Pacific Shellfish Institute

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July 31, 2014

Ken B. Moore, Executive Director
Interstate Shellfish Sanitation Conference
209-2 Dawson Road
Columbia, SC 29223-1740

Dear Mr. Moore:

Please see the attached proposal from the Pacific Shellfish Institute (PSI) to the Interstate Shellfish Sanitation Conference (ISSC) for the July 21, 2014 request for proposal: "Techniques and Practices for Vibrio Reduction".

If I can offer further details to facilitate review of this proposal, please feel free to contact me at (360) 754-2741 or bobbi@pacshell.org.

Sincerely,

Bobbi Hudson

Bobbi Hudson, Executive Director

1) Executive Summary

Vibrio parahaemolyticus is a common bacterial contaminant of bivalve shellfish, primarily oysters, and a major source of seafood-related food poisoning. Numerous outbreaks of *V. parahaemolyticus* illnesses associated with consumption of raw or poorly cooked shellfish have occurred between 1997 and 2013, both in the United States and elsewhere. On the U.S. West Coast and particularly in Washington, elevated *V. parahaemolyticus* levels in waters where shellfish are grown, and associated illnesses, continue to cause extensive seasonal harvest closures and product recalls. The closures cause reduced farm and harvester revenue, payrolls, and lost opportunity for tribal and recreational harvest. *V. parahaemolyticus* levels in many growing areas nationwide appear to be increasing and outbreaks could occur with higher frequency and severity across a greater geographic range in the future.

The Pacific Shellfish Institute (PSI) has been engaged in laboratory and field experiments focused on *Vibrio* for over a decade. We believe existing research provides preliminary evidence that elevated *V. parahaemolyticus* levels in intertidal cultivated shellfish can be mitigated by on-site exposure to ambient water conditions. In Washington State and other locations with access to tidelands, shellfish farmers have an enhanced ability to apply innovative post-harvest methods for reducing *V. parahaemolyticus* in their oysters and other shellfish crops, but further studies are needed. In all likelihood, findings would be relevant to other *Vibrio* strains and certainly to other coastal regions. We propose the following two low-cost, high-return ideas for ISSC funding:

1. **Assess the effectiveness of deepwater to purge *V. parahaemolyticus*.** In preliminary experiments, Taylor Shellfish researcher Kurt Johnson demonstrated the effectiveness of deepwater to purge *V. parahaemolyticus* from oysters collected at beaches with historically high levels. The intake is located at their hatchery in Dabob Bay and can be run 24 hours/day. The temperature in waters from this intake is typically 10.5˚C (51˚F). Oysters placed in this water from warmer intertidal beaches (18˚C, 64˚F average) continued to feed and thus purged bacteria. Levels of MPN/g dropped from >11,000 at day 0 (2 replicates of 3 oysters each, not placed in deepwater) to 2400 or 230 at day 1 (per each 51replicate) and 0 and day 2 (both replicates). Results were less spectacular in oysters from beaches were summertime temperatures reached 40˚C (104˚F) likely due to shock which temporarily halted or greatly slowed feeding and purging behaviors.
2. **Assess the effectiveness of re-immersion in sink floats to purge *V. parahaemolyticus*.** Immersion of oysters in deeper, cooler waters has been used to successfully prevent *V. parahaemolyticus* related illness from oysters in Alaska. Washington Department of Health (WDOH) is currently testing its potential in collaboration with a local South Puget Sound producer. These proposed experiments will collaborate with that same producer, and with another producer, also located in a growing area with historically high levels of *V. parahaemolyticus.*

The current management of *V. parahaemolyticus* in shellfish focuses on two primary tactics: 1) closure of growing areas for harvest when contaminated shellfish are found and when

environmental factors indicate high risk of further contamination, and 2) restriction of post harvest times to refrigeration. Most other measures tend to alter the freshness of the product, have uncertain efficacy, and increase the cost to the processor and consumer. PSI and others have investigated a few alternative tactics that showed promise but were inconclusive due to low levels of naturally occurring *V. parahaemolyticus* which limited experimental treatment, and problems with the analytical technique used to quantify *V. parahaemolyticus*. The relay of oysters to waters with lower ambient *V. parahaemolyticus* levels and/or different temperature and salinity conditions was particularly encouraging. The focus of the proposals outlined here, to ISSC, center on the relay of oysters from intertidal culture to: 1) recirculating tanks with deepwater; and 2) sink floats with deeper water.

PSI staff are familiar with the particular challenge of studying *Vibrio* in the field (e.g., identification of appropriate study sites, specialized sample collection and transport needs to avoid cross contamination, etc.). Furthermore, we have a long-standing relationship with the West Coast shellfish aquaculture industry, including Pacific Coast Shellfish Growers Association (PCSGA) members and staff. Recent and proposed PSI research features strong collaboration with both shellfish farmers and regulatory agencies, including the WDOH and FDA. If selected through this 2014 ISSC RFP, PSI would collaborate closely with these entities to complete the proposed research.

2) Approach and Methodology

The proposed research is a collaborative effort to address the project objectives in one year. The research has two primary integrated task elements which assess the potential of alternative post-harvest tactics to suppress the development of *V. parahaemolyticus* in oysters. Ancillary assessments will address some current practices associated with the monitoring of *V. parahaemolyticus* in oysters.

All experiments will depend upon the presence of naturally occurring *V. parahaemolyticus*, so field trials will target sample sites identified as having elevated *V. parahaemolyticus* levels during routine WDOH monitoring. These will likely be the same as those used in previous studies, which consistently exhibit high levels of *V. parahaemolyticus* during the summer months (Figure 1).

