenditures, and employment to measure industry levels of spending and employment in each state. The study team also gathered detailed expenditure data from seven Washington State shellfish growers to model the additional economic effects generated by shellfish growers in Washington and California.

1.1 Purpose

Knowledge of the economic impact of shellfish aquaculture is beneficial in several policy contexts. The economic model developed in this study can be applied to future shellfish aquaculture projects to understand their economic impacts. The quantification of the existing industry impacts demonstrates part of the economic loss that is possible from lost shellfish aquaculture production due to ocean acidification or water quality degradation. In addition, the economic impacts can illustrate the relative importance of shellfish aquaculture to other industries in the state.

Note that the economic impacts described in this report are only part of the total value of shellfish and shellfish production. Shellfish provide numerous benefits to society including food for human consumption and removal of nitrogen through bioextraction. The study *Washington State Shellfish Production & Restoration—Environmental and Economic Benefits and Costs* (http://pacshell.org/pdf/NMAIeconfinalreport.pdf) enumerates the full suite of these values and estimates a value for some of them in a series of memoranda. Northern Economics, Inc.'s 2010 report, *Assessment of Benefits and Cost Associated with Shellfish Production and Restoration in Puget Sound* (Northern Economics, 2010a) provides context for how economic impacts relate to the full valuation of shellfish production and restoration.

1.2 Report Organization

The following sections describe first the study methodology (Section 2), then the analysis of survey responses from Washington State (Section 3), Oregon (Section 4), and California (section 5). The final section discusses the study's conclusions (Section 6).

[1] The term 'shellfish aquaculture industry' in this report refers strictly to the cultivation of shellfish for market consumption or shellfish growers. We do not address the economic impacts of tribal, wild harvest, or restoration of shellfish beds.

2 Methodology

To assess the economic impact of shellfish aquaculture in Washington, Oregon and California, Northern Economics implemented a survey of shellfish growers and conducted an Input-Output (I-O) analysis. I-O analysis is a modeling tool used to measure the economic effects of a project or industry using a matrix that tracks the flow of money between the industries within a specified economic region of interest. For the purpose of our analysis, the regions of interest were the states of Washington, Oregon and California. The model measures how many times a dollar is re-spent in, or "ripples" through, each of these states' economies before it leaks out.

Expenditure data form the basis of an I-O analysis. For this analysis, the team collected shellfish aquaculture industry spending data through a major survey effort. This section of the report describes the data gathering effort (Section 2.1) and the study team's I-O approach (Section 2.2).

2.1 Surveys and Key Respondent Interviews

The development of the survey instrument for this study began with an NEI 2010 pilot study for this analysis. In this study, Northern Economics worked with one shellfish grower, going through their 2009 line-item expenditures to determine the sectors where shellfish growers make their largest purchases. We used the expenditure data to develop a pilot survey that two other growers completed. While the results of this work were never fed into an I-O analysis, Northern Economics gained insight into grower activities and documented other lessons learned.

Northern Economics, with input from the study team members and the Pacific Coast Shellfish Growers Association, developed this more recent project's survey. For the purposes of this study we used a hybrid approach.[2] Those respondents willing to share more detailed expenditure data would be interviewed and become "key respondents." Those willing to participate, but only prepared to share less-detailed information would be asked to complete a more general survey. All respondents were asked to report on 2010 production.

2.1.1 Key Respondent Interviews

The key respondent interviews were exhaustive, and provided the detailed data necessary to determine the shellfish aquaculture industry's spending patterns. Pacific Shellfish Institute (PSI) research biologist Bobbi Hudson conducted the key respondent interviews from May 2011to August 2012. For these interviews, PSI received complete expenditure data for 2010 from respondents in addition to the general survey data. The key respondent interviews provided the critical information that allowed for the proper coding of the industry and location of each supplier, and data for determining the purchasing patterns of each state's aquaculture industry, described in section 2.2.1.

The seven key respondents were all from Washington, and represented $27 million in expenditures, or 37 percent of the $72 million total Washington aquaculture industry expenditures estimated by this study. Key respondent interviews were not possible in Oregon

[2] We recognized that gathering detailed data from all growers would not be possible due to the hesitancy of some growers to provide sensitive business-related information.

and California. As a result, the study team generated I-O results for California using general responses and sector data spending patterns from Washington. Data collected in Oregon were insufficient for conducting an I-O analysis.

2.1.2 General Surveys

The general survey was easy for respondents to complete and provided the bulk of the data for gauging total industry spending. The study team developed slightly different general surveys for Washington, Oregon and California in order to accommodate their unique characteristics (please see Appendix A for a copy of each survey). Generally, the surveys provided the following information:

- Acres leased, owned, and under production
- Expenditures by category (payroll, capital purchases, fuel purchases, payments to government, etc.)
- Production by species and product type
- Gross sales

Bobbi Hudson administered the general survey to shellfish aquaculture producers between May and August 2012. A paper copy and cover letter were mailed to every certified shellfish "entity" in Washington (330), Oregon (42), and California (30). Licensed shellfish contact lists were obtained from the appropriate state agencies. Shellfish production data was established through the FDA's National Shellfish Sanitation Program (NSSP) (http://www.fda.gov/Foodfoodsafety/Product-SpecificInformation/Seafood/FederalStatesPrograms/NationalShellfish Sanitation portal/state_permitting_shelflish_aq.pdf). NSSP dictates a license structure to protect human health and each state has a designated manager required to maintain monthly updated lists of licensed producers (Washington Department of Health, Oregon Department of Agriculture, and California Department of Fish and Wildlife respectively). Due to the license structure in each state, not all shellfish "entities" were a match for our target audience—shellfish growers with 2010 production numbers. In Washington "harvesters" were included because some harvesters maintain their own tidelands for commercial production. In Oregon there are so few "growers" (23); surveys were also mailed to "shellstock shippers" and "shellstock producers." In California, registered "aquatic farmers" included non-bivalves such as abalone and algae producers, which were eliminated from the survey. In Washington, the team also had email addresses for nearly all of the DOH registered shellfish producers, so non-respondents were emailed an additional request to fill out the survey with a link to an online copy. In Oregon, David Landkamer of Oregon Sea Grant called non-respondents to solicit responses. Ted Kuiper (formerly of Kuiper Mariculture) of California called or met with each grower to complete the survey, as well as followed up with several Oregon growers. All responses were mailed to Bobbi Hudson of PSI for input into Excel spreadsheets

2.2 Input-Output Analysis

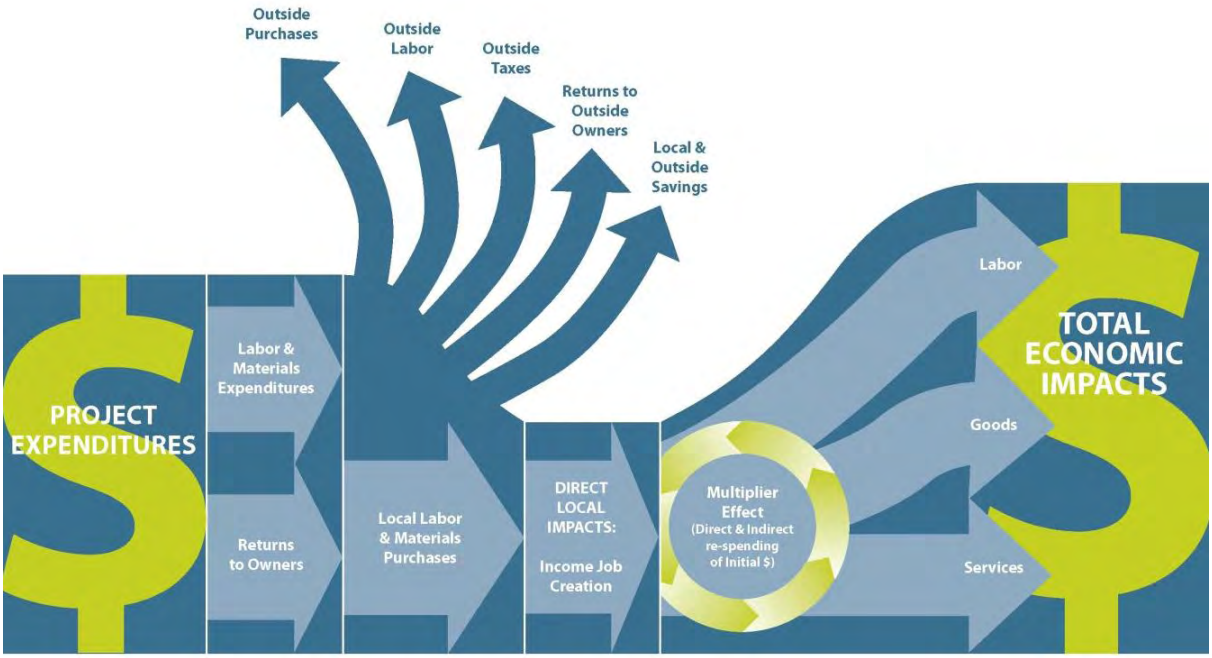
Economies are complex networks of relationships among businesses and people. I-O analysis is a modeling approach that economists use to map these complex relationships. An I-O model portrays an economy as a matrix of inputs and outputs; it allows economists to understand and

quantify how regional industries interact with one another. For the purpose of our analysis, I-O allows us to estimate what impact shellfish aquaculture has on the Washington, Oregon and California economies.

Figure 1 illustrates conceptually how an I-O analysis calculates economic impacts. The dollar sign on the left represents project or industry expenditures; in our case, this is the money that is spent by the shellfish aquaculture industry. This money is either spent on labor and materials or distributed as returns to owners. Only a portion of this spending is retained within the I-O framework; as indicated by the upward arrows, money distributed outside of the study area is considered a leakage. The I-O framework only uses the purchase of local labor and materials to calculate direct local impacts.

Once the study team determines direct local impacts, they can use an I-O model to estimate how this spending affects other businesses within the study area economy. Like a rock tossed into a pond, the direct expenditures produce rings of additional activity, referred to as indirect and induced impacts. Indirect impacts quantify the effect of spending within the study region on supplies, services, labor, and taxes. Induced impacts measure the money re-spent in the study area as a result of the indirect impacts. Direct, indirect, and induced impacts sum to the total economic impacts of a project or industry. This analysis presents total impacts as economic output, jobs created, and labor income generated within the study area.

Figure 1. Framework for Evaluating the Total Economic Effects or Impacts of Local Spending



Source: Northern Economics, Inc. 2011.

The study team used IMPLAN™ software to estimate economic impacts to the Washington, Oregon and California economies. IMPLAN is a software tool which uses information sourced from local and census sources to produce region-specific economic impact models. IMPLAN uses specific data on what inputs are needed to produce the goods or services for over 440 economic

sectors, and county-specific data on what industries are available locally from which to purchase those inputs. This analysis used IMPLAN 2010 data.

2.2.1 Shellfish Aquaculture Industry Multipliers

Developing an accurate sector profile requires knowledge of the purchasing patterns of the industry being analyzed. The 440 sectors within IMPLAN are an aggregation of the many more industries which make up the U.S. economy. Each of the sectors of the national economy is assigned to a North American Industry Classification System (NAICS) code. The thousands of available NAICS codes are condensed into the 440 IMPLAN sectors. For example, IMPLAN maps NAICS codes beginning with 1122-1129 (which includes raising hogs and pigs, sheep and goat farming and animal aquaculture) to IMPLAN sector 14 – Animal Production, except cattle, poultry, and eggs.

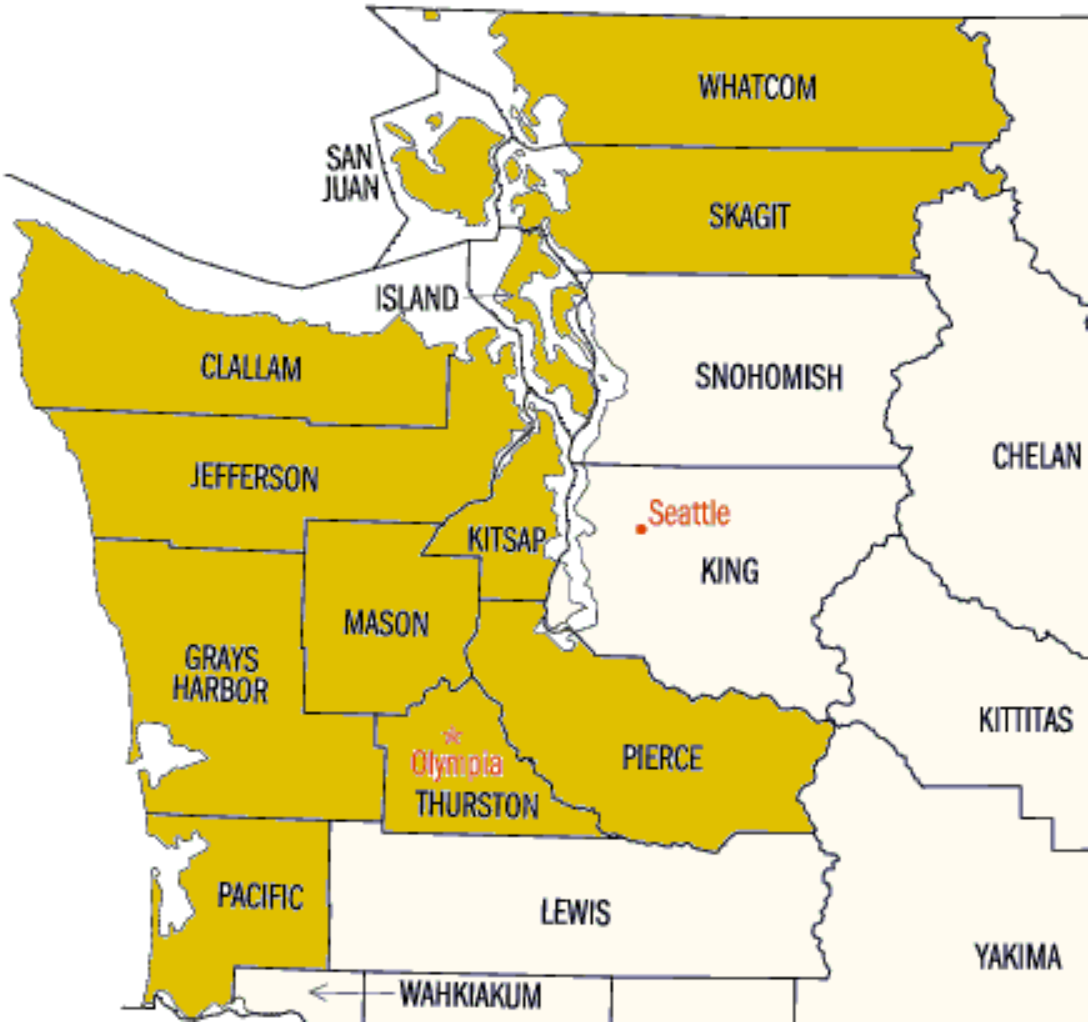
Rather than simply use IMPLAN sector 14, the study team sought a more accurate sector profile for shellfish aquaculture. To this end, the study team identified the spending patterns unique to shellfish aquaculture growers using the information obtained through the survey effort. The shellfish aquaculture purchasing pattern tells us which industries the shellfish industry purchases inputs from and the location of those suppliers. The study team then mapped this spending pattern to IMPLAN support sectors, generating the I-O multipliers used to calculate the indirect and induced effects on jobs, income, and business sales/output generated per dollar of spending on various types of goods and services in the study area[3].

[3] It is worth noting that the 'other' spending category required use of the Washington detailed survey responses for both Washington and California. The study team assumes that general spending categories for 'other' spending are similar in both states, however, California results are generated using California multipliers.

3 Washington State Analysis

Shellfish aquaculture in Washington takes place in 12 of the 39 counties in the state. Figure 2 highlights these counties.

Figure 2. Washington Counties with Shellfish Aquaculture Activity



Source: Adapted from U.S. Census Bureau 2012

This section summarizes survey responses, highlights the acreage and expenditure data that formed the basis of the Washington shellfish aquaculture I-O analysis, and presents statewide economic impacts, with an estimate of contribution of impact by county.

3.1 Survey Results

Of the approximately 330 commercial[4] shellfish growers in the state of Washington, a total of 43, or 13 percent, responded to the survey. However, these respondents accounted for 76 percent of the total permitted acreage in the state (Table 1). Seven of these firms submitted detailed expenditure data, while the remaining 36 submitted responses to the more general survey. It is worth noting, however, that only 32 of the 43 total respondents reported acreage and expenditure data, two elements critical to our study. The metrics presented in the tables and figures below are based primarily on these 32 responses.

Table 1 summarizes the survey response rate as a percentage of commercially farmed acres by county. Again, the numbers shown include only responses which included both acreage and expenditure data.

Table 1. Survey Response Rate by Acreage and County

County	Survey Acreage	Total Acreage	Response Rate (%)
Grays Harbor	3,278	2,288	143*
Island	55	87	63
Jefferson	666	1,155	58
Kitsap	25	485	5
Mason	814	4,079	20
Pacific	14,681	17,288	85
Pierce	39	138	28
Skagit	2,233	3,018	74
Thurston	710	1,037	68
Other	-	88	0
Total	**22,502**	**29,663**	**76**

Note: Total acreage by county was supplied to Northern Economics, Inc. by PSI.
*Acreage reported for Grays Harbor by survey respondents exceeds total acreage in Washington Department of Health database. PSI confirmed with respondents that the survey total is likely correct and the difference is due to inaccuracies in the WDFW database.
Source: Northern Economics, Inc. using survey data provided by PSI.

3.1.1 Employment

Survey respondents[5] reported 1,266 direct jobs in Washington. Responses from individual firms ranged from a low of 0 to more than 400 employees. The study team believes that the majority of non-responses to the question stem from self-employed farmers who do not employ additional staff and failed to include themselves when reporting. The breakdown of firm size (as measured by employment) is illustrated in Table 2.

[4] It is worth noting that the 330 non-tribal commercial shellfish growers include harvest license holders who are not necessarily shellfish growers. Consequently the 330 total overstates the actual number of shellfish aquaculture farmers.

[5] Only respondents who reported acreage, employment and expenditures are included.

