

Waterlines

WESTERN REGIONAL AQUACULTURE CENTER

2022
ANNUAL REPORT

Alaska • Arizona • California • Colorado • Idaho • Montana • Nevada • New Mexico • Oregon • Utah • Washington • Wyoming

This issue of *Waterlines* contains our newsletter and report to USDA-NIFA of our accomplishments for September 2021–August 2022.

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Kenneth K. Chew
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At the Podium



Photo by Keri Rouse for Virginia Tech



Photo: US College of the Environment

“After interacting with most of you virtually for much of the 2020–2022 period, it was a sincere pleasure to meet with the Industry Council, Technical Committee, and Work Group members in person in October 2022.”

Dear WRAC community, stakeholders, and state and federal partners,

After interacting with most of you virtually for much of the 2020–2022 period, it was a sincere pleasure to meet with the Industry Advisory Council (IAC), Technical Committee (TC), and Work Group members in person in October 2022. Together, we heard eight annual and termination reports, which form the basis for the WRAC Project Highlights described in this issue of *Waterlines*, the annual report for 2022. Herein, the depth and breadth of WRAC’s current portfolio of research and outreach projects is apparent. Projects include new species development (1), disease prevention and control (3), nuisance species (1), nutrition (1), product quality (1), and characterization of the western region’s aquaculture industry (1). These projects reflect the priority areas that were identified by the IAC, developed into problem statements jointly by the IAC and TC, and then formed the basis for our biennial request for pre-proposals.

The need for quality targeted research and the resulting technology and information transfer to stakeholders through our talented and overworked extension specialists has become even more apparent in view of some recent regulatory decisions in our region that ignore available science. These decisions have impacted the ability of some sectors of our industry to provide affordable and healthy aquaculture products at a time when the country’s relatively fragile food security has been highlighted through the COVID pandemic and current world tensions and conflicts.

Shortly before the 2022 IAC/TC meeting, we received the sad news that our friend, colleague, and supporter, Dr. Ken Chew, had passed away on September 24. His wonderful wife, Maeghan, passed a few weeks later. Ken was Director of WRAC almost continuously from its inception in 1987 until he retired in 2004. Ken was instrumental in the genesis of the national RAC program and a fierce advocate of WRAC and the western region’s aquaculture industry. He mentored an impressive number of undergraduate and graduate students during his time at the University of Washington, many of whom have gone on to successful careers in industry, academia, and state and federal agencies. He leaves a unique legacy. You may be interested in viewing some memories and tributes at: <https://fish.uw.edu/2022/11/remembering-ken-chew-a-collection-of-memories>. See WRAC’s tribute to Ken on pages 3–4 in this issue of *Waterlines*.

Best wishes,
Graham Young

Editor’s note: Due to publication timing, we have chosen to include the Kenneth K. Chew In Memoriam article in this issue of Waterlines.

IN MEMORIAM

Remembering Ken Chew

October 29, 1933 – September 24, 2022

Thank you to the Chew family and Ken's students, colleagues, and friends for their contributions to this memorial.

Former Director of WRAC Kenneth K. Chew passed away peacefully on September 24, 2022, with his wife Maegan by his side and surrounded by his loving family,

Ken was Director of WRAC almost continuously from its inception in 1987 until he retired in 2004. He was a fierce advocate of WRAC and the western region's aquaculture industry.

It is no exaggeration to state that Ken's efforts were instrumental in the establishment of the U.S. Department of Agriculture/National Institute of Food and Agriculture-funded national RAC program. He was tireless in promoting his vision for a regionally based funding program in which members of industry could work together with the research and extension communities to overcome barriers to the responsible development of the domestic aquaculture industry.

Ken was a visionary, a valued colleague, and a mentor and friend to many. His fierce advocacy for sustainable aquaculture has had considerable impacts on industry and on state, regional, and federal agencies and policies. Many of these impacts are based on the relationships that Ken developed with state and federal legislators and regulators, seemingly effortlessly. His passion for shellfish and the achievements of his research program still resonate,

and his legacy is reflected in and respected by the vibrant community of shellfish researchers and shellfish growers on the west coast and elsewhere in the United States.