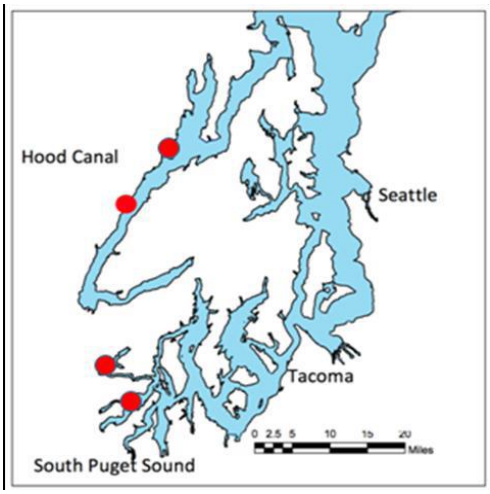

Figure 1 Likely locations of study sites.

All samples will comprise 13 representative oysters taken from the same tidal elevation and the same general area at each study area. Nine oysters will be assayed for *V. parahaemolyticus,* 3 will be reserved for measurement of internal temperatures, accidental loss, and laboratory error, and 1 oyster will be delivered to WDOH for validation of assay results by their laboratory. Oysters will be in the shell with no gapers or broken shells. Oysters will be rinsed with fresh or sea-water to remove sediment, and then be placed in waterproof plastic bags

and held on ice or in refrigeration prior to shipment for assay. Holding and shipping conditions and procedures will be the same as those used by WDOH, except in the ancillary studies which directly assess those procedures.

Samples will be analyzed by the Environmental Engineering Laboratory (EEL), part of the Institute of Environmental Health (IEH), (IEHEEL) in San Diego, and by WDOH for quantitative PCR to gather MPN/g of *V. parahaemolyticus*. The laboratories feature high throughput realtime PCR protocol to quantify *V. parahaemolyticus* (Vp), thermolabile hemolysin (tlh+), and thermostable-direct hemolysin positive (tdh+) Vp. This assay provides quantitative results for both Vp and tdh+ Vp in as little as 24 hours. The protocol will be similar to the multiplexed real-time PCR TaqMan fluorescent probe assay described in Ward and Bej (2006). Shipping methods will be the same as the WDOH methods using Styrofoam shipping boxes and gel packs for refrigeration, except when those methods are compared with alternative tactics.

Transfer Permits will be acquired from the Washington Department of Fish and Wildlife in association with the transport of oysters among areas.

Task 1. **Compare levels of *V. parahaemolyticus* clearance in oysters from areas with consistently high levels of *V. parahaemolyticus* after holding in deepwater intake for various time intervals.**

We propose to augment Kurt Johnson's preliminary studies in collaboration with Mr. Johnson and Taylor Shellfish. Three separate studies will be conducted in succession:

- Purging will be reduced from 24, 48, and 72 hrs to 12, 24, and 36 hrs (untreated oysters from time 0 will also be assayed for levels of *V. parahaemolyticus*).
- Temperature of the deepwater will be elevated by 5˚C to test purging in oysters from especially warm beaches.
- A third test will be conducted to further refine or more precisely test the result of either of the first two tests.

For each experiment, oysters removed from the deepwater treatment will be immediately placed in ice-slurry for ½ hr prior to packing with gel ice pack and shipped with over-night delivery to the laboratory for analysis, in keeping with Mr. Johnson's previous protocols.

The internal temperatures of an ancillary replicate sample of oysters will be measured prior to ice-slurry and shipment.

Task 2. **Compare levels of *V. parahaemolyticus* clearance in oysters from areas with consistently high levels of *V. parahaemolyticus* to oysters resubmerged in nearby deeper cooler waters using sink floats.**

This technique has been used to successfully prevent *V. parahaemolyticus* illness from oysters in Alaska and WDOH is currently testing its potential in collaboration with a local South Puget Sound producer. These proposed experiments will collaborate with that same producer, and with another producer, also located in a growing area with historically high levels of *V. parahaemolyticus*.

The experiment will be conducted at each study site, beginning when numbers of total *Vibrio* and *tlh+* numbers are elevated, as determined in consultation with WDOH. For each experiment, 3 replicate samples of oysters will be collected at the experiment's onset and shipped immediately to the laboratory for quantitative assay of *V. parahaemolyticus*. The internal temperatures of 3 ancillary replicate samples will also be measured and tissue will be sampled at the experiment's onset. An additional 12 replicate samples will be placed in a sink float located in deeper, cooler water. Three samples will be removed and shipped for assay at 1, 3, and 7 days post the initial submergence. The internal temperatures will be measured and tissue will be sampled for each of the 3 remaining replicate samples at each sample interval.

Additional observations will comprise:

- During immersion sampling, water temperature will be recorded with temperature loggers. Salinity and dissolved oxygen will also be measured on site to duplicate WDOH protocols. In-water elements will also be measured off-site to provide ancillary information.
- Internal oyster temperatures will be taken along with tissue samples by opening a market sized oyster, pushing the thermometer into the meat as far as the dimple (or 1 inch), and measuring the temperature. This oyster will not be a part of the tissue sample.

Results will be compared among immersion interval and repetition using analysis of variance. Trends among the variables will also be examined visually.

Ancillary assessments

Compare levels of *V. parahaemolyticus* in oysters placed in ice-slurry prior to shipment with ice-gel packs to shipment no ice-slurry treatment and shipment with ice-gel packs only.

Additional pre-treatment samples from the sink-float studies will be assayed for levels of *V. parahaemolyticus* after shipment to the laboratory in California using Mr. Johnson's ice-slurry pre-shipment protocol or WDOH protocol featuring ice-gel packs only. In anticipation of high variability among replicates and low difference between shipment methods, 9 replicate samples per method will be assayed rather than 3.

Validation of California EEL laboratory results with results from WDOH laboratory.

As previously noted, an additional sample at each of the sample interval for both tasks 1 and 2 will be shipped or hand-delivered to WDOH for comparative analysis and validation with their laboratory.