Table 2. Count of Washington Respondents by Number of Employees, 2010

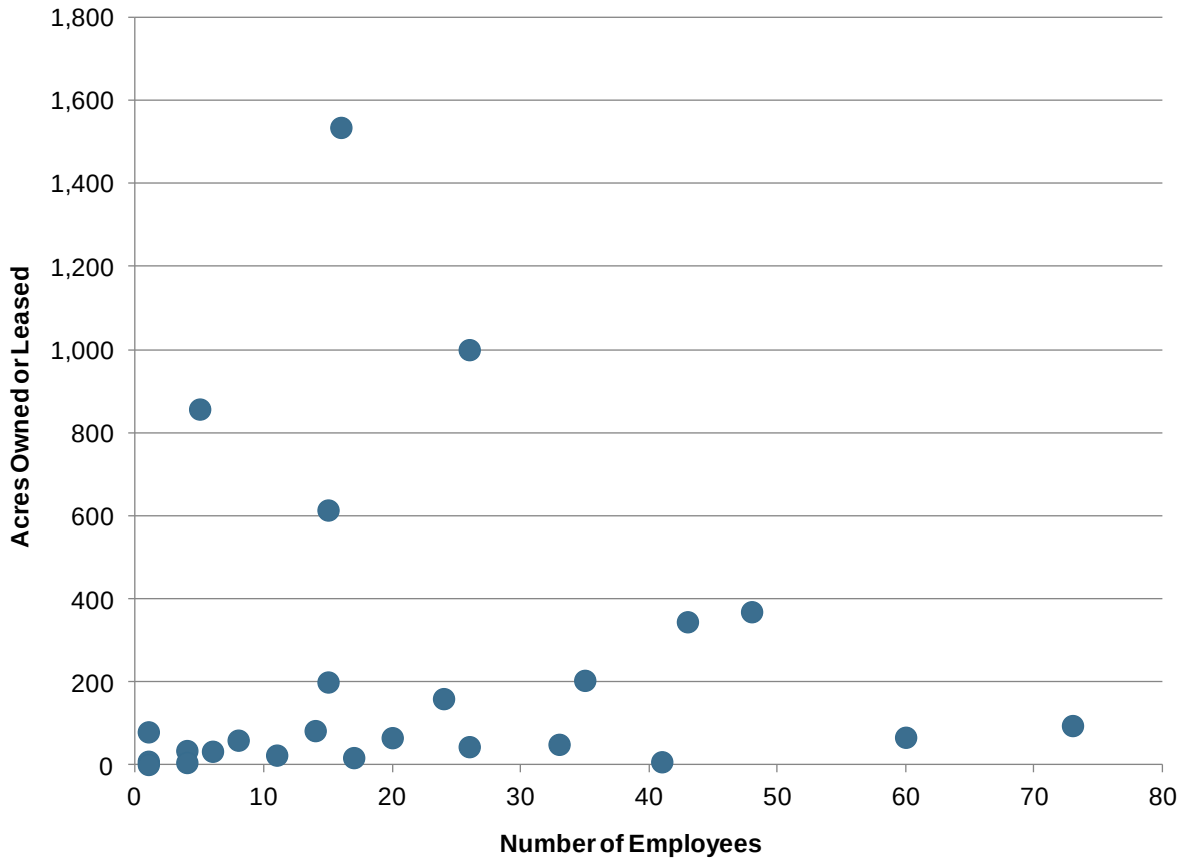
Size of Business	Count of Firms[6]	Percent of Total
No Employment Reported	14	33
1 to 10 Employees	9	21
11 to 30 Employees	10	23
31 to 50 Employees	5	12
>50 Employees	5	12
Total	**43**	**100**

Source: Northern Economics, Inc. using survey data provided by PSI.

Employment numbers reported by shellfish growers vary significantly by operation type. As shown in Figure 3, the number of employees reported by an individual firm varies across farm size. Of those survey respondents who provided employment and acreage information, minimum employment was .01 persons per farmed acre (or 1 person per 100 farmed acres) while maximum employment is reported as 5 people per farmed acre (or 500 people per 100 acres). On average, Washington growers employ a total of 1 person per farmed acre. Assuming the lowest employment ratio reported, we estimate a total of 1,840 direct jobs statewide (1 employee per 100 farmed acres).

[6] This 14 count is a minimum. Additional employment was reported for the aquaculture industry, but related to processing, so omitted from the data summary.

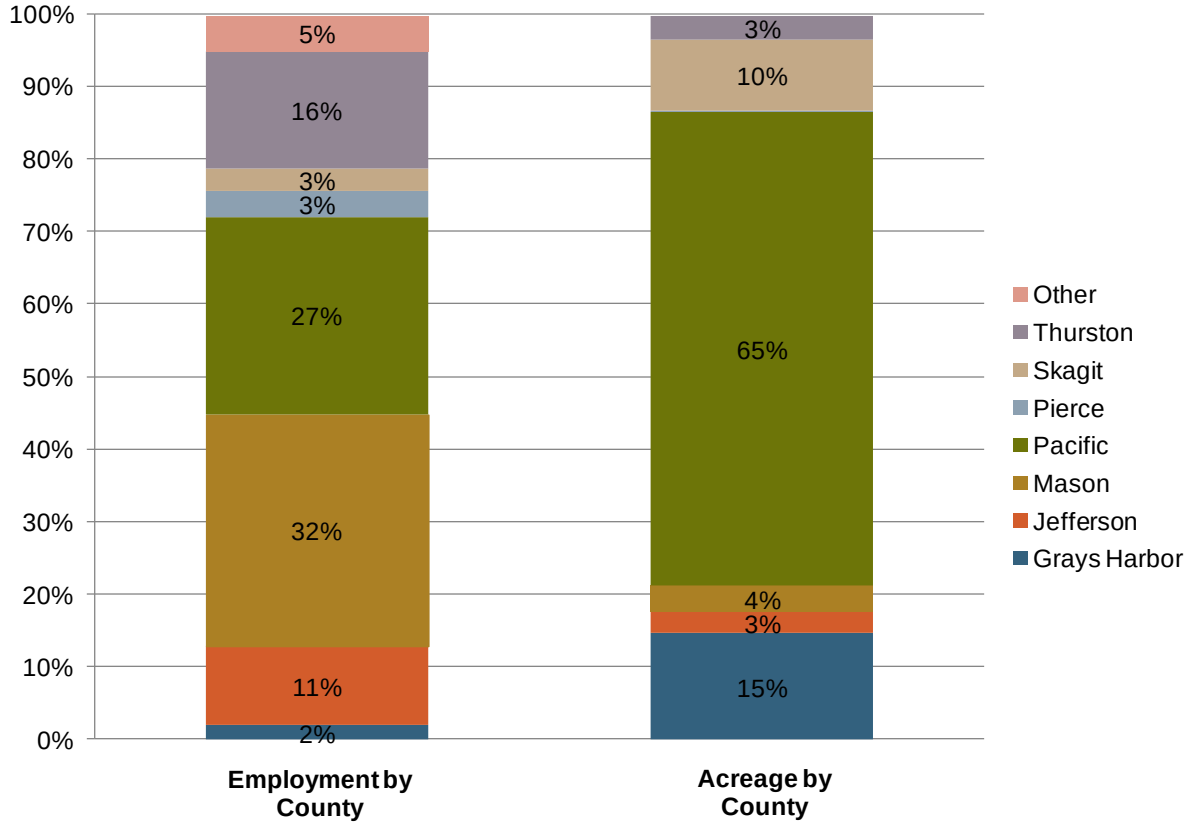
Figure 3. WA Shellfish Aquaculture Employment and Farmed Acreage, 2010



Note: Two survey respondents are omitted from this figure to avoid identification. Only respondents who reported both employment and acreage are included.
Source: Northern Economics, Inc. using survey data provided by PSI.

The majority of the leased or owned acreage of survey respondents was held in Pacific, Grays Harbor, and Skagit Counties; however, employment at these shellfish farms was not restricted to the county in which the leases are held. For example, only 4 percent of the acreage reported by survey respondents was held in Mason County, but 32 percent of the employees were reported to be residents of Mason County. Survey respondents also reported having employees in non-shellfish producing counties (grouped below as 'Other'). This confirms that employment activity generated by shellfish aquaculture farms impacts surrounding counties.

Figure 4. WA Surveyed Shellfish Aquaculture Acreage and Employment by County, 2010



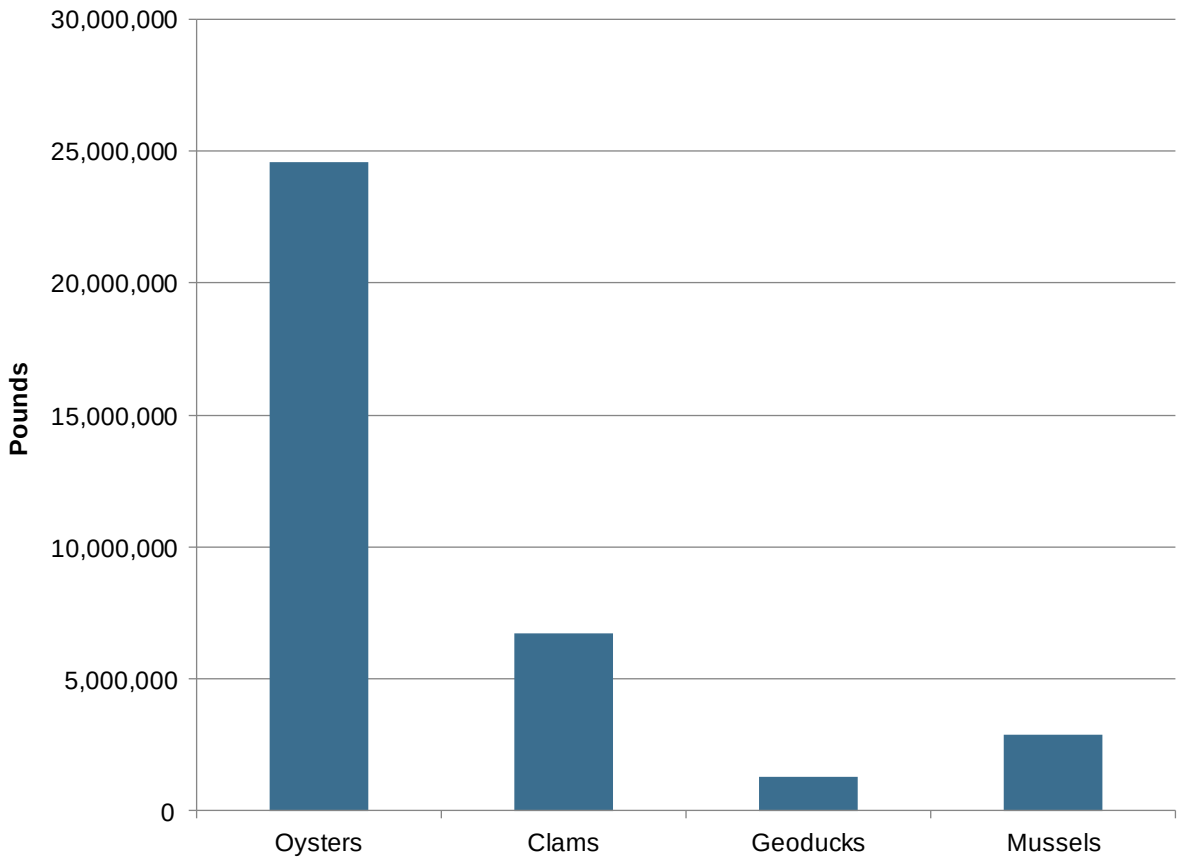
Source: Northern Economics, Inc. using survey data provided by PSI.

3.1.2 Production and Revenues

Respondents reported 2011 shellfish production by species and product type. Of the 43 total respondents, 30 provided information on both revenues and production. The responses from the 30 survey respondents represented more than $90.3 million dollars in total revenue and $89.4 million worth of shellfish sales. While survey respondents did not attribute sales to species types, they did supply total production volumes, summarized in Figure 5. Data were reported in round pounds, dozens, bushels and gallons. The study team standardized responses using pounds of meat weight for oysters[7] and round pounds for other shellfish species.

[7] Per the Washington Department of Fish and Wildlife: 1 dozen oysters assumed to weigh .546 pounds (meat weight). 1 gallon of oyster meat is assumed equivalent to 1 bushel of shell-on oysters; both weigh 8.75 pounds in meat weight.

Figure 5. WA Survey Response Production Volumes, 2010



Source: Northern Economics, Inc. using survey data provided by PSI.

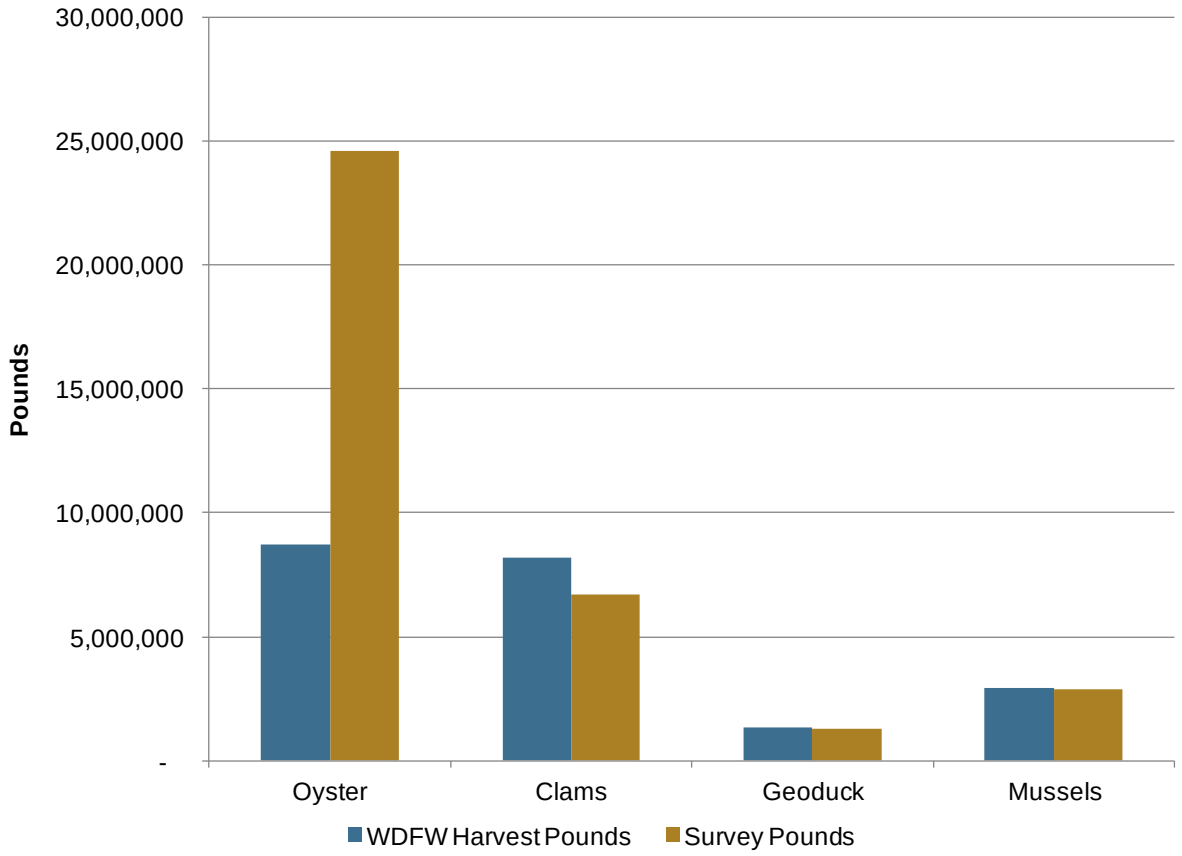
Washington Department of Fish and Wildlife (WDFW) maintains a database of shellfish harvest and production. Until recently, reporting production was voluntary. Table 3 and Figure 6 summarize reported survey production volumes and WDFW recorded production volumes. Of significant note is the difference in oyster volumes, which suggests that the state data omit a large portion of annual production.

Table 3. WDFW 2010 Shellfish Aquaculture Data

Species	WDFW Harvest Pounds (2010)	Survey Pounds (2010)	Reported Survey Volumes as a Percent of WDFW Recorded Volumes
Oyster	8,736,978	8,115,126	93
Clams	8,207,220	6,728,674	82
Geoduck	1,351,310	1,297,814	96
Mussels	2,947,456	2,867,974	97
Total	**21,242,964**	**19,009,588**	**89**

Source: Northern Economics, Inc. using survey data provided by PSI and WDFW 2010

Figure 6. WA Survey Response Production Volumes and WDFW Recorded Volumes, 2010



Source: Northern Economics, Inc. using survey data provided by PSI and WDFW 2010

3.1.3 Acreage and Expenditures

The study team estimated the total economic impact of the shellfish aquaculture industry in Washington using estimates of acreage and expenditures. The Washington Department of Health tracks statewide tideland acres permitted for shellfish aquaculture. Using their database, PSI filtered leased acres for duplicate permits, wild catch areas and tribal acres to derive the estimates of total commercially permitted acres by county (Table 4).

Table 4. Non-Tribal Permitted Acres (Excluding Wild Catch)

County	Acres	Species Cultured
Grays Harbor	2,288	oyster, clams
Island	87	oyster, clams
Jefferson	1,155	oyster, clams, geoduck
Kitsap	485	oyster, clams, geoduck
Mason	4,079	oyster, clams, geoduck
Pacific	17,288	oyster, clams
Pierce	138	oyster, clams, geoduck
Skagit	3,018	oyster, clams
Thurston	1,037	oyster, clams, geoduck
Clallam	86	oyster, clams
King	-	
Snohomish	-	
Whatcom	2	
Grand Total	**29,663**	

Source: PSI using DOH 2008

As previously noted, survey respondents who supplied both acreage and expenditure data accounted for 22,500 acres or 76 percent of the 29,663permitted acres in Washington State. The shellfish aquaculture growers that either own or lease these acres spent a total of $69.8 million in 2010. Of this total, approximately 81.1 percent[8] or $56.6 million were spent in the State of Washington. The remainder was paid to firms or individuals out of state. Expenditures by firm varied significantly, as shown in Table 5.

Table 5. Washington Survey Respondents by Scale of Operations

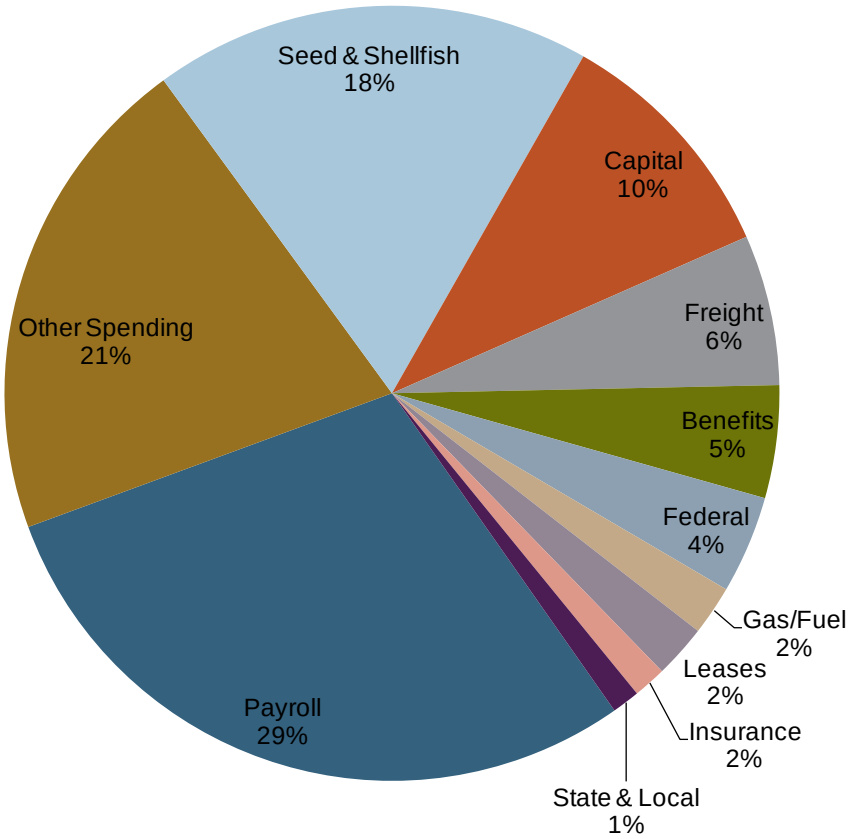
Scale of Operations (Spending Levels)	Number	Percent
Greater than $10 M	3	8
Between $1 to $10 M	7	19
Between $500 K and $1 M	9	25
Between $100 K and $500 K	7	19
Between $50 K and $100 K	3	8
Less than $25 K	7	19
Total	**36**	**100**

Source: Northern Economics, Inc. using survey data provided by PSI

[8] Based on key respondent data

The majority of firms' expenditures are payroll, intermediate inputs (seed and shellfish) and capital purchases. Figure 7 illustrates the general spending pattern of Washington State shellfish aquaculture firms.