Ken was also Professor (and after retirement, Professor Emeritus) at the University of Washington's School of Aquatic and Fishery Sciences (SAFS). His legacy within the School lives on with the Kenneth K. Chew Endowed Professorship in Aquaculture. His enthusiastic support for younger scientists is manifested in his desire that endowment funds be used to support visits of eminent shellfish researchers to the School where they could spend quality time with younger researchers.

Graham Young, current Executive Director of WRAC shared: "At the first WRAC meeting that I chaired as Director after Ken retired, a member of one of WRAC's committees told me that I had very big shoes to fill. By that time, I knew Ken well enough to laugh and inform that person that anyone who thinks they could fill Ken's shoes was either stupid, delusional, or both. That's as true now as it was then."

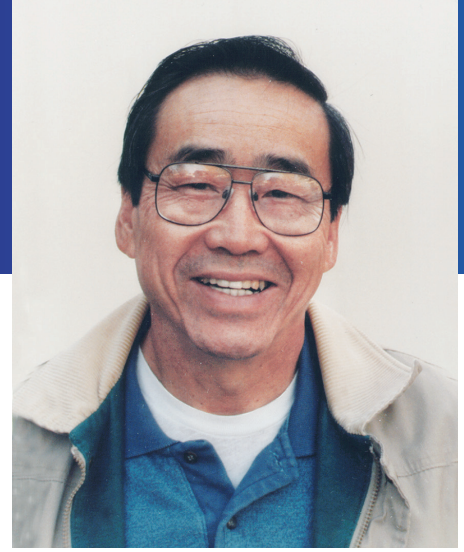


Photo: SAFS Archives



Ken, with his son Curtis and grandson Bradford, enjoying a favorite pastime (circa 2004).

Photo: Courtesy of Curtis Chew

Teaching and maintaining a close rapport with students were important parts of Ken's life, and he inspired many students to continue their studies in molluscan biology. During his tenure at SAFS, Ken supervised close to 100 MS and PhD students. In recognition of his outstanding teaching ability, he received the 1993 Distinguished Undergraduate Teaching Award from the UW College of Ocean and Fishery Sciences.

Throughout his professional career, Ken maintained a close working relationship with the shellfish industry, particularly in the Pacific Northwest. Much of his research and that of his graduate students focused on finding solutions to problems that would further the development of the industry. The importance of the shellfish industry as an economic and sustainable force is in large part due to the efforts of Ken Chew and the students who work in the industry.

As Bill Dewey, a former student of Ken's and current Director of Public Affairs at Taylor Shellfish Farms in Washington, wrote: "Like so many of his students, I owe my career to Ken. When I graduated, he introduced me to Dick Steele with Rock Point Oyster Company. That was the beginning of 40+ years and counting working in the shellfish industry and loving every day of it. I am blessed to have had Ken (aka Dr. Shellfish) as a mentor and friend and am forever indebted to him. Ken was immensely proud of his students, never failing to call them out and sing their praises whenever he had the chance."

Ken was recognized nationally and internationally as an authority on the biology of shellfish and aquaculture. In 2014, NOAA recognized Ken's major contributions to shellfish research and aquaculture, the contribution of



Photo: Courtesy of Curtis Chew

Ken in the lab, 1957.

his students who continue to advance this work, and the importance of efforts to restore shellfish in Puget Sound by announcing the Kenneth K. Chew Center for Shellfish Research and Restoration (established in partnership with the Puget Sound Restoration Fund). The center, located in Manchester Bay, Washington, provides scientific expertise and specialized facilities to support research and production of native oysters and other Pacific Northwest living marine resources.

After he retired, Ken served as the Western Washington Commissioner for the Washington Department of Fish and Wildlife from January 1, 2005 to December 31, 2010.

The aquaculture industry and all of WRAC are indebted to Ken for his many years of dedication and tireless support.



Photo: WRAC Archives



Photo: UW SAFS Archives

left to right:

Ken at the party to celebrate the establishment of the Kenneth K. Chew Endowed Professorship in Aquaculture at the School of Aquatic and Fishery Sciences at the University of Washington. (2001)

Ken enjoying a favorite treat.