If possible, apply field data to assess key environmental parameters for correlations and interactions with *V. parahaemolyticus* growth and clearance to potentially better predict and manage elevated levels in oysters.

In previous studies, samples collected from areas in Hood Canal, Washington consistently had higher levels of *V. parahaemolyticus* in oysters and sediments compared to samples collected from sites in the southern main basin of Puget Sound, Washington. Water salinity and temperatures are often very similar at these two areas, but Hood Canal is known to differ from the rest of Puget Sound in terms of dissolved oxygen levels, types and abundances of phytoplankton, and the dynamics of water circulation. Further investigation of the

oceanographic and biological conditions associated with *V. parahaemolyticus* during the summer season would be of great value in developing tools to predict levels of *V. parahaemolyticus* and areas at risk in Hood Canal and elsewhere.

PSI currently has a moderate data base of the key environmental factors and associated levels of *V. parahaemolyticus* in oysters at the same site and time. Though the proposed studies are small in scale and sample size, they are better replicated than previously, and would augment that base.

Data from all PSI and potentially WDOH studies will be analyzed using correlation analysis, trend and analysis, and potentially multivariate analysis.

3) Project Deliverables

Results of the research outlined above would provide shellfish growers and harvesters across the country with two proactive post-harvest management practices to reduce and/or minimize the risk of *V. parahaemolyticus* derived food poisoning in raw and under-cooked shellfish. Specific deliverables would be recommendations toward the feasibility of submerging oysters with high levels of using *V. parahaemolyticus* in 1) recirculating deepwater and 2) deeper cooler water using sink floats. These tactics would allow oysters to purge and depurate *V. parahaemolyticus.* For each tactic, recommendations will include optimal post-harvest holding temperatures and duration for effective *Vibrio* reduction. In addition to ongoing discussions with research collaborators (Taylor Shellfish and WDOH), recommendations will be detailed in a final report to ISSC. The final report will summarize the scope, approach, results, statistical analysis of results, and recommendations stemming from this research.

Adoption of these post-harvest management practices would improve harvest predictability during periods of potential *V. parahaemolyticus* contamination in shellfish, increase consumer confidence in the safety of the products, reduce or minimize the *V. parahaemolyticus* related closures, recalls, and associated economic losses.

The proposal outlined above would also complement other *Vibrio* research on shellfish. It would contribute to the cooperative relationships between local, state and federal regulatory agencies, tribes, academic institutions, shellfish growers and scientific consultants distributed along the entire West Coast. Findings would also assist ISSC and public health regulators in providing valuable feedback to the FDA regarding the *V. parahaemolyticus* risk assessment.

4) Project Management Approach

PSI will collaborate closely with Taylor Shellfish and WDOH to establish the location and specifics of the study design outlined in section 2 "Approach and Methodology" above. However, project oversight will be the responsibility of PSI, including financial management. Roles of specific PSI staff will be as follows:

As Executive Director, Bobbi Hudson will be responsible for the organization and management of this grant within PSI. She will actively supervise all PSI staff and subcontractors supported by this grant and conducting the research. Ms. Hudson will also be actively involved in all aspects of the research and the production of the final report to ISSC. She will also be responsible for submitting all necessary financial data and information to fulfill project deliverables and reporting requirements. Ms. Hudson will be actively involved in outcome dissemination and communication of this project.

Dr. Cheney will responsible for final experimental design, data interpretation and contribute to the final report to ISSC.

Dr. Steven Booth will be responsible for experimental design, product procurement, data acquisition, data evaluation, data interpretation and contribute to the final report to ISSC. He will also be actively involved in analysis and reporting and outcome dissemination.

Andy Suhrbier will be responsible for conducting studies, especially sample procurement and data acquisition. He will be involved with finalizing experimental design and collecting information and data for all activities for this grant. He will be responsible for data evaluation and interpretation with the consulting help of Drs. Cheney and Booth. He will also be actively involved in collaboration with Taylor Shellfish, other shellfish aquaculture farms, WDOH, and the outcome dissemination and communication of this project.

5) Detailed and Itemized Pricing

The research outlined above is detailed by major task below. Laboratory and shipping costs for individual experiments are separated to allow comparison. *PSI encourages ISSC to consider partial funding of this proposal if 100% funding is not available, and/or a portion of this proposal is not of significant interest to ISSC.*

Task 1.

Deep Water: Testing to see timing of depuration of Hood Canal Oysters in 100ft intake water.

Samples:	36 samples in 3 experiments (deepwater, elevated water, best one) 12 Samples each experiment (3 samples at 0, 12, 24 and 36 hrs)	
		Overnight shipping (including boxes and ice):
Sample Analysis:	$168	40
# samples	36	36
Total:	$6,048	$ 1,440
Experimental Total:		$ 7,488

Ancillary comparison of ice-slurry to normal gel-pack shipping

Sample Analysis:	$168	40
ice-slurry # samples	6	6
gel-pack only # samples	9	9
Total:	$ 2,520	$600
Experiment Total:		$3,120

Task 2.
Sink Float: Testing to see timing of depuration of South Puget Sound Oysters in sink floats.