Figure 7. Washington Shellfish Aquaculture Expenditures by Type, 2010



Source: Northern Economics, Inc. using PSI Survey responses, 2012

Using acreage and expenditure data reported, the study team derived metrics for expenditures per acre. On average, shellfish aquaculture firms spend approximately $3,100 for every acre that they own or lease. Given that 37.8 percent of tidelands are left unfarmed in any given year, this dollar amount becomes $4,988 for every farmed acre. It should be noted that given 81.1 percent of non-payroll expenditures are spent directly in Washington,[9] we calculated an estimate of $4,880 per farmed acre.

3.2 Economic Impact in Washington State

In order to assess the economic impact of Washington's shellfish aquaculture industry, the study team estimated the industry's total expenditures, including those growers that did not respond

[9] This is based on the assumption that 100 percent of payroll was paid locally (employees worked in Washington). Nineteen percent of non-payroll expenditures were spent out of state (only 81% of non-payroll was spent locally).

to the survey. Using PSI's estimates of total acreage under cultivation, the study team extrapolated the Washington expenditures per farmed acre ($4,880) to those acres not accounted for by survey responses. The results of these calculations are shown in Table 6.

Table 6. Estimates of Spending by Acre

County	Total Acreage	Survey Acreage	Missing Acres	Missing Productive Acres	Washington Dollars Missing from Survey Responses
Grays Harbor	2,288	3,278	n/a	0	0
Island	87	55	32	20	97,076
Jefferson	1,155	666	489	304	1,483,438
Kitsap	485	25	460	286	1,395,463
Mason	4,079	814	3,265	2,029	9,904,481
Pacific	17,288	14,681	2,607	1,620	7,908,059
Pierce	138	39	99	61	299,994
Skagit	3,018	2,233	785	488	2,380,478
Thurston	1,037	710	327	203	991,203
Other	86	-	88	55	266,958
Total	**29,663**	**22,502**	**8,151**	**5,067**	**24,727,150**

Source: Northern Economics, Inc. using survey and acreage data provided by PSI

The extrapolated expenditures for non-survey respondents were distributed according to the spending pattern shown in Figure 7. The most recent (2010) IMPLAN data for all the economic sectors within the state were applied, generating the estimated output, employment, and labor income shown in Table 7.

Table 7. Economic Impacts of Non-Survey Respondents

Total Impacts	Output	Employment	Labor Income
Direct	24,727,200	580	7,100,000
Indirect	9,670,300	90	4,400,500
Induced	13,813,300	90	4,012,200
Total	**48,210,800**	**760**	**15,512,700**

Note: Labor Income is a subset of Output.
Source: Northern Economics, Inc. using survey and acreage data provided by PSI and IMPLAN

The spending impacts generated by survey respondents are shown in Table 8.

Table 8. Economic Impacts of Respondents

Total Impacts	Output	Employment	Labor Income
Direct	76,690,900	1,320	30,190,600
Indirect	28,562,400	300	16,793,900
Induced	30,961,587	330	14,625,400
Total	**136,214,887**	**1,950**	**61,609,900**

Note: Labor Income is a subset of Output.
Source: Northern Economics, Inc. using survey and acreage data provided by PSI and IMPLAN

Combining estimated impacts of survey and non-survey respondents' results in the total economic impacts of shellfish aquaculture to Washington State as illustrated in Table 9.

Table 9. Economic Impact of Shellfish Aquaculture in Washington, 2010

Multipliers per dollar	Output	Employment	Labor Income
Direct	101,418,100	1,900	37,290,600
Indirect	38,232,700	390	21,194,400
Induced	44,774,900	420	18,637,600
Total	**184,425,700**	**2,710**	**77,122,600**

Note: Labor Income is a subset of Output.
Source: Northern Economics, Inc. using survey and acreage data provided by PSI and IMPLAN

In summary:

- The study team estimates that the shellfish aquaculture industry in Washington spent approximately $101.4 million in the Washington economy in 2010, which in turn generated $184 million, or 1.8 times the activity.
- Shellfish farmers were responsible for approximately 1,900 direct jobs in 2010. They also generated an additional 810 jobs through indirect and induced activity, for a total of 2,710 jobs in Washington State.
- Shellfish farmers paid approximately $37.3 million in wages in 2010. Their economic activity generated additional labor income of $39.9 million, for a total of $77.2 million in labor income in the state of Washington.

The economic multipliers generated through industry spending are summarized in Table 10. For every dollar spent by the industry, a total of $1.82worth of economic activity is generated in Washington. In addition, every $1 spent by the industry in Washington generates $0.76 in wages in the state. For every $1 million worth of spending by the industry, nearly 27 jobs are generated.

Table 10. Washington Shellfish Aquaculture Multipliers

	Output (per $)	Employment (per $ Million)	Labor Income (per $)
Multiplier	1.82	26.72	0.76

Source: Northern Economics, Inc. using survey data provided by PSI and IMPLAN

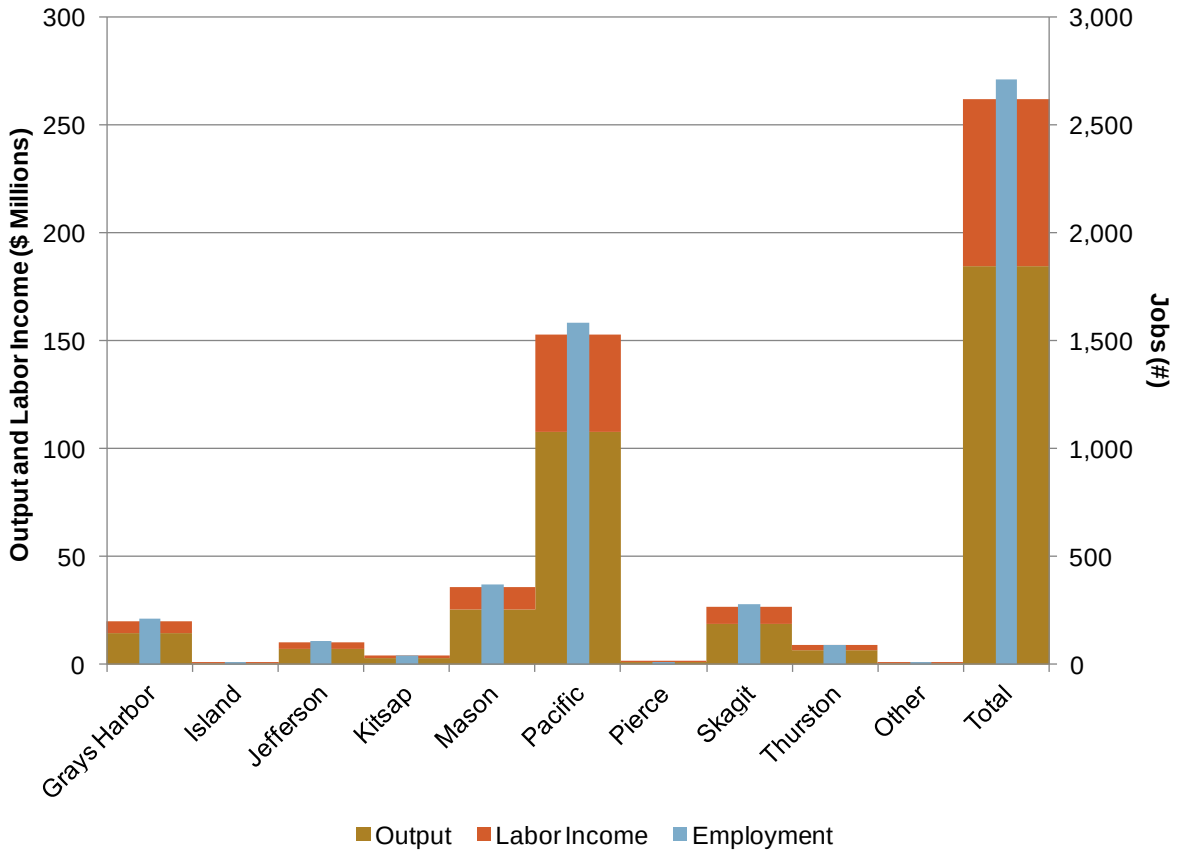
Assuming that output, employment, and labor income are generated in proportion to acreage of leased tidelands, the following table highlights the economic contribution that each county would make toward the statewide impact.

Table 11. Economic Impact of Shellfish Aquaculture, by County, 2010

County	Percent of Acres	Output	Employment	Labor Income
Grays Harbor	7.7%	11,966,300	210	5,957,500
Island	0.3%	455,000	10	226,500
Jefferson	3.9%	6,432,900	110	3,007,400
Kitsap	1.6%	2,536,600	40	1,262,800
Mason	13.8%	22,452,500	370	10,621,000
Pacific	58.3%	90,416,800	1,580	45,014,700
Pierce	0.5%	721,700	10	359,300
Skagit	10.2%	16,045,700	280	7,858,300
Thurston	3.5%	5,423,500	90	2,700,200
Other	0.3%	460,200	10	229,100
Total	**100**	**156,911,400**	**2,710**	**77,236,900**

Note: Labor Income is a subset of Output.
Source: Northern Economics, Inc. using survey and acreage data provided by PSI and IMPLAN

Figure 8. Economic Impact of Shellfish Aquaculture, by County, 2010



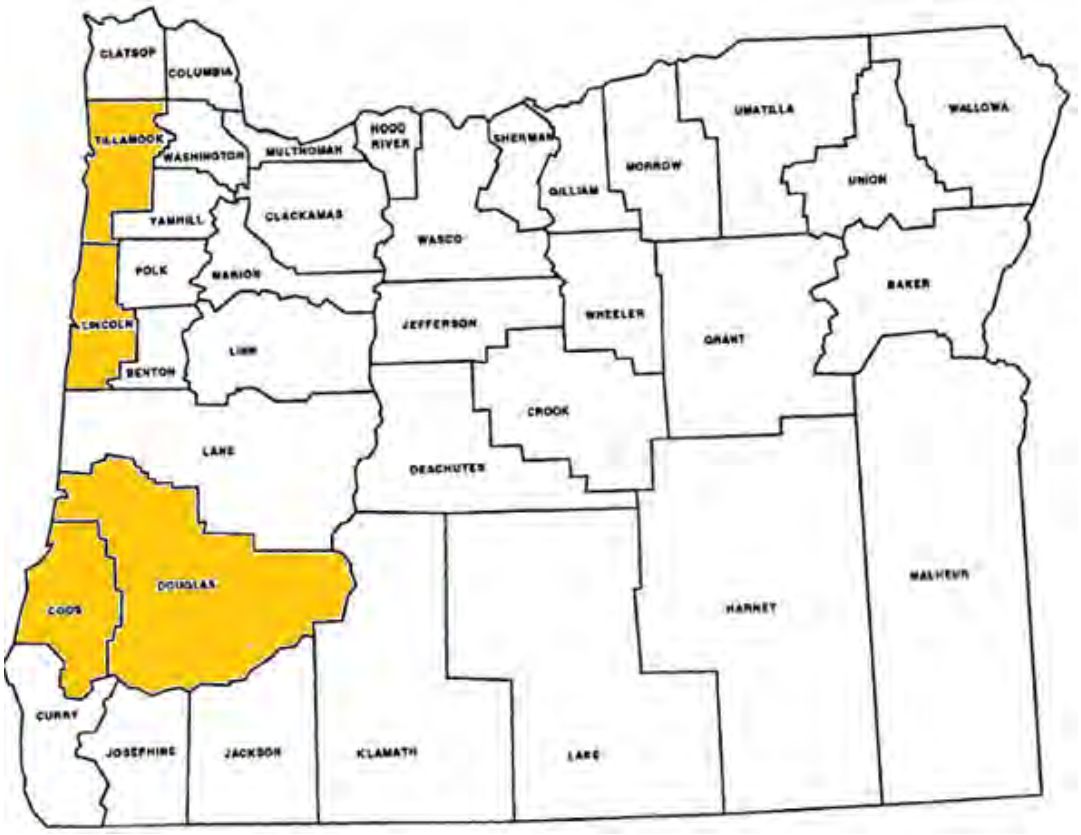
Note: Labor Income is a subset of Output.
Source: Northern Economics, Inc. using survey and acreage data provided by PSI and IMPLAN

By way of comparison to these results, the economic impacts of the nursery and landscaping industry in Washington State show a total (direct and indirect) impact of $2.4 billion in output (sales) and 43,000 total jobs (Holland and Bhattacharjee, 2006). The fruit tree industry in Washington State provides $5.6 billion in total output impacts and $2.8 billion in total income impacts (Jensen, 2004). Radtke (2011) illustrates a range of values from the literature. The economic contribution from the Washington State commercial fishing industry ranges from $60million to $3.48 billion while number of jobs generated ranges from 3,520 to 14,572. Finally, the total economic impact of the petroleum refining industry to Washington State is 26,000 jobs and $1.7 billion in personal income (Washington Research Council, 2012)

4 Oregon State Analysis

Shellfish aquaculture is more limited along the coast of Oregon than in Washington with a total of only 23 current producers. Due to the limited number of survey responses received in Oregon, the study team decided that a statewide economic impact analysis would not provide meaningful or robust information. Instead, the study team summarized the survey data they did receive in the following section to provide a glimpse of the Oregon shellfish aquaculture industry.

Figure 9. Oregon Counties with Shellfish Aquaculture Activity



Source: Adapted from State of Oregon Health Authority, 2013

4.1 Survey Results

Survey response rates in Oregon were lower than those in Washington and California as only eight of 23 shellfish growers responded to the general survey. Of the eight shellfish grower responses, only four reported useable expenditure data. Table 13 summarizes the grower-reported commercially farmed and not-farmed acres by county.

Table 12. Oregon Survey Response Rate by Acreage and County

County	Reported Acres	Not Farmed Acres	Farmed Acres	Farmed Acres (%)
Tillamook	2,860	2,025	835	29
Coos	123	40	83	67
Douglas	60	0	60	100
Total	**3,043**	**2,065**	**978**	**32**

Source: Northern Economics, Inc. using survey data provided by PSI.

Only 32 percent of the acres reported by survey respondents are actually under shellfish cultivation. In the following section we describe the employment, production, revenues, and expenses associated with these acres.

4.1.1 Employment

Employment reported by survey respondents equaled 107 direct jobs. Responses from individual firms ranged from a low of 0 (self-employed) to a high of 85

Of the survey respondents who reported both employment and acreage, there was approximately one employee reported per 23 acres of tideland under cultivation, or .04 people per acre. This rate is much lower than that reported by both Washington and California growers, and may be the product of the limited survey and data response.

4.1.2 Production and Revenues

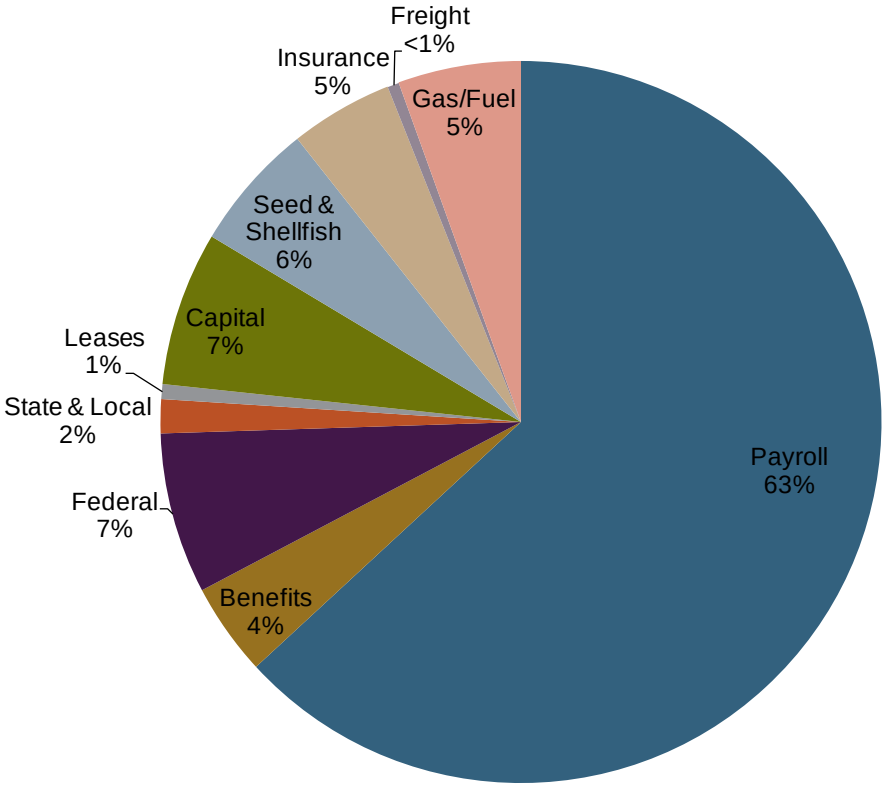
Survey respondents reported $9.7 million worth of total revenue and $9.3 million worth of revenue from shellfish sales respectively in 2011. Survey respondents did not attribute sales to species types, and many did not report sales volumes. Therefore, a summary of total production volumes cannot be derived.

4.1.1 Acreage and Expenditures

Only four growers responded to the survey with useable expenditure estimates. Total spending reported by these growers amounted to $377,000 in 2011.[10] More than half of operating funds were spent on payroll (63 percent). Unlike respondents from other states, Oregon survey respondents reported a relatively small expenditure on intermediate inputs; seed and shellfish accounted for only seven percent of total expenditures. Figure 1410 illustrates the general spending pattern of Oregon shellfish aquaculture firms.

[10] Note that in this case several growers reported revenues but only a subset of total expenditures.

Figure 10. Oregon Shellfish Aquaculture Expenditures by Type, 2010



Source: Northern Economics, Inc. using PSI Survey responses

5 California State Analysis

Sixteen shellfish aquaculture farmers in California participated in the study according to PSI and a local industry expert.[11] These 16 respondents represent the industry in its entirety or a 100 percent response rate. Shellfish aquaculture in California takes place in 7 of the state's 15 counties bordering the Pacific Ocean.

Figure 11. California Counties with Shellfish Aquaculture Activity

Source: Adapted from California Secretary of State's Office 2013

[11] Ted Kuiper formerly of Kuiper Mariculture

5.1 Survey Results

The survey effort in California was similar to that in Washington with the exception that all growers responded to the general survey; no detailed responses were obtained. Surveyed firms included both shellfish growers and seed producers, but excluded abalone-only growers. Table 13 summarizes the reported commercially farmed and not-farmed acres by county.