Strengthening extension

As a result of one of the listening sessions, the Board asked Ron Hardy to lead an ad hoc “strengthening extension” committee; this committee’s recommendations led to changes in the language in the FY23 RFP, and, in recognition of inflationary costs and the need to support PIs responsible for outreach, an increase in the maximum annual funding for projects rose from \$120,000 to \$130,000.

External review of the national RAC program

The USDA/NIFA-funded external review of all the RACs is well underway, and we in the Administrative Office have been busy responding to the review team’s requests for a variety of information. Although the main focus is 2014–2021, some of the information has us digging back in files from 1987(!).

Awards to attend the 2022 National Aquaculture Extension Conference

Aquaculture Extension representatives meet every 4–5 years and a Request for Applications for USDA-NIFA funds to support their attendance in Portland, Maine (June 2022) was well received. Awards were made to Amsalia Almada (University of Southern California Sea Grant Extension), Jake Bledsoe (University of Idaho Extension), Samuel Chan (Oregon State University Sea Grant Extension), Jackson Gross (University of California Davis Coop Extension), and Rossana Sallenave (New Mexico State University Extension).

Budget

At the time of writing, our application for FY22 funding is undergoing review by NIFA. The RAC program was again funded at \$5M. Sarah will begin processing subawards as soon as the FY22 funds arrive at the University of Washington, with the aim of having most subawards issued by September 1 of this year. Because we are now permitted to make awards without needing approval from NIFA, we were able to issue most subawards for the three new FY21 projects before September 1, 2021. This should avoid any of the problems new PIs have experienced with very delayed initiation of projects because of late arrival of funds.

RFP FY23—Proposal cycle in full swing

Twelve pre-proposals were submitted and evaluated by the Executive Committee (ably led by Chair Brian Small) in April 2022. The Committee’s recommendations were considered at the May 2022 Board meetings, and five pre-proposal submissions were invited to submit full proposals. Currently, the five full proposals are in the external review process, and the Lead PIs have been notified of preparations for their presentations on October 12, 2022.

Advocacy—strong industry support sends a message to NIFA and Congress

We are ever so grateful for strong representation from the industry and those who wrote powerful letters of testimony to Congress last spring. Their testimonies addressed the current RAC funding scenario and educated legislators about WRAC-funded research projects and the positive impact they have had on the industry. This year’s testimony submissions were received from:

- **Ken Beer**, President, The Fishery, Galt, CA
- **Mark Daily**, President, Idaho Aquaculture Association, Hagerman, ID
- **Jeff Hetrick**, Director, Alutiiq Pride Marine Institute, Seward, AK

Website

The Board approved funding for development of a new WRAC website! With the help of a web task force and long hours of planning the new site, we aim to have a beta site for you to test while at the IAC/TC meeting. Your input and comments will be much appreciated!

UPCOMING WRAC MEETINGS

Wednesday–Thursday

October 12–13, 2022 IAC/TC meeting (in person)

Friday

November 18, 2022 Board of Directors (virtual)

Monday

November 28, 2022 Board of Directors (virtual)

Thanks to all of you for your hard work and dedication to WRAC!

Changes to the Roster

WRAC welcomes new and continuing members of the Board, IAC, and Research and Extension Subcommittees and thanks all who have served this past year. The Board strives to consider a mix of geographic representation and diverse areas of expertise when considering new appointments to WRAC committees. Changes to the roster are provided here and in the July 2022 WRAC Directory (depts.washington.edu/wracuw/about/organization.html).

BOARD OF DIRECTORS

With gratitude for Chair **Walt Dickoff**'s service over the last term (and several other terms as President), the Board elected a new Chair, **Chris Myrick**, for the 2022–2024 term. Please congratulate Chris in his new leadership role!

INDUSTRY ADVISORY COUNCIL

Renewals approved for 3-year terms 2022–2025

Mark Francis (Aquaneering, Inc., CA), serving as a Supplier of Goods and Services/Coastal States; **Jeremy Liley** (Liley Fisheries, Inc., CO), serving as a Finfish Producer/Intermountain States; **Beau Perry** (Blue Evolution, CA), serving as a Mariculture Producer/Coastal States; and **Jackie Zimmerman** (Merck Animal Health, Aquaculture, ID), serving as a Supplier of Goods and Services/Intermountain States. All were approved by the Board to renew terms through June 30, 2025. Thank you all!