Samples:	24 samples (12 Samples at each site.) 3 samples at 0, 1, 3 and 7 days.	
		Overnight shipping (including boxes and ice):
Sample Analysis:	$168	40
# samples	24	24
Total:	$4,032	$960
Experiment Total:		$4,992

Budget for PSI staff time and expenses:

Personnel	**Amt. of effort**			
Executive Director	25%	1.50	months	$2,065
Research Director	25%	1.00	months	$1,997
Senior Scientist	25%	1.50	months	$2,408
Senior Biologist	25%	2.00	months	$2,700
	Total Salaries and Wages			$9,169
	Direct Staff Benefits (35%)			$3,209
	Total Personnel Costs			$12,379
Travel				
Domestic Travel				
	Auto travel ($0.56/mile)			$952
	Other travel (meals & incidental reimbursement)			$180
	Total Travel			$1,132

As detailed above, the total budget for Task 1, Task 2 and ancillary studies is $29,111. No overhead or indirect fees are included. Matching funds of at least 1:2 can be documented through in-kind and direct expenses associated with Task 1 and Task 2, but exact amounts will depend on which tasks and/or ancillary studies ISSC encourages. Collaboration with WDOH, Taylor Shellfish and two additional shellfish aquaculture farms will be the source of matching funds. If allowable, PSI can also demonstrate matching funds through circumvented indirect costs (PSI's currently approved indirect rate with the Department of Commerce is 46.22%).

Citations:

Ward, L. N. and A. K. Bej (2006). "Detection of *Vibrio parahaemolyticus* in shellfish by use of multiplexed real-time PCR with TaqMan fluorescent probes." Applied and Environmental Microbiology **72**(3): 2031-2042.

Appendix A: References

PSI has conducted numerous grant-funded *Vibrio* studies for the NOAA Saltonstall-Kennedy grant program and the NOAA/National Sea Grant Aquaculture Research Program. Current grant program administrators are:

Dr. Gene Kim
NOAA National Sea Grant Program Director for Aquaculture
(301) 734-1281
gene.kim@noaa.gov

Penelope D. Dalton, M.S.
Washington Sea Grant Director
(206) 685-9215
pdalton@u.washington.edu

All recent PSI studies focused on *Vibrio parahaemolyticus* have included substantial collaboration with the Washington Department of Health, Office of Shellfish and Water Protection, Division of Environmental Public Health. Numerous staff within the division can speak to PSI's research capabilities and *Vibrio* knowledge, but the main point of contact is:

Jerrod Davis, P.E.
Office of Shellfish and Water Protection Director
Washington State Department of Health
(360) 236-3391
Jerrod.Davis@DOH.WA.GOV

Appendix B: Project Team Staffing

Project staff will include executive director Bobbi Hudson, senior scientists Dr. Daniel Cheney and Dr. Steven Booth, and senior biologist Andrew Suhrbier. All staff are familiar with the particular challenge of studying *Vibrio* in the field, including identification of appropriate study sites, specialized sample collection and transport needs to avoid cross contamination. PSI staff will also work closely with Kurt Johnson at Taylor Shellfish, and Washington Department of Health staff, including Laura Wigand. Recent and currently proposed PSI research features strong collaboration with both shellfish farmers and regulatory agencies, and this project would continue PSI's well-established reputation in this regard.

All PSI project staff are hourly or salaried regular employees of PSI. PSI carries a $2,000,000 business liability insurance policy and a $1,000,000 Directors and Officers (D&O) insurance policy. No current PSI employees have ever been convicted of a felony.

Biographies follow for the following PSI staff that will contribute to this project:

- Bobbi Hudson, MSc, *Executive Director*
- Daniel Cheney, PhD, *Research Director*
- Steven Booth, PhD, *Senior Scientist*
- Andrew Suhrbier, BSc, *Senior Biologist*

Biographical Sketch Bobbi M. Hudson

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Tel: (360) 754-1359; Cell: (360) 490-6910
Email: bobbi@pacshell.org

PROFESSIONAL QUALIFICATIONS
M.S., Evergreen State College – Environmental Science -- 2005
B.S., Evergreen State College – Environmental Science, Fisheries -- 2001

DISSERTATIONS
MS thesis: *Environmental, economic & policy considerations of the net-pen salmon farming industry in Washington State*

PROFESSIONAL COLLABORATIONS
Thom Allen, Alexis Bond, Steven Booth, Susan Burke, Daniel Cheney, Aimee Christy, Leah Cuyno, Jonathan Davis, Ralph Elston, Joao Ferreira, Caroline Friedman, Julie Hampden, Molly Jackson, Teri King, Brian Kingzett, Leah Kuehl, David Landkamer, Mary Middleton, Danna Moore, Betsy Peabody, David Preikshot, Kristin Rasmussen, William Schenken, Sue Shotwell, peter Steinberg, Andrew Suhrbier, Brent Vadopalas, Katherine Wellman

PROFESSIONAL AFFILIATIONS
Member, National Shellfisheries Association

RELAVENT EXPERIENCE
Executive Director, Pacific Shellfish Institute, Olympia, Washington, July 2013 – Present
The Pacific Shellfish Institute (PSI) is a non-profit research organization originally created by the Pacific coast commercial shellfish industry in 1995. PSI retains a diverse portfolio of biological, oceanographic and social science research projects. Routine tasks of the executive director include grant and technical writing, research design and execution, presentations, public outreach, response to public, government and media inquiries and overall management of the organization. Bobbi's primary research interests include valuation of ecosystem services, economic impacts of shellfish cultivation, social and ecological carrying capacity, and intertidal ecology. Bobbi also specializes in evaluation of sustainable bivalve aquaculture production in nearshore environments.

Research Biologist, Pacific Shellfish Institute, Olympia, Washington, Nov. 2006 – June 2013
Conducted research, project management, and technical writing. Contributed to applied research projects on the interactions of shellfish culture with the natural environment, organic pollutants, and disease and environmental stress. Directed a multi-faceted project evaluating the benefits and costs of shellfish in Washington State, and a survey-based study of the economic contributions of the West Coast shellfish industry. Served as a inspector for sustainable shellfish product certifications.

Public Information Officer, Wash. Dept. Retirement Systems, Olympia, WA, Feb. 2002 – Dec. 2005
Produced a wide variety of print and web-based communications for agency staff, retirees, public officials and the Governor. Communications lead to implement new legislation.