Table 13. Survey Response Rate by Acreage and County

County	Reported Acres	Not Farmed Acres	Farmed Acres	Farmed Acres (%)
Marin	1,413	1,071	342	24
Santa Barbara	70	35	35	50
San Luis Obisbo	135	120	15	11
Humboldt	4,577	4,234	343	7
Other	6.036	0	6	100
Total	**6,201**	**5,460**	**740**	**12**

Source: Northern Economics, Inc. using survey data provided by PSI.

According to the responses received, only 12 percent of the permitted tidelands in California are actually under shellfish cultivation. In the following section we describe the employment, production, revenues, and expenses associated with these acres.

5.1.1 Employment

Employment reported by survey respondents represented 204 direct jobs in California. Responses from individual firms ranged from a low of 1 to a high of 60. One respondent listed zero employees; as in Washington, the study team believes this to be a self-employed farmer who did not employ additional staff and failed to include themselves when reporting. The breakdown of firm size (as measured by employment) is shown in Table 14.

Table 14. Count of California Respondents by Number of Employees, 2010

Size of Business	Count of Firms	Percent of Total
No Employment Reported	1	6
1 to 10 Employees	10	63
11 to 30 Employees	3	19
31 to 50 Employees	1	6
>50 Employees	1	6
Total	**16**	**100**

Source: Northern Economics, Inc. using survey data provided by PSI.

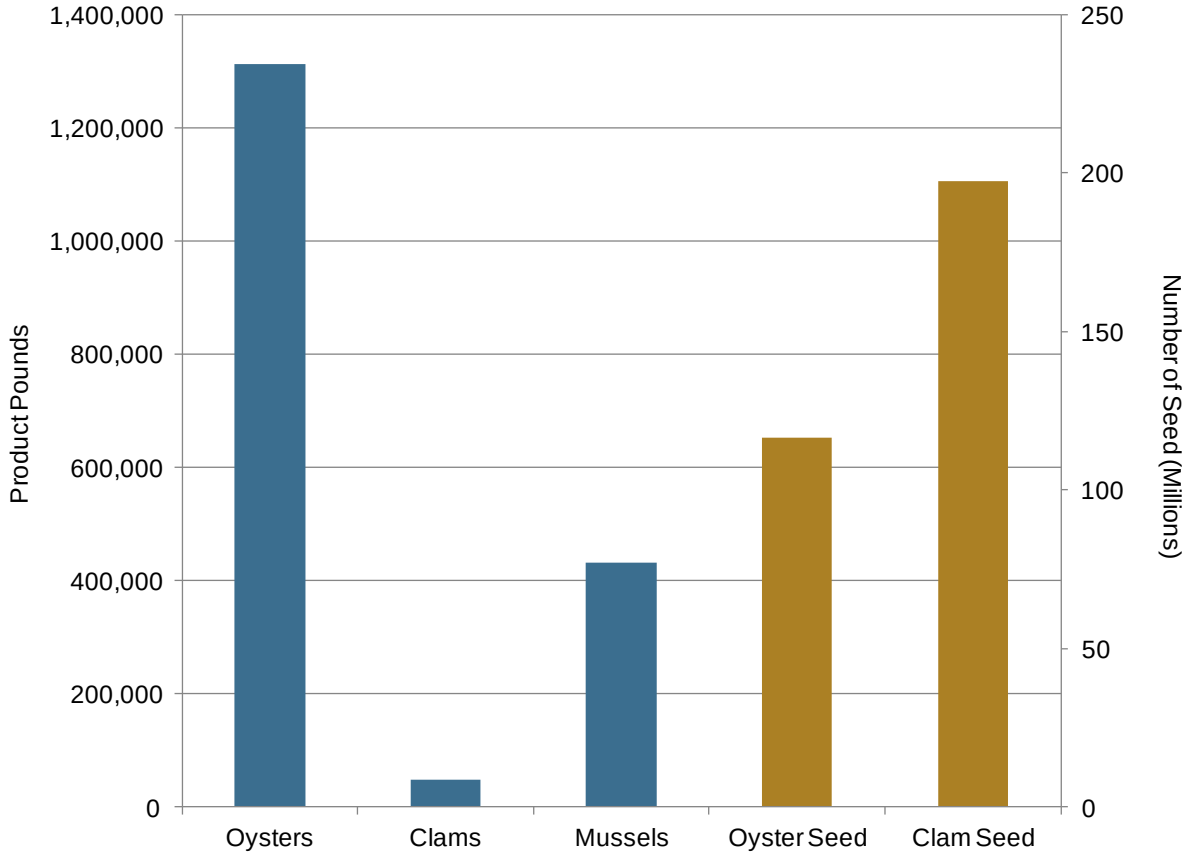
On average, California growers employ four people for every acre of tideland under cultivation; this is nearly four times the rate reported for Washington. Survey respondents note a minimum employment of .03 persons per farmed acre (or three people per 100 acres) and a maximum employment of 6 people per farmed acre (or 600 people per 100 acres).

California survey respondents reported total employment for the state; a breakdown of jobs by county is unavailable.

5.1.2 Production and Revenues

Survey respondents reported $25.9 million worth of total revenue and $23.9 million worth of revenue from shellfish sales in 2011. While survey respondents did not attribute sales to species types, they did supply total production volumes, summarized in Figure 12. Data were reported in round pounds, dozens, singles and gallons. The study team standardized responses using pounds of meat weight for oysters[12] and round pounds for other species.

Figure 12. CA Survey Response Production Volumes, 2010



Source: Northern Economics, Inc. using survey data provided by PSI.

California shellfish aquaculture production data are gathered by the California Department of Fish and Wildlife. According to the state's records, total production of oysters, clams, and mussels amounted to 34 million pounds in 2011. There is great variation between survey and state reported data due to differences in means by which data are compiled and the conversion used from count to pounds.

[12] 1 dozen oysters is assumed to weigh .546 pounds (meat weight). 1 gallon of oyster meat is assumed equivalent to 1 bushel of shell-on oysters; both weigh 8.75 pounds in meat weight.

Table 15 summarizes reported survey production volumes and CDFW recorded production volumes.

Table 15. CDFW 2011 Shellfish Aquaculture Data

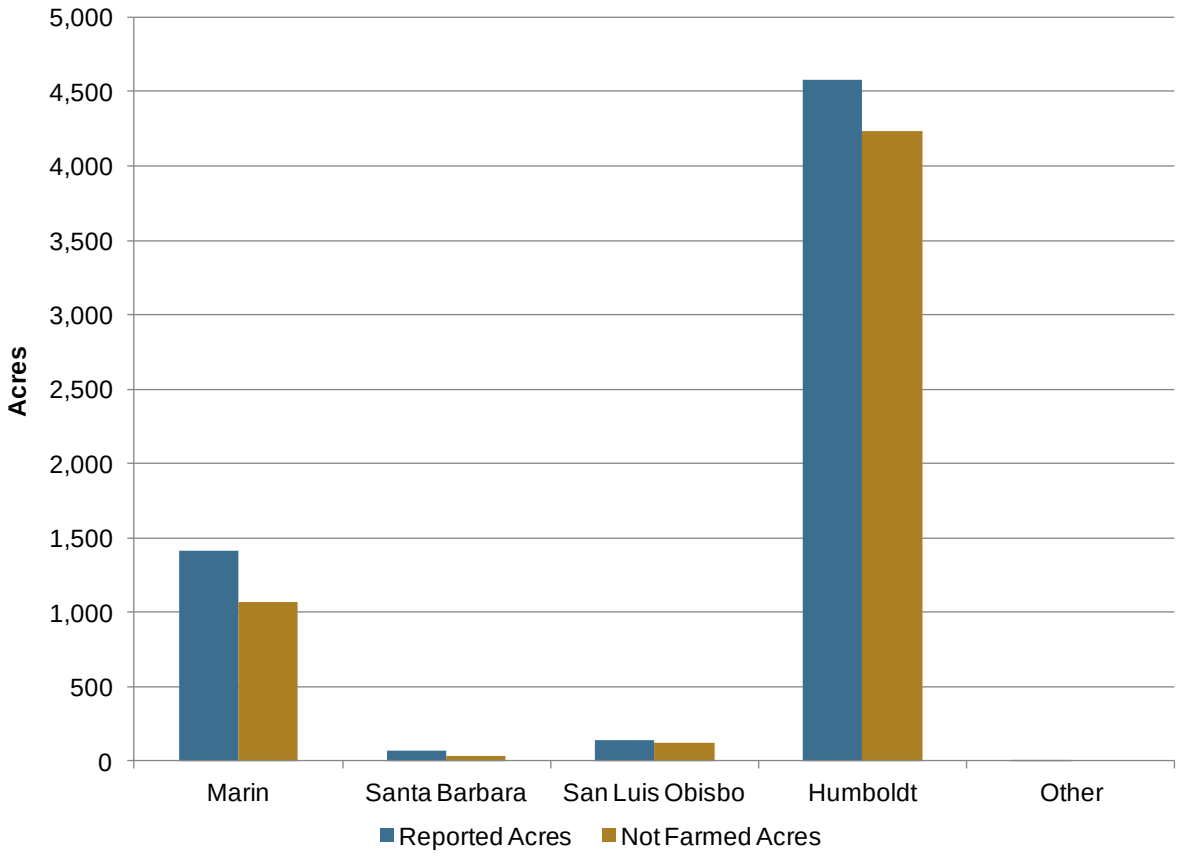
Species	CDFW Harvest Pounds (2011)	Survey Pounds (2011)	Reported Survey Volumes as a Percent of CDFW Recorded Volumes
Oyster	31,434,304	1,312,353	4
Clams	1,333,440	48,407	4
Geoduck	--	--	--
Mussels	1,350,280	432,035	32
Total	34,118,024	1,792,795	5

Source: Northern Economics, Inc. using survey data provided by PSI and CDFW 2011

5.1.3 Acreage and Expenditures

The study team estimated the total economic impact of the shellfish aquaculture industry in California using acreage and expenditures reported by survey respondents. Humboldt and Marin counties have the largest volumes of permitted tidelands (Figure 13), and are estimated to have the most significant economic impact on the state.

Figure 13. California Survey Reported Tideland Acreage by County, 2010



Source: Northern Economics, Inc. using survey data provided by PSI

Firms in California tend to be relatively small or relatively large. 31 percent of respondents report spending less than $50,000 a year on operations, while 44 percent report spending more than $1 million on operations in 2011. No firms reported spending more than $10 million (Table 16).

Table 16. California Survey Respondents by Scale of Operations

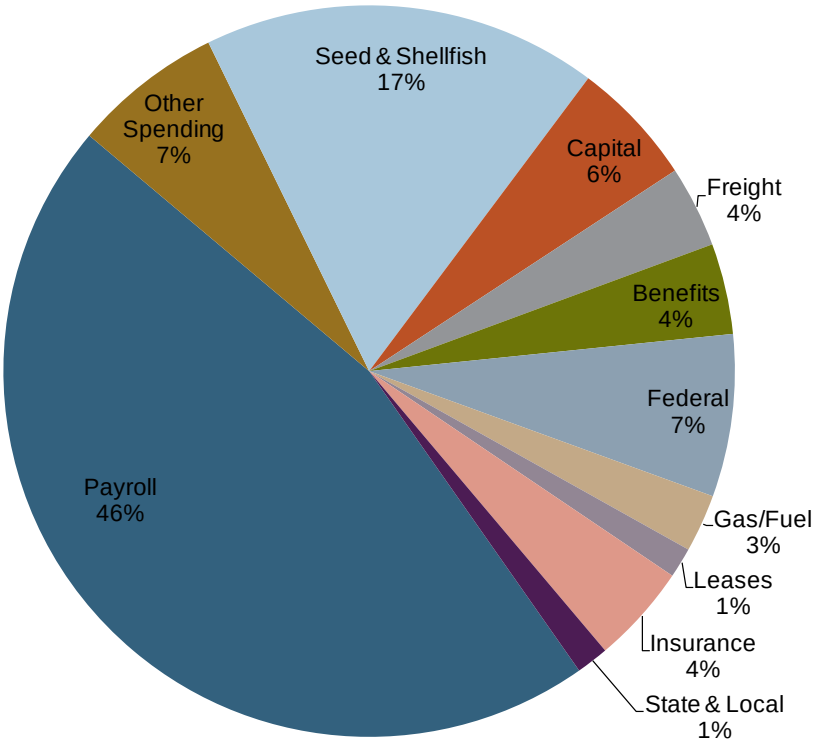
Scale of Operations (Spending Levels)	Number	Percent
Greater than $10 M	0	0
Between $1 to $10 M	4	25
Between $500 K and $1 M	3	19
Between $100 K and $500 K	3	19
Between $50 K and $100 K	1	6
Less than $50 K	5	31
Total	**16**	**100**

Source: Northern Economics, Inc. using survey data provided by PSI and WDFW 2010

Total spending for California growers amounted to $11.9 million in 2011. Almost half of operating funds were spent on payroll (46 percent). Another large cost item is intermediate

inputs; seed and shellfish accounted for 17 percent of total expenditures. Figure 14 illustrates the general spending pattern of California shellfish aquaculture firms.

Figure 14. California Shellfish Aquaculture Expenditures by Type, 2010



Source: Northern Economics, Inc. using PSI Survey responses[13]

On average, California shellfish aquaculture firms spend approximately $1,912 for every acre that they own or lease. Given that 88.1 percent of tidelands are left unfarmed in any given year, this dollar amount jumps to $16,017 for every farmed acre ($11.9 million / 740 farmed acres). While there are likely expenditures made to firms outside of California, the general survey responses are not sufficient to accurately estimate this leakage.

5.2 Economic Impact Analysis

In order to assess the economic impact of the California shellfish aquaculture industry, the study team used the expenditures reported by survey respondents to estimate the output, employment and labor income generated by the shellfish aquaculture industry. The results of our analysis are summarized in Table 17.

[13] In the case of California, some firms buy shellfish from other firms and then sell it. This is grouped with the seed expenditure category as an intermediate input from the same industry.

Table 17. Economic Impact of Shellfish Aquaculture in California, 2010

Multipliers per dollar	Output	Employment	Labor Income
Direct	11,859,800	200	5,440,000
Indirect	3,586,600	30	2,194,700
Induced	7,863,900	50	2,405,200
Total	**23,310,300**	**280**	**10,039,900**

Note: Labor Income is a subset of Output.
Source: Northern Economics, Inc. using survey and acreage data provided by PSI and IMPLAN

In summary:

- The study team estimates that the shellfish aquaculture industry in California spent approximately $11.9 million in the California economy in 2010, which in turn generated $23.3 million or 1.9 times the activity.
- Shellfish farmers were responsible for approximately 200 direct jobs in 2010. They also generated an additional 80 jobs through indirect and induced activity, for a total of 280 jobs in California.
- Shellfish farmers paid approximately $5.4 million in wages in 2010. Their economic activity generated additional labor income of $4.6 million, for a total of $10 million in labor income in California.

The economic multipliers generated through industry spending are summarized in Table 18. For every dollar spent by the industry in California, a total of $1.97 worth of economic activity is generated. In addition, every $1 spent by the industry in California generates $0.85 in wages in the state. For every $1 million worth of spending by the industry, nearly 24 jobs are generated.

Table 18. California Shellfish Aquaculture Multipliers

	Output (per $)	Employment (per $ Million)	Labor Income (per $)
Multiplier	1.96	24	0.85

Source: Northern Economics, Inc. using survey and acreage data provided by PSI and IMPLAN

6 Conclusions and Recommendations

This study assesses the economic impacts associated with non-tribal shellfish aquaculture in Washington, Oregon and California. As indicated in our analysis we were unable to assess the complete range of economic impacts for Oregon due to data limitations. For Washington State and California we were able to estimate direct, indirect, and induced impacts as well as identify related multipliers. The study team calculated the economic impacts differently for Washington and California, however, again due to different levels of detailed expenditure data collected. Since the team was able to collect detailed expenditure data for Washington, we were able to calculate the expenditures going to each supporting industry and whether those expenditures remained in the study area. The expenditure data reported through the general survey implemented in California demonstrated a pattern similar to that of Washington. As a result, the study team assumed the spending in the "other" category of expense was the same as in Washington and that expenditures remained in the study area. Because of the diverse nature of the data sets for each state, comparison of economic impacts between states is not meaningful. However, in general, the statistics generated in this study enhance our knowledge about the west coast shellfish aquaculture industry and can be used to inform management and policy decision making.

This study is the first complete analysis of the economic impact of Washington State shellfish aquaculture production (by county), and the first study to report the spending patterns (the production function) for the shellfish aquaculture industry in any region of the United States. The Washington industry spending pattern data provided in this report will allow analysts to estimate the economic impact of developments in the aquaculture industry in the future.

This study illustrates the inconsistencies in data collection in the shellfish aquaculture industry. Note that our analysis is based on estimates of total acres of shellfish beds in production. Because of uncertainties in these data, our results may under or overestimate economic impacts. In addition, it should be noted that mapping expenditures to IMPLAN support industries was a particularly difficult task given the range of businesses that supply shellfish growers. The study team used business license records and internet searches to determine the appropriate industries to assign to businesses. Where business types were unclear, we worked with respondents to determine what goods or services they received from the specific vendor. Consequently, some businesses may be coded sub-optimally, despite our best efforts.

The results of the analysis presented here apply specifically to commercial shellfish growers. Our analysis is not representative of the entire shellfish industry as wild and tribal harvest and shellfish bed restoration are not included.[14] The study team believes tribal growers and harvesters, wild harvesters, and shellfish restoration activities have unique production and expenditure patterns and warrant further investigation. Finally, our study focuses on the economic impacts of the production of cultured shellfish only and did not include sales trends and demand factors. Another area of potential future research is the economic impacts of shellfish consumption. Residents and tourists of west coast communities all enjoy and benefit from the supply of fresh shellfish provided by the aquaculture industry. People purchase shellfish

[14] The study team contacted regional tribes as part of the survey effort. However, responses from these groups were not received.

through retail markets, consume shellfish in restaurants, and enjoy local seafood fare at fundraisers and events. An investigation into the revenue generated through these types of shellfish sales could serve as a means to quantify additional economic impacts of the shellfish aquaculture industry.

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Appendix A: Shellfish Grower Expense and Revenue Surveys

***Please complete by*: April 1, 2012**

Shellfish Aquaculture Expenses Survey

Tidelands permitted for aquaculture and under your control (owned, leased, etc.)

Location (County)					
Size (Acres)					
Species cultured					
Of the total tidelands listed above, how many acres were not under cultivation in 2010?					**acres**
In a typical year, what percentage of your tidelands are not under cultivation?					**%**

Expenses for the 2010 Calendar Year

Total Expenses	**$**	*Likely more than the sum of categories listed below*
Labor Expenses		
Total Payroll (wages)	**$**	*Owners and employees*
Total Non-Wage Benefits	**$**	*Include medical, bonuses, etc.*
Payments to Government		
Federal	**$**	*Include payroll taxes, income taxes, etc.*
State & Local	**$**	*Include permit and license fees, property taxes, etc.*
Other Expense Categories		
Tideland Leases	**$**	*Lease payments for tidelands, but not permit fees*
Capital Expenditures	**$**	*Include vessels, buildings & heavy machinery > $10K*
Seed & Shellfish	**$**	*Payments for seed or shellfish for grow-out or resale*
Insurance Carriers	**$**	*Total payments to insurance companies*
Freight	**$**	*Expenses paid to freight companies (ground & air)*
Gas/Fuel	**$**	*Expenses paid to fueling stations or fuel deliveries*

Shellfish Production Volume harvested and sold from tidelands listed above. Please be sure to include *units* (gallons, pounds or dozens) and write in the species for any "Other" shellfish.