Nominations

The two nominees were well qualified and highly recommended, but there were no open seats on the IAC. We hope to engage them on other WRAC committees and projects.

TECHNICAL COMMITTEE/RESEARCH SUBCOMMITTEE (RSC)

Renewals approved for 3-year terms 2022–2025

Mark Drawbridge, Senior Research Scientist, Hubbs-Seaworld Research Institute, CA

Ken Overturf, ARS, Research Geneticist, Hagerman Fish Culture and Experiment Station, University of Idaho, ID
Wendy Sealey, ARS, Research Physiologist, Bozeman Fish Technology Center, MT

Brent Vadopalas, Research Scientist, University of Washington, WA

Stepping down from the RSC

We are sad to say that new member **Jordan Hollarsmith** (Research Biologist, Ted Stevens Marine Research Institute, AFSC/NOAA, AK) regrettably decided to step down from the RSC due to time constraints of a new family member and workload. (Congratulations!) Jordan looks forward to staying involved with WRAC in the future.

New Research Subcommittee member in 2022

Schery Umanzor (Assistant Professor, College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, AK). Schery's expertise is in macroalgae aquaculture, including nutrient cycling, selective breeding, and farm optimization. Welcome!

TECHNICAL COMMITTEE/EXTENSION SUBCOMMITTEE

A big thanks goes to Luke Gardner (CA Sea Grant Extension Moss Landing Marine Laboratories, CA) for his ongoing commitment to WRAC. While Luke starts a new term on the Extension SC, he continues as an Outreach representative on a project and completes a term on the Executive Committee.

While we must rely on Extension Subcommittee members to be appointed by leadership of their institutions, we continue working towards growth of this small but mighty committee.

EXECUTIVE COMMITTEE (EC)

Chairs of the IAC and the Research and Extension Subcommittees are automatically members of the EC, while two more representatives per committee are elected by their peers. Current members are listed on the WRAC Organizational Chart.

- The EC Chair rotates every two years among the committee leadership; the Research SC Chair leads the EC in its functions through 2023. (Brain Small, EC Chair 2021–2023)
 - * IAC Representation – IAC Chair **Jackie Zimmerman** and **Sean Nepper** remain through 2023, while **Sue Cudd**'s term ended this year.
 - * Extension Subcommittee – New Chair **Jackson Gross** and **Angee Doerr** remain through 2023, while **Luke Gardner**'s term ended this year.
 - * Research Subcommittee – Research Chair **Brian Small** serves until 2023 along with **Mackenzie Gaverty**, while **Ken Overturf**'s term ended this year.
 - * Extension SC Chair: **Jackson Gross**, Extension Aquaculture Specialist, Department of Animal Science, University of California, Davis

WRAC Project Highlights

September 1, 2021–August 31, 2022

Contact the
WRAC Administrative Office
for complete annual reports.



Developing “Freshwater Cod” or Burbot (*Lota lota*) into a Viable Commercial Aquaculture Species in the United States

Termination Report

Principal Investigators: Kenneth Cain, Luke Oliver, and Moureen Maruha, *University of Idaho*; Christopher Myrick and Ben Vaage, *Colorado State University*; Rick Barrows (retired), *USDA*, Shawn Young (*Kootenai Tribe of Idaho*)

Outreach Representatives: Kenneth Cain, Gary Fornshell (retired), *University of Idaho*; Christopher Myrick, *Colorado State University*

Industry Advisor: Linda Lemmon, *Blind Canyon Aqua Ranch*

Project Monitor: Mark Drawbridge, *Hubbs-Seaworld Research Institute*

ISSUE: The integration of burbot (freshwater cod) production into existing trout farms presents a novel, low-risk strategy to develop this species for freshwater commercial aquaculture. The goal and challenge is to provide US fish growers with applied knowledge of burbot farming, thereby encouraging diversification or new ventures to establish commercial production of this species.

RESPONSE: We have focused on: 1) optimizing spawning, early larval rearing, grow-out, and other important aspects of burbot aquaculture; 2) conducting pilot-scale trials at commercial facilities and supporting potential burbot farms by providing fish when possible; 3) determining water-quality limits (ammonia and oxygen) of production; 4) determining if triploid induction is possible as a means to produce sterile burbot; 5) conducting a basic economic analysis of production costs; and 6) disseminating results

broadly to the aquaculture industry. This project has been completed with only final outreach and publication submissions remaining.