Biological Science Technician, U.S. Fish and Wildlife Service, Flagstaff, AZ, Oct. 1998 – Sept. 2000
Conducted fisheries research in remote areas of Grand Canyon National Park and adjacent tribal lands. Prepared reports and delivered presentations about research and analysis at regional meetings. Extensive research, writing and editing of technical reports, some published. Trained other personnel in fish species identification, PIT tagging ESA species, and habitat classification.

SELECTED PUBLICATIONS & REPORTS

Wellman, K.F., **Hudson, B.M**., Schenken, W.S., Bond, A. and L. Cuyno. *In prep*. The Economic Impact of Shellfish Aquaculture in Washington State.

Hudson, B., Christy, A., and A. Suhrbier. 2014. Nutrient bioextraction using wild set of blue mussel (*Mytellis trossulus*) in Budd Inlet, Southern Puget Sound, Washington State. *Abstracts*: 106th Annual Meeting, National Shellfish Association, Jacksonville, FL. (abstract).

Davis, J., Vadopalas, B., Suhrbier, A., Cheney, D., Middleton, M., **Hudson, B**., Rasmussen, K., Kuehl, L. and C. Friedman. 2012. Growth and Maturation in Triploid Pacific Geoducks (*Panopea generosa)* in Puget Sound, Washington. *Abstracts* World Aquaculture Society (WAS)/National Shellfisheries Association (NSA)/American Fisheries Society (AFS) Finfish Section meeting, Nashville, Tennessee, February 21-25, 2013. (abstract).

Hudson, B. and K. Wellman. 2012. Economic impact of West Coast shellfish aquaculture. *Abstracts*: 104th Annual Meeting, National Shellfish Association, Seattle, WA. (abstract).

Davis, J., Vadopalas, B., Jackson, M., Suhrbier, A., Cheney, D., Middleton, M., **Hudson, B**., Rasmussen, K., Kuehl, L. and C. Friedman. 2013. Performance of Triploid Geoducks. *Abstracts*: 104th Annual Meeting, National Shellfish Association, Seattle, WA. (abstract).

Hudson, B. 2011. Washington State Shellfish Production and Restoration - Environmental and Economic Benefits and Costs. National Sea Grant Final Report for NA08OAR4170822.

Gorman, O., R. Bramblett, **B. Hervin (Hudson)**, D. Van Haverbeke, and D. Stone. 2005. Distribution and abundance of native and non-native fishes of the Colorado River ecosystem in Grand Canyon, Arizona, p. 78–94. In: M. Brouder, C. Springer, and S. Leon (eds.). The lower Colorado River: restoring natural function and native fish within a modified riverine environment; proceedings of July 8–9, 1998 and July 13–14, 1999 symposia in Las Vegas. U.S. Fish and Wildlife Service, Albuquerque, NM. 188 p.

SELECTED PRESENTATIONS

What's All the Fuss About? Gauging Public Perceptions of Shellfish Farming. Washington Sea Grant 21st Conference for Shellfish Growers. Union, Washington, March 3-4, 2014.

Engaging and Communicating with the Public: A Review of Creative Seafood and Fisheries-Related Outreach Tools, Technologies and Activities. Pacific Coast Shellfish Growers Association (PCSGA)/National Shellfisheries Association (NSA)-Pacific Coast Section 67th Annual Shellfish Growers Conference. Sunriver, Oregon, October 1-3, 2013.

Economic Impact of West Coast Shellfish Aquaculture. National Working Waterfronts & Waterways Symposium. Tacoma, Washington, March 25-28, 2013.

Money & Jobs: The Economic Impact of Shellfish Aquaculture in WA, OR & CA. Pacific Coast Shellfish Growers Association (PCSGA)/National Shellfisheries Association (NSA)-Pacific Coast Section 66th Annual Shellfish Growers Conference. Tulalip, Washington, September 24-27, 2012.

Environmental, Economic & Social Benefits of Washington State Shellfish Production. World Aquaculture Society (WAS)/National Shellfisheries Association (NSA)/American Fisheries Society (AFS) Finfish Section meeting, San Diego, California, March 1-5, 2010.

Hudson, B., Cheney, D., Wellman, K., Davis, J., Peabody, B., Steinberg, P., Hampden, D., and S. Burke. 2010. Environmental, Economic & Social Benefits of Washington State Shellfish Production. World Aquaculture Society (WAS)/National Shellfisheries Association (NSA)/American Fisheries Society (AFS) Finfish Section meeting, San Diego, California, March 1-5, 2010 (poster).

Biographical Sketch Daniel P. Cheney

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Email: cheney@pacshell.org

PROFESSIONAL QUALIFICATIONS

Ph.D., University of Washington -- Fisheries, Physiology -- 1975
M.S., University of Hawaii -- Zoology, Biochemistry -- 1967
B.S., University of Washington -- Fisheries, Mathematics -- 1964
Postdoctoral, Vanderbilt University – Zoology – 1973

PROFESSIONAL COLLABORATIONS

Peter Becker, Steve Booth, Aimee Christy, Jeffery Cordell, Jonathon Davis, William Dewey, Brett Dumbauld, Ralph Elston, Dennis Hedgecock, Bobbi Hudson, Joao Ferreira, Carolyn Freidman, Adam James, Kurt Johnson, Gordon King, Chris Langdon, Jeff Layton, David Preikshot, Andrew Suhrbier, Brent Vadopalas

PROFESSIONAL AFFILIATIONS

Member, World Aquaculture Society
Member, past member-at-Large and section Chairman, National Shellfisheries Association

RELAVENT EXPERIENCE

Senior Scientist, 2009 – Present; Executive Director, 1996 – 2009. Pacific Shellfish Institute (PSI). PSI is a non-profit research and public education organization originally created by the Pacific coast commercial shellfish industry. Dan is PSI's project developer, principal investigator and research scientist for regional and federally funded applied research to: 1) examine the environmental and economic interactions of shellfish production practices; 2) develop new species and production methods; 3) explore methods to control *Vibrio* bacteria contamination and reduce the public health risk of raw shellfish; 4) assess pollutants in west coast shellfish and human health risks; 5) examine harvest and production methods to improve shellfish quality; 6) and other related shellfish studies. His associated activities include management of collaborative research teams from regional and national research organizations, presentations of project results at national and international conferences and workshops, and communications with members of the shellfish industry, and the regulatory and research communities. Dan is a board member of the University of Washington Center for Urban Waters, a water quality research and education center based in Tacoma, Washington. He is also a co-owner and board member of Baycenter Farms, an oyster and clam production and processing company based in Willapa Bay, southwest Washington State.