	Total volume	Fresh Whole	Fresh Shucked	Frozen	Other	Seed or larvae
Oysters						
Clams						
Geoducks						
Mussels						
Other 1:						
Other 2:						
Other 3:						

Number of Employees by County of Residence (where employees *live*, refer to W-4 forms if necessary)

Jefferson	Clallam	Grays Harbor	Pacific	Mason	Thurston	Pierce	Kitsap	San Juan	Snohomish	Skagit	Whatcom	Other

Continue to page 2

Revenue for the 2010 Calendar Year

Gross sales (wholesale and retail)	$

Revenue from Shellfish Products

Estimated gross sales of shellfish	$
Estimated % of gross sales not farmed by you	%

Answer Yes or No to the following. **Does your company…**

	Yes/No
Buy market sized aquacultured shellfish products from other growers?	
Buy market sized shellfish from wild harvesters? *Example: DNR managed geoduck in WA*	
Operate a retail store?	
Operate another tourist attraction, such farm tours offered on a regular basis?	
Export shellfish outside the U.S.?	
If you export, estimate the percentage of shellfish exported (by volume, not revenue):	%

Comments Please provide any additional information you deem necessary to explain the information you have provided above, and/or any comments or concerns about this survey. Please indicate if you would like us to follow up with you about your comments.

Return this survey to our secure, private post office box:

Pacific Shellfish Institute
Attn: Aquaculture Survey
120 State Ave. NE #1056
Olympia, WA 98501

Alternately, you may access and submit this survey electronically at www.pacshell.org/survey.html

For *tracking purposes only*, please provide the following:

Business name			
Dept. of Health permit #			
Survey completed by			
Phone #		**Email address**	

***Please complete by*: April 1, 2012**

Shellfish Aquaculture Expenses Survey

Tidelands permitted for aquaculture and under your control (owned, leased, etc.)

Location (County)					
Size (Acres)					
Species cultured					
Of the total tidelands listed above, how many acres were not under cultivation in 2010?					**acres**
In a typical year, what percentage of your tidelands are not under cultivation?					**%**

Expenses for the 2010 Calendar Year

Total Expenses	**$**	*Likely more than the sum of categories listed below*
Labor Expenses		
Total Payroll (wages)	**$**	*Owners and employees*
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Payments to Government		
Federal	**$**	*Include payroll taxes, income taxes, etc.*
State & Local	**$**	*Include permit and license fees, property taxes, etc.*
Other Expense Categories		
Tideland Leases	**$**	*Lease payments for tidelands, but not permit fees*
Capital Expenditures	**$**	*Include vessels, buildings & heavy machinery > $10K*
Seed & Shellfish	**$**	*Payments for seed or shellfish for grow-out or resale*
Insurance Carriers	**$**	*Total payments to insurance companies*
Freight	**$**	*Expenses paid to freight companies (ground & air)*
Gas/Fuel	**$**	*Expenses paid to fueling stations or fuel deliveries*

Shellfish Production Volume harvested and sold from tidelands listed above. Please be sure to include *units* (gallons, pounds or dozens) and write in the species for any "Other" shellfish.

	Total volume	Fresh Whole	Fresh Shucked	Frozen	Other	Seed or larvae
Oysters						
Clams						
Geoducks						
Mussels						
Other 1:						
Other 2:						
Other 3:						

Number of Employees (where employees *live*, refer to W-4 forms if necessary)

OR	Outside OR

Continue to page 2

Revenue for the 2010 Calendar Year

Gross sales (wholesale and retail)	$

Revenue from Shellfish Products

Estimated gross sales of shellfish	$
Estimated % of gross sales not farmed by you	%

Answer Yes or No to the following. **Does your company…**

	Yes/No
Buy market sized aquacultured shellfish products from other growers?	
Buy market sized shellfish from wild harvesters? *Example: DNR managed geoduck in WA*	
Operate a retail store?	
Operate another tourist attraction, such farm tours offered on a regular basis?	
Export shellfish outside the U.S.?	
If you export, estimate the percentage of shellfish exported (by volume, not revenue):	%

Comments Please provide any additional information you deem necessary to explain the information you have provided above, and/or any comments or concerns about this survey. Please indicate if you would like us to follow up with you about your comments.

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For *tracking purposes only*, please provide the following:

Business name			
Dept. of Ag. permit #			
Survey completed by			
Phone #		**Email address**	

***Please complete by*: April 1, 2012**

Shellfish Aquaculture Expenses Survey

Tidelands permitted for aquaculture and under your control (owned, leased, etc.)

Location (County)					
Size (Acres)					
Species cultured					
Of the total tidelands listed above, how many acres were not under cultivation in 2010?					**acres**
In a typical year, what percentage of your tidelands are not under cultivation?					**%**

Expenses for the 2010 Calendar Year

Total Expenses	**$**	*Likely more than the sum of categories listed below*
Labor Expenses		
Total Payroll (wages)	**$**	*Owners and employees*
Total Non-Wage Benefits	**$**	*Include medical, bonuses, etc.*
Payments to Government		
Federal	**$**	*Include payroll taxes, income taxes, etc.*
State & Local	**$**	*Include permit and license fees, property taxes, etc.*
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Shellfish Production Volume harvested and sold from tidelands listed above. Please be sure to include *units* (gallons, pounds or dozens) and write in the species for any "Other" shellfish.

	Total volume	Fresh Whole	Fresh Shucked	Frozen	Other	Seed or larvae
Oysters						
Clams						
Geoducks						
Mussels						
Other 1:						
Other 2:						
Other 3:						

Number of Employees (where employees *live*, refer to W-4 forms if necessary)

CA	Outside CA

Continue to page 2

Revenue for the 2010 Calendar Year

Gross sales (wholesale and retail)	$

Revenue from Shellfish Products

Estimated gross sales of shellfish	$
Estimated % of gross sales not farmed by you	%

Answer Yes or No to the following. **Does your company…**

	Yes/No
Buy market sized aquacultured shellfish products from other growers?	
Buy market sized shellfish from wild harvesters? *Example: DNR managed geoduck in WA*	
Operate a retail store?	
Operate another tourist attraction, such farm tours offered on a regular basis?	
Export shellfish outside the U.S.?	
If you export, estimate the percentage of shellfish exported (by volume, not revenue):	%

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For *tracking purposes only*, please provide the following:

Business name			
Dept. of Ag. permit #			
Survey completed by			
Phone #		**Email address**	

Appendix C

December 8, 2014

Mr. Derek Rockett
Washington State Department of Ecology
Water Quality Program
Southwest Regional Office
PO Box 47775
Olympia, WA 98504

Transmitted electronically to derek.rockett@ecy.wa.gov

Re: Comments on draft EIS and NPDES permit
12733-06

Dear Mr. Rockett:

On behalf of the Willapa Grays Harbor Oyster Growers Association (WGHOGA), please find below comments from Hart Crowser on the Draft Environmental Impact Statement (EIS) and National Pollutant Discharge Elimination System (NPDES) permit for application of imidacloprid to commercial clam and oyster beds in Willapa Bay and Grays Harbor, Washington.

Proposed SIZ Exclusion of South Willapa Bay

The public notice letter for the Sediment Impact Zone (SIZ) Application indicates that the Washington State Department of Ecology (Ecology) proposes to exclude the southern end of Willapa Bay from the SIZ authorization. The area of exclusion is approximately 15,000 acres and includes over 6,000 acres of productive commercial shellfish beds, much of which is actively farmed. Many of the commercial shellfish beds have, or are vulnerable to large populations of burrowing shrimp that need to be controlled in order to maintain shellfish production.

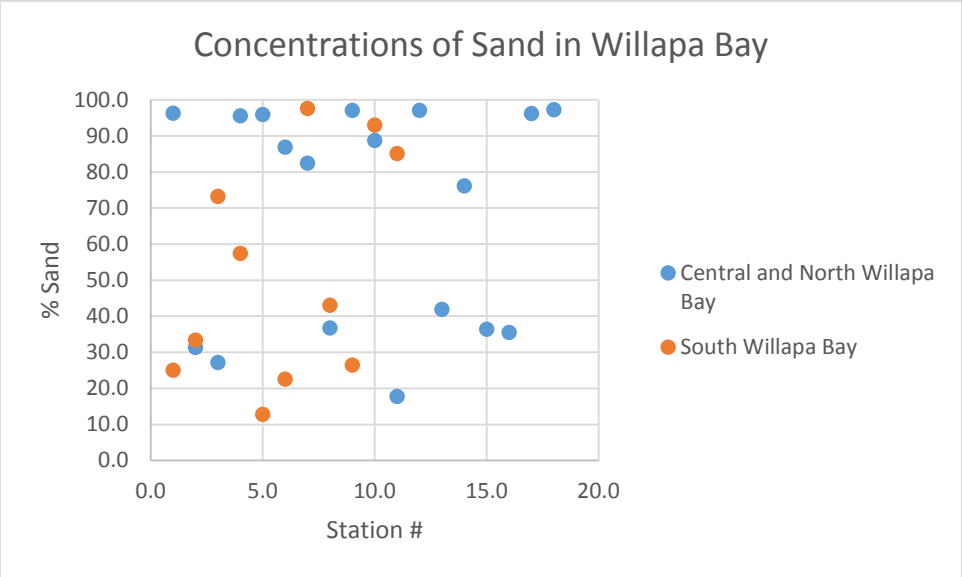
There is no scientific reason to exclude these southern areas entirely, even if more data on the effects of imidacloprid are wanted by Ecology. At worst, southern Willapa Bay should have a conditional designation, thereby allowing WGHOGA and the team of scientists it works with to collect more information as a condition of the permit. Even a conditional designation is unwarranted, however, as conditions in southern Willapa Bay are largely similar to those in other parts of Willapa Bay where prior studies of the effects of imidacloprid application on sediment conditions and invertebrates have been conducted. In particular, based on existing information, there are sufficient similarities between southern Willapa Bay and other areas of the bay in terms of sediment type/total organic carbon (TOC), invertebrate populations, and circulation and dilution to warrant including southern Willapa Bay in the SIZ authorization.

190 W Dayton Street, Suite 201
Edmonds, Washington 98020
Fax 425.778.9417
Tel 425.775.4682

Sediments in North and South Willapa Bay

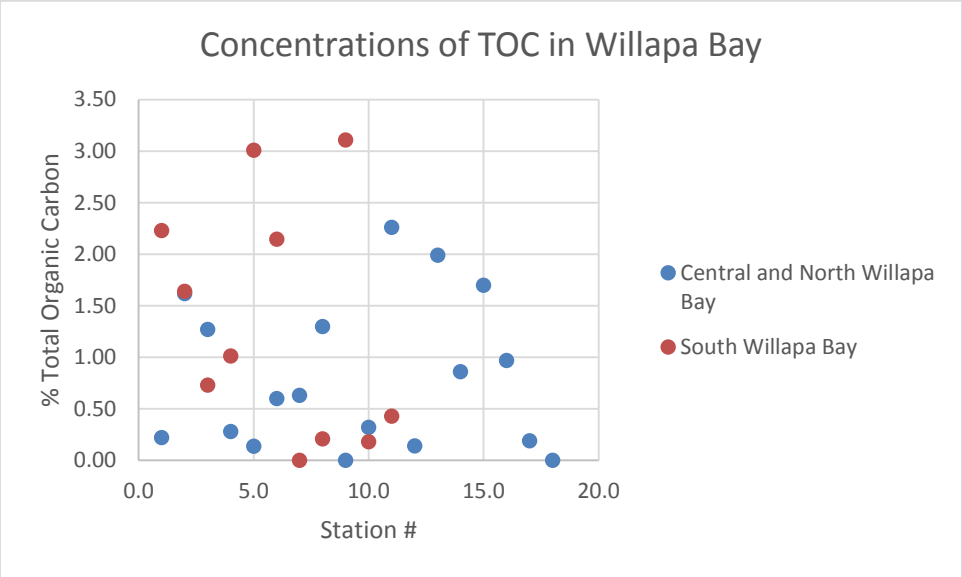
Data are available to conduct a comprehensive review of sediment conditions in south Willapa compared to other parts of the bay. Information includes data from Ecology's own Environmental Monitoring and Assessment Program (EMAP). EMAP sampled 29 stations throughout Willapa Bay in 2002 (Figure 1). Data collected from each station included sediment composition, specifically the percentage of the sediment composed of sand and TOC.

Results from the EMAP sediment sampling are plotted on the attached figure. The colored circles show concentrations of TOC and sand at the various sampling stations. These data show that there are many areas in South Willapa Bay that contain high concentrations of sand (12.8 – 97.6 percent) and have a range of TOC concentrations (0.21 – 3.11 percent). Three of the 11 stations sampled in South Willapa Bay have sand concentrations greater than 75 percent and 5 of the 11 stations have sand concentrations greater than 50 percent. Conversely, when looking at the rest of the stations sampled in Willapa Bay, 7 out of 18 stations have sand concentrations that are less than 50 percent. Further, sampling stations near Cedar River, which is proposed to be a "conditional" SIZ, also has a mix of high and low concentrations of sand. Three of the 5 stations sampled in this area during the 2002 EMAP program have sand concentrations greater than 75 percent. The other two stations have sand concentrations of 36.8 and 36.4 percent. Since northern and southern Willapa Bay are very similar in sediment types, and Ecology is appropriately proposing to authorize a SIZ in northern Willapa Bay, there is no reason to exclude southern Willapa Bay based on sediment type.



We can conduct the same analysis for TOC concentrations in Willapa Bay. The results are presented in the figure below. Five of the 10 stations sampled in South Willapa Bay have TOC concentrations less

than or equal to 1.00 percent and 6 stations are less than 2.00 percent. In the rest of Willapa Bay, 6 out of 16 stations have TOC concentrations greater than 1.00 percent.



Again, although there are some areas of higher TOC concentration in South Willapa Bay, there are also many stations with lower TOC than the levels in more northern portions of the bay. The variability in TOC levels within south Willapa and those that overlap with north Willapa show that TOC cannot be used as a basis for excluding south Willapa Bay from the SIZ authorization.

A second source of sediment data was found for Willapa Bay and is depicted in the attached Figure 2. This figure was generated by Dr. Brett Dumbauld of the US Department of Agriculture (Dumbauld and McCoy, unpublished data) based on sediment samples that they collected throughout Willapa Bay. Sandy sediments are represented by light yellow and silt is represented by dark yellow. Willapa Bay as a whole has both highly and moderately sandy areas, as well as areas that are high in silty sediments. South Willapa Bay has many areas dominated by sandy sediments, as well as areas dominated by silty, organic-rich sediments. However, this also holds true for the rest of Willapa Bay. Although the central bay area is highly dominated by sandy sediments, there are still areas with high silt concentrations here, as well. This figure provides a good visual indication that all types of sediments can be found in all parts of the bay, and again demonstrates that South Willapa Bay should not be excluded from the SIZ authorization based on concerns about sediment.

A third source of sediment data was obtained by personal observations of the growers who have commercial shellfish beds in South Willapa Bay. Through personal observations and detailed knowledge of their commercial shellfish beds, growers have indicated there are many areas of sandy sediment in South Willapa Bay. Specifically, sandy sediment occurs along the eastern shore of the peninsula; the

northern tip of Long Island; between the northern end of Long Island and the mainland; and in some of the most southern areas of Willapa Bay (personal communication from members of WGHOGA). Many of these sandy areas are where growers have their commercial shellfish beds. These areas are identified by the polygons shown on Figure 2. Growers also report that these sandy areas are prone to infestation with burrowing shrimp. Hence, the NPDES permit and SIZ must include commercial shellfish beds in South Willapa Bay in in order to maintain the viability of these beds for shellfish production.

The three sediment data sources discussed above all point to the conclusion that there are ample amounts of sandy sediment in South Willapa Bay, and that South Willapa Bay is not unique from the rest of Willapa Bay. Personal observations by members of WGHOGA also indicate that there may be more sand present than depicted by Figure 2. Although TOC concentrations are higher in some parts of South Willapa Bay, there are also areas with TOC concentrations similar to those found in the rest of Willapa Bay.

Given the heterogeneity of sediment types and TOC levels in South Willapa Bay, and the overlap in these variables with more northern portions of Willapa Bay, there is no scientific basis for using these variables to exclude South Willapa Bay from the SIZ authorization.

Invertebrates in North and South Willapa Bay

Ecology's EMAP program in 2002 also resulted in the collection of invertebrates from a number of stations in Willapa Bay. Results on invertebrate samples taken during imidacloprid trials were also available; specifically, the results from 2011 and 2012 experimental trials previously submitted to Ecology. Results from these two data sources show that a total of 157 invertebrate taxa have been recorded from Willapa Bay (Table 1; attached). This table is arranged so that the northernmost stations in Willapa Bay are on the left, central Willapa stations are the central data columns, and the southernmost stations are on the right. This arrangement allows for a comparison of the invertebrate assemblages across Willapa Bay in order to test, using invertebrate data, the hypothesis that conditions in South Willapa are different than those in the rest of the bay. This is of scientific interest because if the invertebrate assemblages are similar in North and South Willapa Bay, then one would expect that the biological response to imidacloprid exposure would be similar for a given concentration and exposure regime.

Although the benthic invertebrates were sometimes identified to different taxonomic levels by the two entities (Ecology and Pacific Shellfish Institute [PSI] and Ecology) identified some invertebrates that are not members of the three taxonomic groups analyzed by PSI, both datasets demonstrate broad similarities in the invertebrate assemblages found in South Willapa Bay compared to other parts of the bay (Figure 1; attached). This is particularly true for a number of the dominant taxa observed during the 2011 and 2012 field studies, including but not limited to *Tharyx parva*, *Mediomasus californiensis, Cryptomya californiensis, Pygospio elegans, Clinocardium nuttali, Streblospio benedicti, and Macoma* sp.

Given there are similar invertebrate assemblages between southern Willapa Bay and other parts of the bay, the response to imidacloprid treatments on shellfish beds should also be similar with respect to both immediate effects, and subsequent recolonization of treated plots. Thus, southern Willapa Bay should not be excluded from the SIZ authorization.

Water Circulation and Dilution

Most or all estuaries have some differences in circulation. Where, as in Willapa Bay and Grays Harbor, the estuary is directly connected with adjacent ocean areas, it is scientifically trivial that portions of the estuary next to the ocean may have relatively higher tidal exchange between those two water bodies than portions of the estuary further from the mouth. Similarly, portions of the estuary into which freshwater streams and rivers empty will tend to have lower salinity and altered circulation patterns compared to areas without such freshwater inputs. The key scientific question is not whether South Willapa Bay has different circulation patterns than other portions of the estuary. Instead, the key scientific question is whether and how any differences in circulation justify excluding South Willapa Bay from the proposed SIZ authorization.

Water circulation in South Willapa does not matter with respect to the imidacloprid concentration on the commercial shellfish beds that are sprayed. In all cases the imidacloprid concentration is equal to 0.5 pounds active ingredient per acre (lbs ai/ac). This concentration is independent of location, size of treated area, tidal inundation levels, or water circulation. And these on-plot concentrations of imidacloprid rapidly diminish over time, first through dilution by incoming tidal waters, and then over 14 days or so in the sediments, as discussed further below. Because imidacloprid is highly soluble in water, and because tidal inundation at commercial clam and oyster beds averages 3 or more feet given the elevations of these beds, it follows that imidacloprid will be substantively removed from treatment plots by the first incoming tide after treatment.