RESULTS: This study clearly shows the biological feasibility and marketability of commercial burbot culture. Results from project trials have been published and include reports of out-of-season spawning, replacement of fish meal with soy meal in diets, temperature impacts on eggs and embryos, triploid induction success, immune response and disease susceptibility, ammonia and oxygen tolerance and limitations. Four graduate students have completed their studies with support from this project, and a PhD student should complete in the next few months. Additional publications demonstrating a reduction in live feed requirements for weaning, economic and market analysis, and protein requirements are expected. Outreach has targeted media and trade journals and direct interaction with multiple industry stakeholders. A WRAC extension bulletin aimed at providing a guide to burbot culture methodology is forthcoming.

IMPACTS: This project has raised the visibility of burbot aquaculture and demonstrated that burbot are a viable commercial aquaculture species for North America. Many potential bottlenecks have been addressed and overcome, and the stage is now set for existing farmers, entrepreneurs, and start-up companies to apply the results of this research to successfully culture this species for the foodfish market. New companies have already begun producing burbot for early stage and growout production.



Identification of Genetic Markers for Disease Resistance to Infectious Hematopoietic Necrosis Virus (IHNV) in Commercial Populations of Rainbow Trout through Genome-wide Association Analysis

Annual Progress Report

Principal Investigators (PI): Kerry Naish, *University of Washington*; Maureen Purcell, *Western Fisheries Research Center, US Geological Survey*; Kyle Martin, *Hendrix Genetics/ Troutlodge Inc.*; Yniv Palti and Rogert Vallejo, *National Center for Cool and Coldwater Aquaculture, USDA*

PI Responsible for Outreach: Luke Gardner, *California Sea Grant Extension*

Industry Advisor: Stephen Reichley, *Mississippi State University (formerly at Clear Springs Foods, Inc.)*

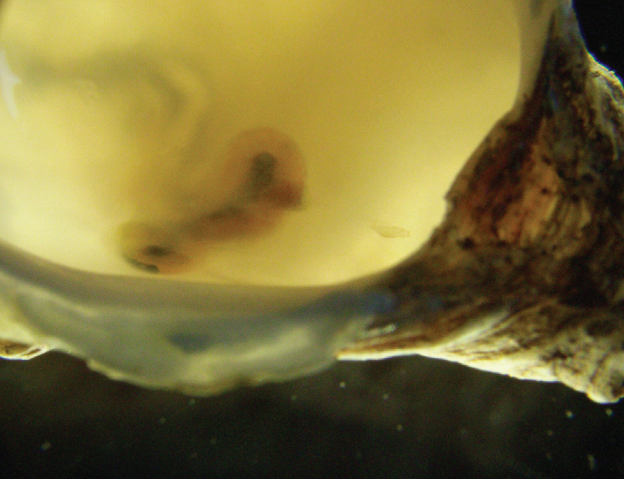
Project Monitor: Kathleen O'Malley, *Oregon State University*

ISSUE: Disease is the single largest cause of production related mortality in the rainbow trout (*Oncorhynchus mykiss*) industry, accounting for 90% of the total losses (25.4 million fish) in 2015 (NASS 2016). Efficacious control methods are not available for all diseases, or if available, may add significantly to production costs. Thus, there is a need and an opportunity to develop additional approaches to mitigate disease losses in aquaculture.

RESPONSE: The collection of genomic information across individual fish used for broodstock can significantly improve the efficiency of selective breeding for many desirable traits, including disease resistance. Researchers are utilizing a high density single nucleotide polymorphism (SNP) array and whole genome sequencing to identify markers linked to resistance to the important salmonid pathogen, infectious hematopoietic necrosis virus (IHNV). These markers can then be used to assess the potential for genomic selection for the improvement of aquaculture populations.