Program Director, 1993 – 1996.

Provided management and technical support for USAID and Asian Development Bank (ADB) funded projects in the south Pacific dealing with development of tuna and bottom fish resources (Tonga and Tuvalu) and a cultured black pearl industry (Cook Islands).

SELECTED PUBLICATIONS

Cheney, D.P. 2010. ***Bivalve shellfish quality: From the hatchery to the consumer***. Journal of the World Aquaculture Society. 41(2):192-206.

Cheney, D.P., Langan, R., Heasman, K., Friedman, B., and Davis, J. 2010. ***Shellfish and shellfish culture in the open ocean: The shellfish farming industry, lessons learned for offshore expansion***. Marine Technology Society Journal. 44(3):55-67.

Cheney, D.P., Davis, J., Ferreira, J., King, T., Preikshot, D., Roberts, and M. Bricker. 2012-2014. ***Planning for sustainable shellfish aquaculture in complex multiple use environments: Determining social and ecological carrying capacity for south Puget Sound, Washington.*** NOAA Sea Grant Aquaculture Research Program; progress reports.

Cheney, D.P., Dewey, B., Davis, J., Cordell, and J. Ferreira. 2010-2013. ***Evaluation and development of advanced farm management and harvesting tools for economically efficient and environmentally sustainable production of Manila clams.*** NOAA, Saltonstall-Kennedy Program, Silver Spring, MD; progress reports.

Chae, M. J., D. Cheney, et al. 2009. T***emperature effects on the depuration of Vibrio parahaemolyticus and Vibrio vulnificus from the American Oyster (crassostrea virginica).*** Journal Of Food Science 74(2): M62-M66.

Cheney, D.P. and C. Friedman. 2009-2013. ***Harvest management tools to control the levels of vibrio parahaemolyticus in oysters and other bivalve shellfish.*** NOAA, Saltonstall-Kennedy Program, Silver Spring, MD; progress reports.

Cheney, D.P., Davis, J. and B. Vadopalas. 2009-2013. ***Biosecure domestication of native geoduck clams.*** NOAA, Saltonstall-Kennedy Program, Silver Spring, MD; progress and completion reports.

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Suhrbier, A.D., Cheney, D.P., Middleton, M.E., Booth, S.R., and J.P. Davis. Submitted***. Examination of farmed geoduck (Panopea generosa gould, 1850) predator protection efficacy and environmental effects***. Journal-of-Shellfish-Research.

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Biographical Sketch Steven R. Booth

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PROFESSIONAL QUALIFICATIONS
Ph.D., Oregon State University -– Entomology -- 1992
M.S., Western Washington University –- Biology -- 1982
B.A., University of Iowa – Zoology -- 1975

PROFESSIONAL COLLABORATIONS
Dr. Kim Patten, Dr. Chris Grue, Dr. Brett Dumbauld, Dr. Joth Davis, Kurt Johnson

PROFESSIONAL AFFILIATIONS
Member, National Shellfisheries Association

RELATED EXPERIENCE
Sr. Scientist, Pacific Shellfish Institute, Olympia, Washington, Fall 2007 – Present
Collaborate with other scientists to study issues related to bivalve aquaculture. Developed experimental designs and protocols, executed them, analyzed results, and presented findings both orally and in writing to scientific and grower groups.

IPM Coordinator, Willapa Grays Harbor Oyster Growers Association, Summer 2001- February 2011. Coordinated activities among growers, investigators, and regulators to develop and implement an IPM plan for burrowing shrimp on commercial oyster beds. Primary and ghost author of several grants to fund research projects involving physical, cultural, and biological control alternatives to carbaryl application. Principal investigator of study of the impact of carbayl on the benthic infauna and co-investigator of several other studies of alternative management tactics. Contributed to development of NPDES permit, NWP 48 Biological Assessment: Screening Level Risk Assessment to Threatened and Endangered Species from the Use of Carbaryl to Control Burrowing Shrimp in Washington State Shellfish Aquaculture, and furnished Commentary on Draft Biological Opinions Issued under the Endangered Species Act.

Consultant Entomologist / Research Scientist, Winter 2000 -2007. 1) In collaboration with Frem Biosciences, research and development of organic slug control materials. 2) Occasional consultant for Crop Health Advising & Research, Kelowna, B.C. regarding root weevil management strategies. 3) In 2003, I completed a study to "Define the status of the invasive cranefly, *Tipula oleracea* L., as a pest in Oregon and Washington: its biology, distribution, and management potential" funded by contracts with WSDA and ODA Nurserymen Associations. 4) Authored QAPP for Pacific Conservation District for “Grayland Cranberry Water Quality BMP Project” for submission to Wash. State Dept. of Ecology.

Research Associate & Consultant Spring, 1998-Winter 2000. Washington State University Long Beach Res. Unit & Pacific Coast Cranberry Research Foundation. Evaluated biorational insecticides and improved tactics to better manage insect pests of cranberry. Implemented “low-risk” insect IPM program via on-farm demonstration trials, grower workshops, and extension bulletins. Monitored seasonal and geographic distributions of recently introduced pests.