Expected water column concentrations of imidacloprid in southern Willapa Bay can be tested either through a mass-balance calculation of imidacloprid concentrations in the water column, or through empirical measurements following treatment. Both approaches were considered by Dr. Kim Patten of Washington State University in his comments on the draft EIS permit and SIZ. They are repeated here with his permission:

Acres treated	Acres of area of recirculated tidal water	Mean water depth (feet)	Imidacloprid concentration within tidal prism first high tide (ppb)
100	10000	4	0.5
100	10000	3	0.60
100	10000	3	0.60
100	10000	6	0.30
20	6000	3	0.15
20	6000	3	0.15

An example calculation (for row 1) is as follows:

(0.5 lbs ai/ac x 453 g/lb x 100 ac)/(4 ac-ft of water x 326,000 gal/ ac-ft x 3.78 L/gal x 10,000 ac) = 0.5 µg/L

Importantly, his calculations above assume zero water exchange between South Willapa Bay and the remainder of Willapa Bay, an overly conservative assumption. Even so, he calculates a maximum theoretical water column concentration of imidacloprid of 0.60 micrograms per liter (µg/L) or parts per billion (ppb).

Dr. Patten's calculations show that the theoretical maximum concentration of imidacloprid in south Willapa Bay after treatment of 100 acres never comes close to the 3.7 µg/L biological threshold for water column exposure that was used in our Ecology reviewed and approved SAP. Indeed, his calculated values range from just 4.1 percent to 16.2 percent of this toxicity threshold. This 3.7 µg/L biological threshold represents 1/10 of the concentration of the chronic no effect level (NOEC) for the most sensitive crustacean invertebrate (Mysid shrimp) found during an extensive literature review on imidacloprid toxicity conducted for the SAP. (Also see additional discussion on this biological threshold in the section on sediment monitoring below). Dr. Patten's calculated concentrations are not only below the biological threshold for water column toxicity of imidacloprid used in the SAP, in reality they are probably as much as 1 to 2 orders of magnitude lower than concentrations that actually would cause toxicity in more imidacloprid resistant invertebrates in Willapa Bay.

Dr. Patten's mass balance calculations represent the theoretical maximum water column concentration of imidacloprid following treatment in a closed water body (e.g., no exchange with other areas). In reality some portion of imidacloprid lifted off the treatment plots by a rising tide is likely to become biologically unavailable very rapidly through: absorption to suspended sediment particles; decomposition due to hydrolysis, photodegradation, and oxidation; and removal from tidal flushing with other parts of Willapa Bay. What are the actual concentrations likely to be? Some estimate can be determined from water quality data on water column concentrations of carbaryl following treatment in South Willapa Bay. Dr. Patten includes some of these data in his comments on the draft NPDES permit and SIZ, which again are reproduced here with his permission.

Date applied	Date sampled	Acres treated	Theoretical concentration 1st tide ppb*	Theoretical concentration at tide samples collected ppb**	Actual ppb measured
7/1/04	7/2/04	27.5	1.99	1.49	0.3
7/23/05	7/24/05	4	0.28	0.21	0.19
7/3/07	7/5/07	32	2.3	0.97	0.2
7/7/08	7/9/08	10	0.7	0.29	0.24
7/23/09	7/25/09	38	2.7	1.13	0.02

** assumes 25% dilution with each tidal flush

Here Dr. Patten assumed that each tidal cycle results in a 25 percent replacement of water within South Willapa Bay with water from other portions of the estuary (e.g., a 25 percent dilution/tidal cycle). This has the effect of reducing the theoretically expected concentrations of water column carbaryl over time, which Dr. Patten included to account for the 1–2 day delay between carbaryl application to commercial shellfish beds and his collection of the water column samples. Results with this dilution rate are in Dr. Patten's column labeled "Theoretical concentration at tide samples collected." If one assumes no circulation between South Willapa Bay and the rest of the estuary, then the expected carbaryl concentration is equal to Kim's column labeled "Theoretical concentration 1st tide." The results clearly and consistently show that actual water column concentrations of carbaryl are much lower than the theoretical levels. On average, the field measured concentrations were only 25.3 percent of the theoretical maximum if one assumes no flushing (range of 0.7 – 67.9 percent), and 43.2 percent with a 25 percent dilution/tidal cycle (range of 1.8 – 90.5 percent).

If the average value of 25.3 percent without flushing is applied to Dr. Patten's table for imidacloprid above, the estimated water column concentrations for each row in the table (top to bottom) become 0.13, 0.15, 0.15, 0.08, and 0.04 ppb, respectively. These values, in turn, represent just 1.1 to 4.1 percent of the biological toxicity baseline of 3.7 ppb discussed above. Obviously, these implied actual concentrations are even further removed from a biologically-relevant concentration of water column imidacloprid following treatment of commercial clam and oyster beds.

Thus, even assuming no exchange of water in South Willapa Bay with water from other portions of Willapa Bay, both the theoretical maximum concentrations of water column imidacloprid and concentrations that reflect empirical results for carbaryl yield the same result: in no case are calculated water column concentrations of imidacloprid following treatment of commercial clam and oyster beds in South Willapa Bay expected to achieve levels toxic to biological organisms.

Because imidacloprid applications will not result in toxic levels in waters of south Willapa Bay there is no scientific basis for excluding southern Willapa Bay from the SIZ authorization on the basis of water column concentrations following treatment.

As noted above, the invertebrate assemblages in North and South Willapa Bay show very broad overlap. This is particularly true for the dominant taxa that dominate both the abundances and community composition of those invertebrate assemblages. Thus, the available scientific evidence is that invertebrates in North and South Willapa Bay are much more similar than they are dissimilar. As also noted above, where invertebrate assemblages are similar the effects of imidacloprid should also be similar; there is no reason to expect the same taxon of organism would respond differently to imidacloprid exposure at any given concentration or time duration.

Based on the extensive data collected to date, it is known that very large numbers of invertebrates are present on imidacloprid treated plots in as little as 14 days after treatment. For example, looking at data

from the Cedar River in 2011, at 14 days the treated plots had an average of 42,655 organisms per square meter (/m^2), while the Bay Center sites had up to 10,005 organisms/m^2. Similarly, in 2012, Bay Center sites had 13,879–14,124 invertebrates/m^2 at 14 days. These data clearly show that, between surviving invertebrates at treated sites and new colonization, invertebrates quickly rebound from imidacloprid treatment despite site specific differences in location, sediment type, and circulation levels at the study sites in Willapa Bay.

Given similarities in invertebrate populations between southern Willapa Bay and other portions of the bay, along with extensive empirical data showing high numbers of invertebrates following imidacloprid treatment, Ecology should authorize a SIZ in southern Willapa Bay.

The data analysis above shows that many parts of south Willapa Bay are similar to more northern portions of the bay with respect to sediment characteristics and invertebrate assemblages. It also demonstrates that there will be adequate dilution in south Willapa Bay and invertebrate assemblages are similar to other areas that have experienced minor impacts from imidacloprid treatments. **Therefore, the proposed exclusion of South Willapa Bay from the SIZ authorization is scientifically unjustified, and the SIZ authorization should be modified to include south Willapa Bay.**

Proposed Monitoring Requirements of NPDES Permit/SIZ

Sediment Monitoring Requirements

The draft NPDES permit has an extensive section outlining proposed sediment monitoring requirements (Sections S4.B to S4.F). Section S4.B, “Sediment Monitoring Schedule” includes a table indicating that sediment monitoring is proposed for Years 1–3 in Cedar River, Years 1, 4 and 5 in central Willapa Bay, and all 5 years in Grays Harbor. Section S4.C, “Sampling Point Location,” specifies that sampling locations will be identified in each year’s Annual Operations Plan, and that the “number of sampling locations are required to be sufficient to meet compliance standards.” Section S4.D, “Sediment Sampling and Analysis Plan,” specifies that a SSAP must be submitted annually by March 1 for that year’s activities. Section S4.E, Sediment Data Report,” indicates that data from whole sediment, sediment pore water, and invertebrate sampling specified in subsequent sections of the permit must be submitted in a data report by December 31 of each year (with supplements for data collected after that date), and that all data must be entered into Ecology’s EIM database. And Section S4.F, “Sediment Persistence Data,” specifies details on proposed whole sediment and sediment pore-water sampling.

Collectively the sediment monitoring requirements proposed for the NPDES permit amount to an extensive program with substantial costs. Assuming a single location is sampled from each geographic area/year combination listed in S4.B, 11 sampling efforts would be required over the 5 years: three in Cedar River, three in central Willapa Bay, and five from Grays Harbor. Four sediment samples are to be taken on each sample date from each location. This collection of four samples is to be taken at 1, 14, and 28 days after imidacloprid application, and then monthly thereafter until “results from two

consecutive sampling events are below the practical quantitation limits (PQL) for both whole sediment and sediment porewater" (Section S4.F, paragraph 1). The PQL is the lowest limit of the laboratory test for imidacloprid that is statistically reliable; lower levels are prone to excessive error from false signals. Past sediment sampling has shown that most sediment samples still have concentrations above the PQL at 56 days. So it would appear this requirement will require, at a minimum, 6 sampling events at each location (days 1, 14, 28, 56, 84, and 112. [Note: the timing of low tide cycles is spaced at 28 days, rather than the 30–31 days in calendar months]). By simple math, the proposed sediment sampling program therefore has a minimum intensity of 11 x 4 x 6 = 264 sediment samples (i.e., sample locations *times* replicate samples on each date *times* the number of sampling dates). And this may not represent the total sediment sampling requirement. More than 6 sampling dates may be required to achieve two consecutive findings of imidacloprid levels below the PQL. In addition, the analysis above assumes only a single location will be sampled from each geographic area/year combination listed in S4.B. But the proposed sampling program nowhere confirms that only a single location will be required for sampling. Instead, section S4.C includes the language, "The number of sampling locations are required to be sufficient to meet compliance requirements." Thus, WGHOGA has no certainty as to what will ultimately be required for sediment sampling, and it will not, until Ecology approves the annual Sediment Sampling and Analysis Plan required under Section S4.D, in which the required level of sampling will be determined.

If we keep to the assumptions above, and conclude that the proposed permit will require collection and analysis of 264 sediment samples, then an approximate cost of the proposed monitoring can be calculated. Each sediment sample costs approximately $325–$350 for laboratory processing ($25–$50 for extraction of pore water from the whole sediment sample, $140 for analysis of the sediment pore-water sample, $160 for analysis of the whole sediment sample). In addition, the samples have to be collected from the field, and transported to the laboratory. Mobilization, field collection of samples, transportation costs to the laboratory, and demobilization "could easily add $100–$150 per sample" (Dr. Kim Patten, personal communication). So summing all costs, each sediment sample will cost approximately $425–$500. Given a minimum of 264 samples, the total costs of sediment monitoring that is proposed as a requirement of the permit is $112,000–$132,000. These costs would rise substantially if Washington State University Extension (WSU) does not conduct monitoring and WGHOGA hires professional consultants to conduct the work.

This is an extraordinarily broad program with extensive costs. For perspective, the minimum of 256 samples represents more than double the total number of sediment samples collected in 3 years of studies conducted by WSU and WGHOGA in preparation for this permit application. So it seems fair to ask, "Is this level of effort scientifically justifiable to document that imidacloprid applications will not violate Sediment Impact Zone (SIZ) regulations?" Those regulations are designed to ensure that any such application does not exceed "maximum allowable biological effects within the SIZ" (Section S.3 B of proposed permit). So sediment samples are meant to provide data on whether there is enough imidacloprid to create biological effects, rather than being of interest in and of themselves. Thus, data

on sediment concentrations of imidacloprid must be related to appropriate biological thresholds or criteria to have value for SIZ evaluation.

Yet the proposed permit monitoring requirements for sediment fail to do this. Indeed they explicitly say that the criterion of interest is documenting when imidacloprid concentrations are below the practical quantitation limit. For example, the PQL for sediment pore water is 0.2 ppb (µg/L). The SAP prepared by WGHOGA, and approved by Ecology, for all field work in 2012 did include a biological threshold for sediment pore water. That value, 0.6 ppb, was based on actual biological data on the effects of imidacloprid on crustaceans. As explained in the SAP:

> "The 0.6 µg/L screening level for sediment porewater is a conservative concentration based upon chronic effects NOEC in 21-day toxicity studies (Ward 1991), since sediment imidacloprid concentrations are at least somewhat persistent, and therefore can produce toxicity from chronic exposure. Mysid shrimp toxicity studies submitted as part of the EPA pesticide registration process (Section 3.1) demonstrated that this taxon was among the most susceptible of any species tested. Therefore, although mysid shrimp live within the water column rather than the sediment, a screening level equal to the NOEC concentration for this species (0.6 µg/L) was selected as the screening level. Based on toxicity studies for benthic arthropods that actually live in sediments, a NOEC screening concentration up to 6 µg/L could be supported, indicated that the screening level proposed here is as much as an order of magnitude more conservative than actual mortality risk from the planned imidacloprid treatments."

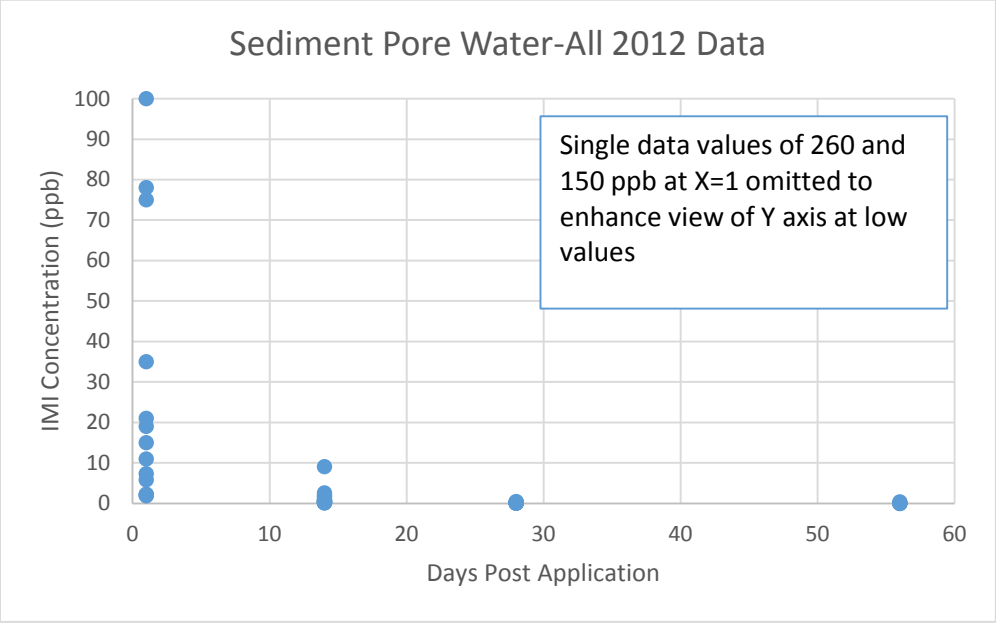
Ecology provides no explanation in the proposed permit for why PQL rather than biologically based thresholds are being used as the endpoint for sediment sampling in the permit, and in fact there are no such convincing explanations.

Because the monitoring is linked to PQL and not biological effects, the proposed sediment monitoring program is not scientifically justified.

It is possible to substitute biologically based endpoints to correct this deficiency. Appropriate biological models must be used; data from completely unrelated organisms (e.g., data on stream mayflies presented by Ecology) are not appropriate because they provide no insight into the response of organisms that are actually present where imidacloprid will be sprayed. But even if appropriate and biologically based endpoints are used, it would not automatically justify the scope and cost of the sediment program being proposed by Ecology. If WGHOGA is to be required to collect at least 256 samples at a cost of more than $100,000, there must be significant scientific uncertainty about sediment concentrations of imidacloprid after treatment of clam and oyster beds, and particularly, uncertainty over how long sediment concentrations are above biologically based endpoints. Yet, data already

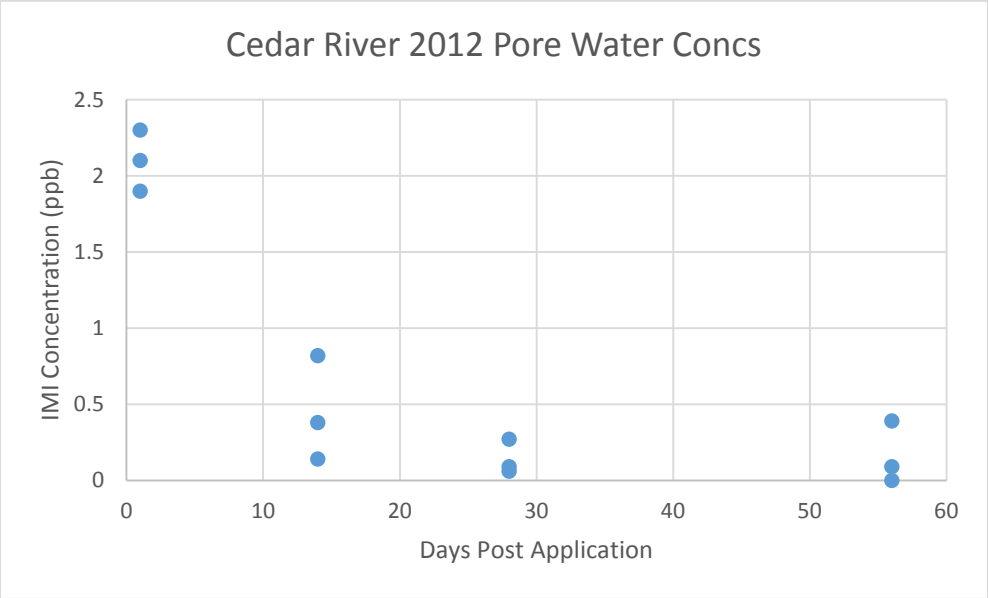
submitted to and reviewed by Ecology demonstrate that there is no such uncertainty. Using field-based sediment studies in Willapa Bay in 2010, 2011, and 2012, Dr. Chris Grue of the University of Washington and his students published several studies showing that imidacloprid exhibits an approximately exponential decline in sediments following application. And these data document that imidacloprid concentrations in sediment fall below biologically based endpoints in all cases within 28 days of application, and in many cases within 14 days.

Starting with pore water, the figure below shows Dr. Grue's results for all sediment sampling in Willapa Bay in 2012. These data were all collected under an Ecology approved SAP.