Research Associate Spring 1993-Spring 1998. Washington State University Vancouver Res. & Ext. Unit. Investigated non-chemical control strategies, especially microbials, to suppress subterranean insect pests of small fruits. Isolated indigenous strains of entomopathogenic fungi, compared their virulence in laboratory bioassays, and, in collaboration with colleagues at Oregon State University,

sequenced their genomes using PCR techniques. Developed a low-cost technology to produce, at moderate scales, a dried mycelium formulation of *Metarhizium anisopliae* and demonstrated its efficacy against black vine weevil and cranberry girdler. Investigated the mechanism of induced resistance to spider mites in raspberry and strawberry.

Postdoctoral Fellow Summer 1991-Spring 1993. Kelowna, B.C. British Columbia Fruit Growers Association. Investigated and implemented predator-compatible program to manage pear pests in the Okanagan Valley. Investigated "soft" insecticides, alternative ground covers or hedgerows, and other tactics to encourage indigenous natural enemy immigration to pear. Compared season-long alternative programs to standard programs among commercial blocks. Several field and laboratory trials focused on the predatory potential of the European earwig, *Forficula auricularia*, and the predaceous mirid, *Deraeocoris brevis*.

Research Cooperator Spring 1991. Oregon State University. Investigated potential of mating disruption/pheromone confusion for orange tortrix in Oregon caneberries. Conducted preliminary survey of predator and phytophagous mites on hops in the Willamette Valley, OR

Graduate Teaching Assistant 1990. Oregon State University, Corvallis, OR. IPM III.

Certification Inspector 1990-1991. Oregon Tilth. Inspected farms for compliance with standards of organic production and made recommendations to certification committee.

Graduate Research Assistant 1986-90. Oregon State University, MCAREC. Hood River, OR. To fulfill Ph.D. requirements, completed course work and conducted dissertation. Described the taxonomic composition of a complex of 43 arthropod natural enemies that colonize and suppress pear psylla in orchards of differing chemical regime, orchard structure, and vegetational setting.
Research Assistant 1983-1987. Oregon State University. Investigated the economic entomology of several orchard pests and beneficials. Conducted pesticide trials, monitored pheromone traps in whole of upper Willamette Valley, determined thresholds of pupal development for apple maggot and walnut husk fly, analyzed data, prepared graphs, and supervised several part-time employees.

Environmental Consultant 1982. Bellingham, WA. Assessed the suitability of ten small streams in the Nooksack Watershed for the establishment of small scale hydro-electric power plants. An index of food available to salmonid populations was calculated based on the abundance and composition of the benthic community at high and low elevations, early and late season, at mid-day and mid-night. Aquatic invertebrates were sampled by surber, kick, and drift-net. Salmonids were sampled by electroshock, and the stomach contents were frequently examined.

Graduate Teaching Assistant 1980-1982. Western Washington University. General Entomology, Aquatic Entomology, Field Entomology, Alpine Limnology, Biological Kingdoms, Introductory Biology; 1991. Oregon State University. IPM III.

RELEVANT PUBLICATIONS AND REPORTS

Booth, S.R. 2012, revised 2014. Dichotomous Key and Illustrated Guide to the Pests of Bivalve Aquaculture in Washington and Oregon. Funded by Prime Award No. 2007-51120-03885, Subaward No.07-001492-WAS15 from the USDA National Institute for Food and Agriculture.

Booth, S.R. and K. Rasmussen. 2013. Impact of imidacloprid on epi-benthic and benthic invertebrates: 2011 studies to describe the Sediment Impact Zone (SIZ) related to imidacloprid treatments to manage burrowing shrimp. Submitted to WSU, Oct, 2013.

Booth, S.R. and K. Rasmussen. 2013. Impact of imidacloprid on epi-benthic and benthic invertebrates: 2012 studies to describe the Sediment Impact Zone (SIZ) related to imidacloprid treatments to manage burrowing shrimp. Submitted to WSU, May, 2013.

Booth, S.R. and D. Tufts. 2003 – 2010. Willapa Bay-Grays Harbor Oyster Growers Association Annual Operations Plan for Carbaryl-based Management of Burrowing Shrimp. Submitted to

WDOE June 1 of every year.
Booth, S.R. and D. Tufts. 2002 – 2010. Willapa Bay-Grays Harbor Oyster Growers Association Annual Report for Burrowing Shrimp Management. Submitted to WDOE December 1 of every year.
Booth, S.R. 2007. An Updated Plan for Integrated Pest Management of Burrowing Shrimp on Commercial Shellfish Beds Submitted to: Washington Department of Ecology February 1, 2007. 34 pp.

CURRICULUM VITAE Andrew D. Suhrbier

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PROFESSIONAL QUALIFICATIONS

B.S. Texas Lutheran University, Seguin, Texas --Molecular Biology, 1996

PROFESSIONAL COLLABORATIONS

Alan Barton, Peter Becker, Jeffery Cordell, Jonathon Davis, William Dewey, Beniot Eudeline, Joao Ferreira, Burke Hales, Adam James, Kurt Johnson, Vassili Kalashnikov, Gordon King, Jan Newton, Kim Patton, Brent Vadopalas

PROFESSIONAL AFFILIATIONS

Member, National Shellfisheries Association

RELAVENT EXPERIENCE

Senior Biologist, Pacific Shellfish Institute, Olympia, WA; 2000 to present
Involved in PSI's marine benthic/water quality sampling and analysis, mapping of marine habitats, data analysis, project development and management. Current projects include the potential of polyculture systems; interactions of shellfish culture with the natural environment; the impact of organic pollutants, and bacterial contaminants on bivalve shellfish; efficiencies of production, and disease and environmental stress studies of shellfish. Interacts with shellfish producers regarding growing areas and methods in California, Oregon and Washington. Developed shellfish certification standards for the west coast shellfish industry for the certification entity: "The Food Alliance". Maintains a coast-wide water quality monitoring related to ocean acidification, part of Northwest Association of Networked Ocean Observing Systems (NANOOS). Charged with the maintenance, deployment, and retrieval of a Sontek current meter, ISCO water samplers, YSI multiparameter dataloggers, pCO2 sensor package, Onset dataloggers, Honeywell meters and PSI developed dataloggers.