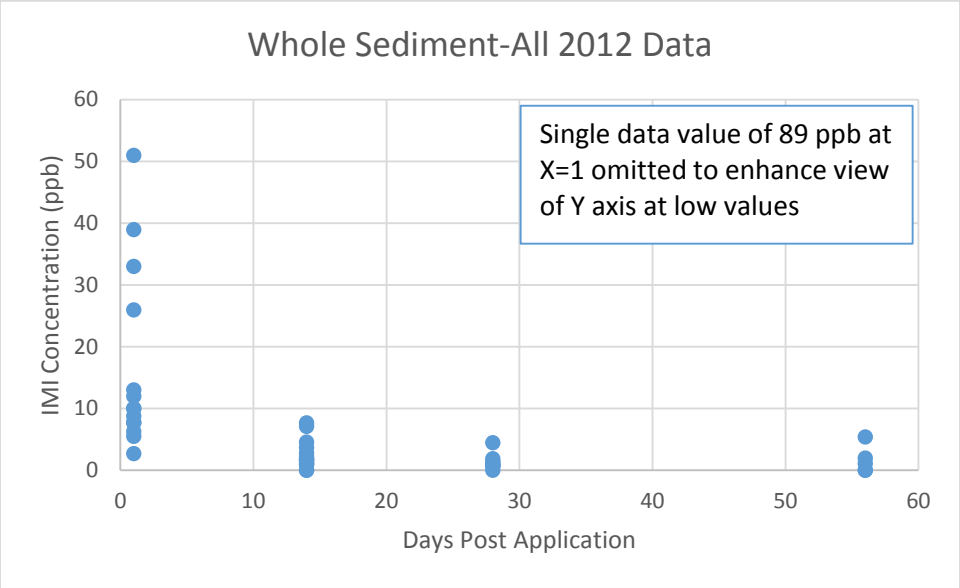
The approximately exponential decline in imidacloprid levels in sediment pore water are evident. Not a single one of the pore water samples collected at 28 or 56 days are above the biologically based endpoint of 0.6 ppb. At day 14, 8 of 15 samples are below this biological baseline.

Ecology has raised concerns that results could be different for areas with higher organic carbon levels. In 2012 Dr. Grue sampled just such an area in Cedar River after it had been treated with imidacloprid. Those results are provided in the figure below.



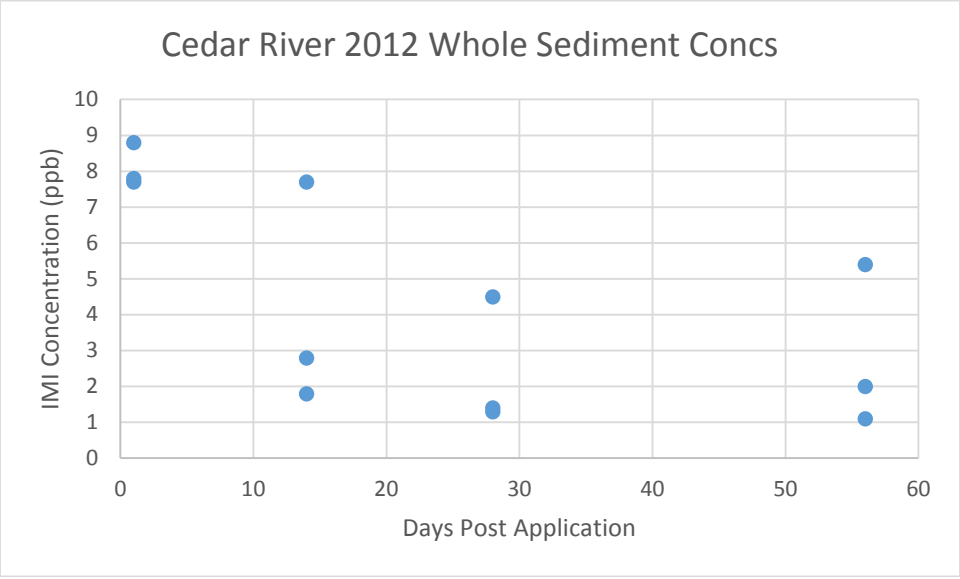
Again, and despite the presence of higher organic carbon levels, not a single one of the pore water samples collected at 28 or 56 day are above the biologically based endpoint of 0.6 ppb, and only one is at 14 days. The shape of the decline in concentrations does not look any different from those in other areas sampled that did not have high organic carbon levels.

If the results for porewater show that there is little scientific uncertainty about imidacloprid concentrations in sediment over time, what about results for whole sediments? Dr. Grue's results for sampling in Willapa Bay in 2012 are again a good starting point. These data were all collected under an Ecology approved SAP.



Again, an approximately exponential decline in imidacloprid levels is evident, with concentrations even 14 days after imidacloprid application at low levels. And, as with pore water, not a single one of the whole sediment samples collected at 28 or 56 day are above the endpoint of 6.7 ppb included in SAPs submitted and approved by Ecology (see below for discussion of this endpoint). At day 14, 13 of 15 samples are below this endpoint.

Results for the high organic carbon sediments at Cedar River show the same results as that evident for all sediment samples taken in 2012.



Note the smaller scale for the Y axis exaggerates the spread in results. Regardless, not a single one of the whole sediment samples collected at 28 or 56 day are above the endpoint of 6.7 ppb. At day 14, two of three samples are below this endpoint.

The 6.7 ppb endpoint selected for whole sediment, unlike that for pore water, was not based on the toxicology literature. Whole sediment results measure the amount of imidacloprid that is bound to sediments. By definition, it is not biologically available to organisms unless they ingest the sediment and the imidacloprid is subsequently dissociated from the sediment particles during digestion. During development of SAPs for imidacloprid application WGHOGA and Ecology were not able to find data in the toxicology literature that determined the toxicity to invertebrates from imidacloprid bound to sediments. Accordingly, Ecology requested, and WGHOGA agreed to use the PQL for whole sediment as the endpoint for whole sediments, despite the absence of data indicating that this is actually a biologically meaningful endpoint.

So, whether for imidacloprid in pore water or whole sediments, data from sediment samples already taken from a variety of sediments in Willapa Bay demonstrate that there is very little uncertainty about the fate of imidacloprid in sediments. Concentrations decline at an approximately exponential level, and concentrations are below biological endpoints in all cases by 28 days, and in most cases by 14 days.

Because there is not significant scientific uncertainty about sediment concentrations of imidacloprid after treatment of clam and oyster beds, the proposed sediment monitoring program is not scientifically justified.

Given all of the above, the proposed sediment monitoring program in the draft NPDES permit is unreasonably large and expensive, and of limited scientific value. Accordingly, the sediment monitoring program of the final NPDES permit should be changed as follows:

1. Sediment sampling should not be required in any location except Grays Harbor, and sampling in this location should be limited to a single sampling location unless sediment results for this location demonstrate results different from those already documented in Willapa Bay.
2. No sediment sampling should require collection beyond 28 days.
3. An exception to the above is to include monitoring of one location in Willapa Bay that extends in duration beyond 28 days until both sediment pore water and whole sediment concentrations are below the PQL. An alternative would be to take sediment samples from an area sprayed with imidacloprid in the prior year. The goal of either effort would be to confirm that imidacloprid falls below detection levels over time, and therefore that long-term accumulation of imidacloprid in areas that are repeatedly sprayed will not occur.

Invertebrate Monitoring Requirements

As for sediment monitoring, the draft NPDES permit has an extensive section outlining proposed invertebrate monitoring requirements (Section S4.G). Section S4.B, "Sediment Monitoring Schedule" includes a table indicating that invertebrate monitoring is proposed for Years 1–3 in Cedar River, Years 1 and 5 in central Willapa Bay, and Years 1, 3, and 5 in Grays Harbor. This represents a very extensive and expensive program of data collection. Unfortunately, this program cannot be justified scientifically for two reasons. First, past invertebrate studies on imidacloprid using methods very similar to those in Section S4.G have revealed strong temporal and spatial heterogeneity in invertebrate populations. Control and treatment plots that were selected for similar characteristics with respect to sediment, elevation, and eelgrass have been found to be very different from one another during pre-treatment invertebrate samples. Similarly, invertebrate numbers within plots taken at 1, 14 and 28 days often look very different with respect to the number and type of invertebrate taxa they contain. This high temporal and spatial heterogeneity, in turn, makes it difficult or impossible to use the kind of statistical tests of significance suggested in the draft permit. This heterogeneity is not the exception; in past invertebrate tests of imidacloprid effects it has been the rule.

Second, beyond the variability and statistical tests past trials with imidacloprid have yielded a consistent result that shows imidacloprid is not exerting any long-term impact on invertebrates: large numbers of invertebrates and invertebrate taxa are invariably found on treated plots within days or weeks of their treatment. Not once has imidacloprid been shown to result in a sizable, long-term decline in the overall invertebrate community of treated plots.

So if WGHOGA is required to conduct these seven experimental trials of imidacloprid effects on invertebrates the result is predictable *a priori*: there will be high variability in invertebrate numbers, there will be resulting confusion about what if any treatment effect is evident, and most invertebrates will have to be evaluated using a variety of site-specific measures that are both non-statistical and often ad hoc in nature. Another result that is predictable is that no treated area will show a significant, long-term impact on overall invertebrate numbers or invertebrate communities.

Against this limited scientific value comes significant additional cost. Dr. Kim Patten in his prepared comments estimated costs of $153,000 in Year 1, $113,700 in Year 3, and $194,216 in Year 5 for these invertebrate studies for a total of $460,916 for the five-year monitoring program. That is half a million dollars to collect data for which the results are predictable.

Because the invertebrate monitoring program will yield little valuable scientific data and costs an extraordinary amount of money, it cannot be justified. Instead, invertebrate monitoring should be streamlined to include simpler tests that do not involve controls or the attempt to run statistical measures and instead focus on the before treatment and after treatment invertebrate community in one or two places only such as Grays Harbor and a site with high total organic carbon. If invertebrate

communities contain abundant numbers of individuals from many different taxa on treated plots after some period of time, for example 56 days, or even one year, then Ecology will have all the information it needs to show that imidacloprid is not having a long-term negative impact on invertebrates.

I want to thank Ecology for the opportunity to submit these comments. Hart Crowser looks forward to working with the Department, and with Ecology staff, in revising the proposed SIZ and its associated monitoring programs to ensure a proper balance between the burdens placed upon WGHOGA, and the protection of the environment.

The process we are engaged in tends to result in a high level of focus on short-term effects or potential effects of imidacloprid applications. This focus on the short-term should not obscure the long-term benefits of permitting imidacloprid applications by WGHOGA. First, very considerable data, cited in comments from Plauché and Carr, document that burrowing shrimp impact more than shellfish; their presence, at high densities, results in the loss of many other species of invertebrates in and on the sediments they infest. Any intervention that reduces their numbers, and imidacloprid is certainly one such intervention, opens ecological space in the treated areas, allowing a more diverse and biologically rich community of invertebrates to develop. Given the importance of these invertebrates to many foraging birds and fish, this is an enhancement to the larger ecosystems in Willapa Bay and Grays Harbor.

The second long-term benefit of imidacloprid is that it allows the shellfish industry in Willapa and Grays Harbor to continue, with all the attendant economic, social, and gastronomic benefits associated with that industry. It would be a tragic loss in perspective to allow any concerns about imidacloprid effects of a days or weeks on localized plots to result in regulation that ignores and eliminates the long term benefits that accrue from imidacloprid use.

Sincerely,

HART CROWSER, INC.

JEFFREY C. BARRETT, PhD
Regional Manager for Natural Resources

Attachments:
Table 1 – Invertebrate Data, Willapa Bay Stations

Figure 1 – Ecology Sediment Sampling Locations
Figure 2 – Willapa Bay Sediment Type

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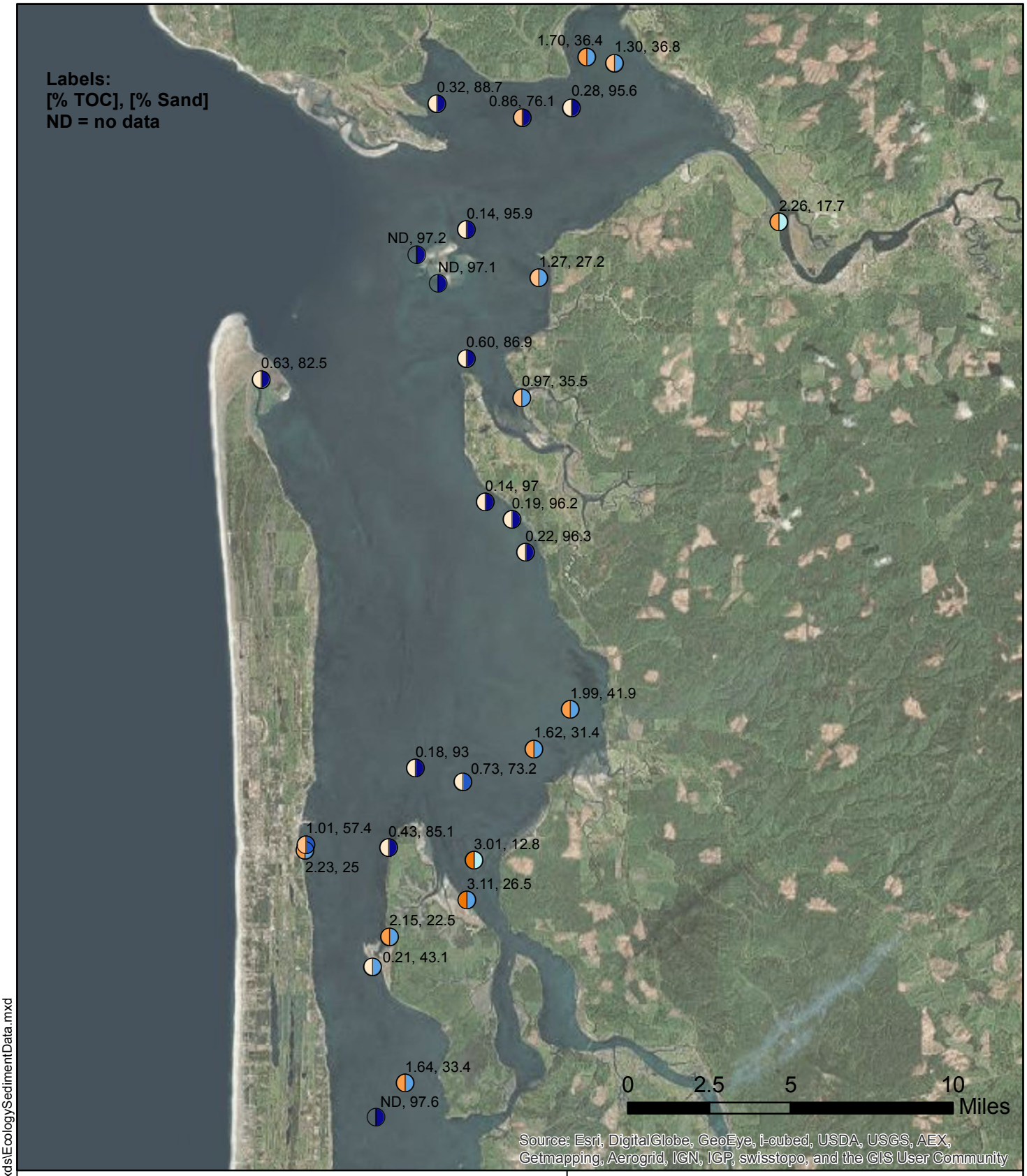
Table 1 – Invertebrate Data, Willapa Bay Stations

Willapa Bay 2011 (Cedar River)	Willapa Bay 78 (North – Cedar River)	Willapa Bay 61 (North – Tokeland)	Willapa Bay 66 (Willapa River)	Willapa Bay 71 (North)	Willapa Bay 143 (North)	Willapa Bay 2012 (Bay Center and Leadbetter)	Willapa Bay 2011 (Bay Center)	Willapa Bay 87 (Central – Bay Center)	Willapa Bay 2 (Central)	Willapa Bay 67 (Central)	Willapa Bay 102 (Central)	Willapa Bay 70 (Central – just north of cutoff)	Willapa Bay 3 (South – East side of Peninsula)	Willapa Bay 75 (South – West side of Long Island)	Willapa Bay 91 (South – East side of Long Island)	Willapa Bay 123 (South – just below cut-off)	Willapa Bay 127 (South – West side of Long Island)
					Allorchestes angusta			*Allorchestes angusta*	*Allorchestes angusta*						*Allorchestes angusta*		
	Americorophium salmonis	*Americorophium salmonis*	*Americorophium salmonis*					*Americorophium salmonis*							*Americorophium salmonis*		
	Americorophium sp.		*Americorophium* sp.														
			Americorophium spinicorne												*Americorophium spinicorne*		
								Amphiporus sp.									
	Ampithoe sp.		*Ampithoe* sp.		*Ampithoe* sp.			*Ampithoe* sp.	*Ampithoe* sp.		*Ampithoe* sp.	*Ampithoe* sp.	*Ampithoe* sp.	*Ampithoe* sp.		*Ampithoe* sp.	*Ampithoe* sp.
	Ampithoe valida							*Ampithoe valida*	*Ampithoe valida*		*Ampithoe valida*	*Ampithoe valida*		*Ampithoe valida*			
					Anisogammarus pugettensis												*Anisogammarus pugettensis*
				Aphelochaeta sp.													
								Arenicolidae	*Arenicolidae*		*Arenicolidae*	*Arenicolidae*		*Arenicolidae*			*Arenicolidae*
Armandia brevis				*Armandia brevis*		*Armandia brevis*	*Armandia brevis*					*Armandia brevis*					
Balanus sp.													*Balanus* sp.		*Balanus* sp.		
Barantolla nr. Americana															*Barantolla nr americana*		
Bipalponephtys cornuta						*Bipalponephtys cornuta*											
Bivalvia						*Bivalvia*	*Bivalvia*					*Bivalvia*					
				Campanularia gelatinosa													
Capitella capitata complex	*Capitella capitata* complex	*Capitella capitata* complex	*Capitella capitata* complex	*Capitella capitata* complex		*Capitella* sp.	*Capitella capitata* complex	*Capitella capitata* complex			*Capitella capitata* complex	*Capitella capitata* complex	*Capitella capitata* complex	*Capitella capitata* complex	*Capitella capitata* complex	*Capitella capitata* complex	*Capitella capitata* complex
				Caprella californica													
											Caprella californica						*Caprella californica*
				Caprella laeviuscula	*Caprella drepanochir*				*Caprella drepanochir*								
				Caprella sp.				*Caprella* sp.	*Caprella* sp.	*Caprella* sp.							*Caprella* sp.
												Chirimia similis					
	Chironomidae		*Chironomidae*					*Chironomidae*	*Chironomidae*		*Chironomidae*	*Chironomidae*		*Chironomidae*			*Chironomidae*
Clinocardium nuttali						*Clinocardium nuttali*	*Clinocardium nuttali*		*Clinocardium nuttallii*	*Clinocardium nuttallii*	*Clinocardium nuttallii*					*Clinocardium nuttallii*	
Corophiidae			*Corophiidae*			*Corophiidae*	*Corophiidae*		*Corophiidae*		*Corophiidae*			*Corophiidae*			
		Crangon franciscorum								*Crangon franciscorum*				*Crangon franciscorum*			*Crangon franciscorum*
										Crangon sp.				*Crepipatella dorsata*			
Cryptomya californica		*Cryptomya californica*			*Cryptomya californica*	*Cryptomya californica*	*Cryptomya californica*		*Cryptomya californica*	*Cryptomya californica*	*Cryptomya californica*				*Cryptomya californica*	*Cryptomya californica*	
	Cumella vulgaris			*Cumella vulgaris*										*Cumella vulgaris*			
Cyclopoida						*Cyclopoida*	*Cyclopoida*								*Cyclopoida*		
												Diadumenidae	*Diadumenidae*	*Diadumenidae*	*Diadumenidae*		
				Dipolydora quadrilobata								*Dipolydora quadrilobata*					*Dipolydora quadrilobata*
			Edwardsiidae														
		Enteropneusta		*Enteropneusta*				*Enteropneusta*						*Enteropneusta*			
			Eogammarus confervicolus complex						*Eogammarus confervicolus* complex	*Eogammarus confervicolus* complex							
		Eohaustorius estuarius			*Eohaustorius estuarius*				*Eohaustorius estuarius*	*Eohaustorius estuarius*	*Eohaustorius estuarius*					*Eohaustorius estuarius*	
Eeone sp. (juv)						*Eeone* sp. (juv)	*Eeone* sp. (juv)										
Eteone californica	*Eteone californica*		*Eteone californica*	*Eteone californica*		*Eteone californica*	*Eteone californica*	*Eteone californica*	*Eteone californica*		*Eteone californica*	*Eteone californica*	*Eteone californica*	*Eteone californica*	*Eteone californica*		*Eteone californica*
Eteone columbiensis						*Eteone columbiensis*	*Eteone columbiensis*										
Eteone fauchaldia						*Eteone fauchaldia*											
				Eusarsiella zostericola								*Eusarsiella zostericola*		*Eusarsiella zostericola*			*Eusarsiella zostericola*
Exogone dwisula							*Exogone dwisula*							*Exogone dwisula*			*Exogone dwisula*
							Exogone sp.										
Family Arenicolidae (juv)						Family Arenicolidae (juv)											
							Family Opheliidae unidentified sp. (juv)										
							Family Pasiphaeidae unidentified sp.										
							Family Sabellidae unidentified juveniles										
							Family Tellinidae unidentified sp.										
Glycinda sp. (juv)							*Glycinda* sp. (juv)										
Glycinde picta						*Glycinde picta*	*Glycinde picta*										
	Glycinde polygnatha	*Glycinde polygnatha*		*Glycinde polygnatha*	*Glycinde polygnatha*			*Glycinde polygnatha*	*Glycinde polygnatha*	*Glycinde polygnatha*	*Glycinde polygnatha*	*Glycinde polygnatha*	*Glycinde polygnatha*	*Glycinde polygnatha*		*Glycinde polygnatha*	*Glycinde polygnatha*

Willapa Bay 2011 (Cedar River)	Willapa Bay 78 (North – Cedar River)	Willapa Bay 61 (North – Tokeland)	Willapa Bay 66 (Willapa River)	Willapa Bay 71 (North)	Willapa Bay 143 (North)	Willapa Bay 2012 (Bay Center and Leadbetter)	Willapa Bay 2011 (Bay Center)	Willapa Bay 87 (Central – Bay Center)	Willapa Bay 2 (Central)	Willapa Bay 67 (Central)	Willapa Bay 102 (Central)	Willapa Bay 70 (Central – just north of cutoff)	Willapa Bay 3 (South – East side of Peninsula)	Willapa Bay 75 (South – West side of Long Island)	Willapa Bay 91 (South – East side of Long Island)	Willapa Bay 123 (South – just below cut-off)	Willapa Bay 127 (South – West side of Long Island)
															Gnorimosphaeroma insulare		
					Grandifoxus grandis					*Grandifoxus grandis*							
	Grandidierella japonica	*Grandidierella japonica*	*Grandidierella japonica*	*Grandidierella japonica*				*Grandidierella japonica*	*Grandidierella japonica*		*Grandidierella japonica*	*Grandidierella japonica*	*Grandidierella japonica*	*Grandidierella japonica*	*Grandidierella japonica*	*Grandidierella japonica*	*Grandidierella japonica*
														Halacaridae			
								Halcampidae					*Halcampidae*				
												Harmothoe imbricata					
Harpacticoida			*Harpacticoida*	*Harpacticoida*	*Harpacticoida*	*Harpacticoida*	*Harpacticoida*					*Harpacticoida*					
Hemigrapsus oregonensis		*Hemigrapsus oregonensis*				*Hemigrapsus oregonensis*	*Hemigrapsus oregonensis*										
						Hesperonoe laevis											
	Heteromastus filiformis		*Heteromastus filiformis*	*Heteromastus filiformis*				*Heteromastus filiformis*					*Heteromastus filiformis*	*Heteromastus filiformis*	*Heteromastus filiformis*		*Heteromastus filiformis*
				Idotea fewkesi													
				Imogine exiguus												*Idotea fewkesi*	*Idotea fewkesi*
Infraorder Capreillida						*Infraorder Capreillida*	*Infraorder Capreillida*										
Infraorder Corophida						*Infraorder Corophida*	*Infraorder Corophida*										
					Lacuna vincta						*Lacuna vincta*						*Lacuna vincta*
	Lacuna sp.			*Lacuna* sp.													
Leitoscoloplos pugettensis						*Leitoscoloplos pugettensis*	*Leitoscoloplos pugettensis*										
Leptochelia dubia		*Leptochelia dubia*	*Leptochelia dubia*	*Leptochelia dubia*		*Leptochelia dubia*	*Leptochelia dubia*	*Leptochelia dubia*	*Leptochelia dubia*			*Leptochelia dubia*	*Leptochelia dubia*	*Leptochelia dubia*	*Leptochelia dubia*		*Leptochelia dubia*
				Leptoplanidae										*Leptoplanidae*			
				Lineidae									*Lineus* sp.		*Lineus* sp.		
	Leuconidae							*Leuconidae*									
																	Lirabuccinum dirum
Macoma balthica	*Macoma balthica*	*Macoma balthica*	*Macoma balthica*			*Macoma balthica*	*Macoma balthica*	*Macoma balthica*	*Macoma balthica*	*Macoma balthica*	*Macoma balthica*	*Macoma balthica*	*Macoma balthica*	*Macoma balthica*		*Macoma balthica*	*Macoma balthica*
Macoma nasuta		*Macoma nasuta*		*Macoma nasuta*			*Macoma nasuta*		*Macoma nasuta*		*Macoma nasuta*					*Macoma nasuta*	*Macoma nasuta*
Macoma sp. (juv)			*Macoma* sp.	*Macoma* sp.		*Macoma* sp. (juv)	*Macoma* sp. (juv)							*Macoma* sp.			
						Magelona hobsonae											
	Manayunkia aestuarina							*Manayunkia aestuarina*					*Manayunkia aestuarina*		*Manayunkia aestuarina*		
Mediomastus californiensis	*Mediomastus californiensis*	*Mediomastus californiensis*		*Mediomastus californiensis*	*Mediomastus californiensis*	*Mediomastus californiensis*	*Mediomastus californiensis*	*Mediomastus californiensis*	*Mediomastus californiensis*	*Mediomastus californiensis*		*Mediomastus californiensis*			*Mediomastus* sp.	*Mediomastus californiensis*	
														Melita nitida			
						Microphthalmus sp.											
		Micrura sp.		*Micrura* sp.				Micrura sp.							Micrura sp.		
				Monocorophium acherusicum					*Monocorophium acherusicum*		*Monocorophium acherusicum*	*Monocorophium acherusicum*		*Monocorophium acherusicum*	*Monocorophium acherusicum*		*Monocorophium acherusicum*
				Monocorophium insidiosum				*Monocorophium insidiosum*	*Monocorophium insidiosum*		*Monocorophium insidiosum*			*Monocorophium insidiosum*	*Monocorophium insidiosum*		*Monocorophium insidiosum*
Monocorophium sp.				*Monocorophium* sp.	*Monocorophium* sp.			*Monocorophium* sp.	*Monocorophium* sp.	*Monocorophium* sp.	*Monocorophium* sp.	*Monocorophium* sp.	*Monocorophium* sp.	*Monocorophium* sp.	*Monocorophium* sp.		*Monocorophium* sp.
Mya arenaria	*Mya arenaria*		*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*		*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*	*Mya arenaria*
Mytilus sp.	*Mytilus* sp.			Mytilidae	*Mytilus* sp.	*Mytilus* sp.	*Mytilus* sp.		Mytilidae								
			Neanthes limnicola	*Neanthes limnicola*													
Neotrypaea callforniensis (juv)						*Neotrypaea callforniensis (juv)*											
Nephtys caeca		*Nephtys caeca*		*Nephtys caeca*	*Nephtys caeca*	*Nephtys caeca*	*Nephtys caeca*		*Nephtys caeca*	*Nephtys caeca*	*Nephtys caeca*			*Nephtys caeca*		*Nephtys caeca*	*Nephtys caeca*
												Nephtys cornuta	*Nephtys cornuta*				
Nephtys sp. indent. (juv)						*Nephtys* sp. indet. (juv)	*Nephtys* sp. indent. (juv)										
Nereididae				*Nereididae*		*Nereididae*	*Nereididae*						*Nereididae*				
			Nippoleucon hinumensis											*Nippoleucon hinumensis*			
Notomastus tenuis						*Notomastus tenuis*	*Notomastus tenuis*					*Notomastus tenuis*					
Oligochaeta	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*	*Oligochaeta*
							Ophelia limacine										
Order Calanoida						Order Calanoida	Order Calanoida										
Order Cumacea						Order Cumacea	Order Cumacea										
Order Cyclopoida																	
						Order Decapoda	Order Decapoda unidentified sp.										
Order Isopoda						Order Isopoda											
Order Ostracoda						Order Ostracoda	Order Ostracoda										
Order Tanaidacea						Order Tanaidacea	Order Tanaidacea										
				Owenia fusiformis												*Owenia fusiformis*	
		Pagurus sp.															
				Paranemertes californica				*Paranemertes peregrina*									
				Paranemertes peregrina													
Paraonella platybranchia	*Paraonella platybranchia*				*Paraonella platybranchia*	*Paraonella platybranchia*	*Paraonella platybranchia*		*Paraonella platybranchia*	*Paraonella platybranchia*	*Paraonella platybranchia*						
		Phoronis pallida		*Phoronis pallida*													

Willapa Bay 2011 (Cedar River)	Willapa Bay 78 (North – Cedar River)	Willapa Bay 61 (North – Tokeland)	Willapa Bay 66 (Willapa River)	Willapa Bay 71 (North)	Willapa Bay 143 (North)	Willapa Bay 2012 (Bay Center and Leadbetter)	Willapa Bay 2011 (Bay Center)	Willapa Bay 87 (Central – Bay Center)	Willapa Bay 2 (Central)	Willapa Bay 67 (Central)	Willapa Bay 102 (Central)	Willapa Bay 70 (Central – just north of cutoff)	Willapa Bay 3 (South – East side of Peninsula)	Willapa Bay 75 (South – West side of Long Island)	Willapa Bay 91 (South – East side of Long Island)	Willapa Bay 123 (South – just below cut-off)	Willapa Bay 127 (South – West side of Long Island)
						Phyllodoce sp.											
Platynereis bicanaliculata				*Platynereis bicanaliculata*		*Platynereis bicanaliculata*	*Platynereis bicanaliculata*		*Platynereis bicanaliculata*		*Platynereis bicanaliculata*	*Platynereis bicanaliculata*					*Platynereis bicanaliculata*
												Polycirrus californicus					*Polycirrus californicus*
												Polycirrus sp.					
Platynereis sp.						*Platynereis* sp.											
													Polycystididae				
Polydora cornuta	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*		*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*	*Polydora cornuta*
																Potamopyrgus antipodarum	
Pseudopolydora kempi	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*		*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*	*Pseudopolydora kempi*
Pseudopolydora paucibranchiata	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*		*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*		*Pseudopolydora paucibranchiata*	*Pseudopolydora paucibranchiata*
Pygospio elegans						*Pygospio elegans*	*Pygospio elegans*		*Pygospio elegans*	*Pygospio elegans*	*Pygospio elegans*				*Pygospio elegans*		*Pygospio elegans*
Rhynchospio glutaea				*Rhynchospio glutaea*		*Rhynchospio glutaea*	*Rhynchospio glutaea*		*Rhynchospio glutaea*		*Rhynchospio glutaea*						*Rhynchospio glutaea*
Sabeco elongatus				*Sabaco elongatus*													
Scolelepis sp. (Juv)						Scolelepis sp. (Juv)											
Scolelepis squamata				*Scolelepis squamata*		*Scolelepis squamata*	*Scolelepis squamata*	*Scolelepis squamata*									
Scoloplos armiger alaskensis			*Scoloplos armiger alaskensis*	*Scoloplos armiger alaskensis*								*Scoloplos armiger alaskensis*	*Scoloplos armiger alaskensis*	*Scoloplos armiger alaskensis*			*Scoloplos armiger alaskensis*
Scoloplos armiger armiger					*Scoloplos armiger armiger*	*Scoloplos armiger armiger*	*Scoloplos armiger armiger*		*Scoloplos armiger armiger*	*Scoloplos armiger armiger*	*Scoloplos armiger armiger*						*Scoloplos armiger armiger*
Scoloplos sp. (juv)						*Scoloplos* sp. (juv)	*Scoloplos* sp. (juv)		*Scoloplos sp.*			*Scoloplos sp.*		*Scoloplos sp.*			
								Sinelobus stanfordi						*Sinelobus stanfordi*			
Sphaerosyllis californiensis				*Sphaerosyllis californiensis*		*Sphaerosyllis californiensis*	*Sphaerosyllis californiensis*	*Sphaerosyllis californiensis*				*Sphaerosyllis californiensis*	*Sphaerosyllis californiensis*				*Sphaerosyllis californiensis*
Sphaerosyllis sp(p).						*Sphaerosyllis* sp(p).								*Sphaerosyllis ranunculus*			
																	Sphaerosyllis sp. N1
Sphenia ovoidea						*Sphenia ovoidea*	*Sphenia ovoidea*										
Spionidae, unidentified (post-larval)						Spionidae, unidentified (post-larval)				*Spionidae*				*Spionidae*			
							Spiophanes bombyx									*Spiophanes bombyx*	
Streblospio benedicti	*Streblospio benedicti*	*Streblospio benedicti*	*Streblospio benedicti*	*Streblospio benedicti*		*Streblospio benedicti*	*Streblospio benedicti*	*Streblospio benedicti*	*Streblospio benedicti*			*Streblospio benedicti*	*Streblospio benedicti*	*Streblospio benedicti*	*Streblospio benedicti*		*Streblospio benedicti*
Suborder Gammaridea						*Suborder Gammaridea*	*Suborder Gammaridea*										
												Syllides japonica					
						Syllides minutes											
					Syllides sp.				*Syllides* sp.	*Syllides* sp.							
							Syllides nr. longocirrata										
						Tapes philippinarum	*Tapes philippinarum*										
	Tetrastemma sp.			*Tetrastemma* sp.				*Tetrastemma* sp.			*Tetrastemma* sp.						
Tharyx parvus		*Tharyx parvus*		*Tharyx parvus*		*Tharyx parvus*	*Tharyx parvus*	*Tharyx parvus*	*Tharyx parvus*	*Tharyx parvus*	*Tharyx parvus*	*Tharyx parvus*		*Tharyx parvus*	*Tharyx parvus*	*Tharyx parvus*	*Tharyx parvus*
						Thoracophelia mucronata	*Thoracophelia mucronata*										
	Tubulanus sp. A			*Tubulanus* sp. A				*Tubulanus* sp.					*Tubulanus* sp. A				
Unidentifed (juv) gastropods						Unidentifed (juv) gastropods	unident sp. (post-larval)										
Unidentifed Myid (adult)						Unidentifed Myid (juv)	Unidentifed Myid (juv)										
Unidentifed Myid (juv)						Unidentified (adult) bivalves	Unidentified crustacean										
Unidentified (juv) bivalves						Unidentified (juv) bivalves	Unidentified Mytilid (juv)										
Unidentified crustacean						Unidentified crustacean	unidentified sp. (adult) bivalves										
Unidentified Mytilid (juv)						Unidentified Mytilid (juv)	unidentified sp. (juv) bivalves										
								Venerupis philippinarum	*Venerupis philippinarum*	*Venerupis philippinarum*	*Venerupis philippinarum*			*Venerupis philippinarum*		*Venerupis philippinarum*	*Venerupis philippinarum*
	Zygonemertes virescens													*Zygonemertes virescens*			



% TOC	% Sand
0 - 0.75	0 - 20
0.75 - 1.5	20 - 50
1.5 - 2.5	50 - 75
2.5 - 3.5	75 - 100

N

Plauche & Carr
Willapa Bay, WA

Ecology Sediment Sampling Locations

12733-02 11/2014

HARTCROWSER

Figure
01

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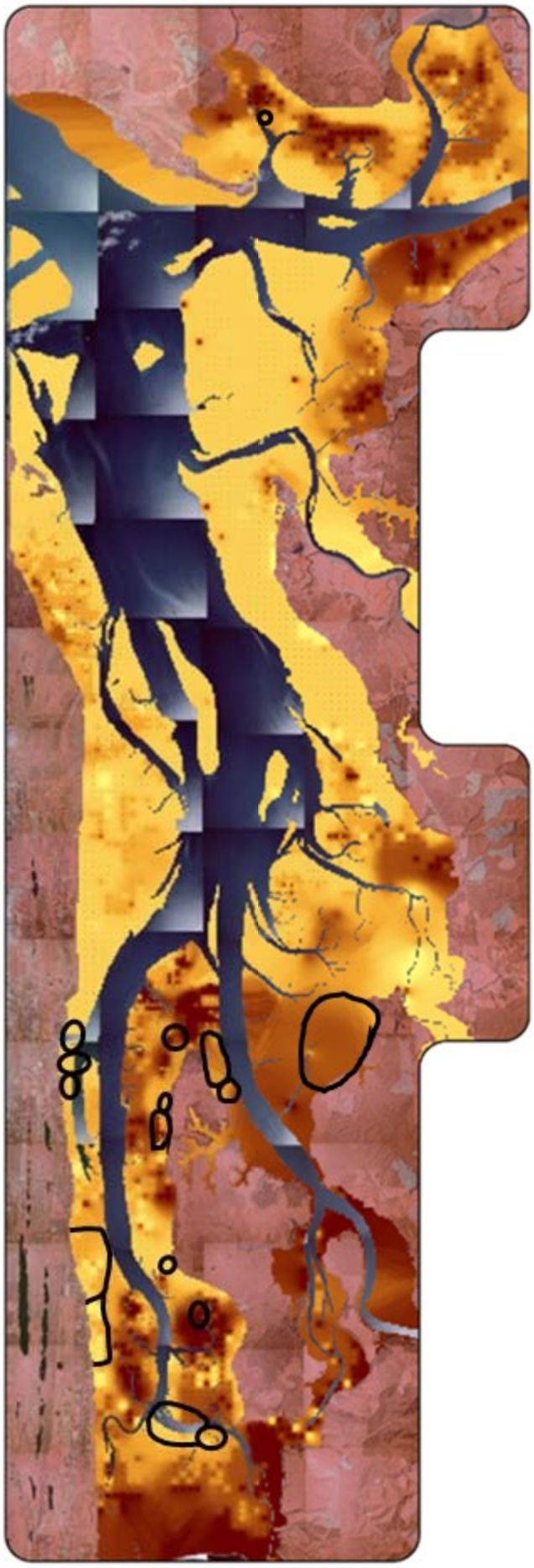

Light = sand-rich sediment
Dark = silt-rich sediment

Representative commercial shellfish beds in South Willapa Bay

Willapa Bay Sediment Type

12722 12/2014

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From: Brett Dumbauld, USDA