Experimental Biologist Aide, Oregon Department of Fish and Wildlife, Nehalem, OR, 1999
Conducted creel surveys of recreational salmon fishermen along the Nehalem river system.

Observer, Saltwater, National Marine Fisheries Service, Anchorage, AK, 1998-1999
Evaluated and enumerated the catch and by-catch of U.S. commercial pacific and black cod fishing vessels in the Bering Sea and Gulf of Alaska.

SELECTED PUBLICATIONS

Suhrbier, A. D., D.P. Cheney, M. E. Middleton, S. R. Booth, J. P. Davis. 2014. Examination of Farmed Geoduck (*Panopea Generosa* Gould, 1850) Predator Protection Efficacy and Environmental Effects, Journal of Shellfish Research, In press.

Cheney, D.P., Dewey, W.F., Suhrbier, A.D., Ferreira, J.G., Cordell, J.R., and J.P. Davis. 2012. Production and environmental effects of manila clam farming in North Puget Sound: Comparison of yields and responses of macrofauna to mechanical and hand harvest.

Abstracts: 104th Annual Meeting, National Shellfish Association, Seattle, WA. (abstract).

Suhrbier, A.D. 2012. Water quality monitoring at Washington State shellfish hatcheries and setting sites. *Abstracts*: 104th Annual Meeting, National Shellfish Association, Seattle, WA. (abstract).

SELECTED PRESENTATIONS

Vibrio Relay Update. PSCGA/NSA Annual Meeting. Bend, OR. October 2, 2013.

Cantwell Project Update: Water quality monitoring efforts at hatcheries and setting sites in Oregon and Washington (with Alan Barton, PCSGA). PSCGA/NSA Annual Meeting. Bend, OR. October 2, 2013.

Manila Clam Harvest Method Evaluation in Samish Bay, WA. PSCGA/NSA Annual Meeting. Tulalip, WA, September 26, 2012.

Appendix C: Pacific Shellfish Institute Company Overview

1. Name: Pacific Shellfish Institute
   DUNS: 948618624
   Address: 120 State Avenue NE #1056, Olympia, WA 98501
   Telephone: (360) 754-2741
   Fax: (360) 754-2246
   E-mail: psi@pacshell.org

2. Key Contact: Bobbi Hudson, Executive Director
   Address: 120 State Avenue NE #1056, Olympia, WA 98501
   Telephone: (360) 754-2741
   Fax: (360) 754-2246
   E-mail: bobbi@pacshell.org

3. Authorized person: Same as Key Contact (above)

4. The Pacific Shellfish Institute (PSI) is a Section 501(c)(3) private nonprofit organization whose mission is: "*Sustainable shellfish resources and healthy marine environment through research and education*." PSI formed in 1995 to develop and disseminate scientific and technical information of value to the general public, shellfish farmers, and public officials in connection with shellfish-related environmental and animal/human health and safety issues. Current PSI research encompasses a broad range of biological, ecological, chemical and social science. Highlighted projects include investigations into the ecological impacts of mechanical clam harvest, *Vibrio parahaemolyticus* reduction strategies, ecological carrying capacity modeling, ocean acidification impacts on shellfish seed rearing, nutrient bioextraction studies, clam population surveys, and water quality monitoring for siting of new shellfish aquaculture infrastructure.

   PSI staff, including executive director Bobbi Hudson, senior scientists Dr. Daniel Cheney and Dr. Steven Booth, and senior biologist Andrew Suhrbier are familiar with the particular challenge of studying *Vibrio* in the field (e.g., identification of appropriate study sites, specialized sample collection and transport needs to avoid cross contamination, etc.). Furthermore, PSI has a long-standing relationship with the West Coast shellfish aquaculture industry, including Pacific Coast Shellfish Growers Association (PCSGA) members and staff. Recent and proposed PSI research features strong collaboration with both shellfish farmers and regulatory agencies, including the Washington Department of Health and FDA. If selected through this 2014 ISSC RFP, PSI would collaborate closely with these entities to complete proposed research.

5. PSI staff members and board of directors must abide by the established "Conflict of Interest Policy for the Pacific Shellfish Institute", which specifically states:

   "A conflict of interest is defined as an actual or perceived interest by a staff or Board member of the Pacific Shellfish Institute (PSI) in an action that results in, or has the appearance of resulting in, personal, organization, or professional gain. Officers and members are obligated to always act in the best interest of the organization. This obligation requires that any officer or member, in the performance of duties, seek only the furtherance of the organization's mission. At all times, officers and Board members are prohibited from using their job title or the organization's name or property, for private profit or benefit."

   Furthermore, the policy describes how conflicts of interest shall be resolved:

   "When a conflict of interest is relevant to a matter requiring action by the Board, the interested person(s) shall call it to the attention of the Board and said person(s) shall not vote on the matter. In addition, the person(s) shall not participate in the final decision or related deliberation regarding the matter under consideration. When there is a doubt as to whether a conflict exists, the matter shall be resolved by vote of the Board, excluding the person(s) concerning whose situation the doubt has arisen. The official minutes of the Board shall reflect that the conflict of interest was disclosed and the interested person(s) did not participate in the final discussion and did not vote on the matter."