RESULTS: The project has, to date, provided information on the best way to achieve repeatability among challenge tests for large-scale IHNV studies by using “common garden” tanks. Such standardization is relevant to informing future studies that disentangle genetic versus environmental effects in host disease responses. Genotyping data from IHNV-challenged animals has been made available for the 2018 and 2019 broodstock lines. These data, along with additional genotyping performed by Troutlodge, have enabled the implementation of genomic selection for improved resistance to IHNV. As a result, eggs selected for increased IHNV resistance will be commercially available starting in November 2022. The genotyping data was also used to map and identify QTL (quantitative trait loci) for resistance to IHNV across the rainbow trout genome. We identified several candidate regions of the genome that may span causative genes. Further characterization of these regions is underway; thus meeting our overall aim of identifying DNA markers that are closely linked to causal variants with large effects on the disease resistant phenotype.

IMPACTS: The immediate benefit of the research has been the application of the tools to the genetic improvement of the aquaculture broodstock lines, which in turn support a significant portion of the rainbow trout grow-out industry. Additional benefits are that these tools can be integrated into broader approaches for disease management in rainbow trout aquaculture, and for informing IHNV epidemiological models of natural populations in Western North America.



Detection and Control of Mud Blister Worm (*Polydora* spp.) Infestation on Commercial Oyster Farms throughout the Pacific Northwest

Annual Progress Report

Principal Investigators: Chelsea Wood, Jacqueline Padillo-Gamiño, and Lorenz Hauser, *University of Washington*; Steve Rumrill, *Oregon Department of Fish and Wildlife*; Teri King, *Washington Sea Grant (WSG)*

Outreach Representative: Teri King, WSG

Industry Advisor: Tom Bloomfield, *Seattle Shellfish, LLC*

Project Monitor: Jackson Gross, *University of California, Davis*

ISSUE: Infestations of mud worms—spionid polychaetes that bore into bivalve shells—are responsible for substantial losses to commercial oyster industries worldwide. These polychaetes can cause unsightly blisters that release detritus, mud, and fecal material, fouling oyster meats. Until our project, there had been no reports in the scientific literature of any shell-boring polychaete species in Pacific oysters from Alaska, Washington, or Oregon. Our data confirm that several species of blister-forming spionid polychaetes are widespread and abundant throughout Alaska, California, Oregon, and Washington. Pacific oysters are the most important cultured shellfish in the Pacific Northwest, and mud worm infections represent a serious threat to the sustainability of this industry.

RESPONSE: To defend against this threat to the region's oyster industry, we must know which growing areas are currently affected, what environmental factors predispose an area to becoming infected, and what treatments are most effective for reducing worm burdens on farms. Our project will assess the scale of the threat represented by *Polydora* spp. infections on oyster farms throughout the US Pacific Northwest and outline the management approaches that will

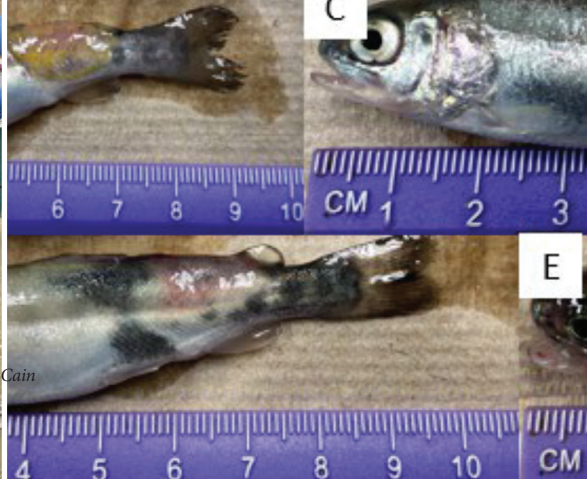
allow oyster growers to surmount this significant obstacle to long-term oyster production sustainability.

RESULTS: We have completed the planned sampling missions to quantify the prevalence and current distribution of shell-boring polychaetes at 33 commercial oyster farms throughout the US Pacific Northwest. We have also collected the primary empirical data needed to identify the environmental factors that predict high infestation rates and have nearly finished the analysis of this data. In addition, we have completed experiments designed to identify the most effective intervention that growers can use to reduce transmission and mitigate the negative impacts of infection on product value. Results have already been reported in the journal *Aquaculture* and will soon be reported in the form of a best practices manual.

IMPACTS: Our sampling has yielded a preliminary map of where infestations are common and where they are rare across the study region, providing growers with the knowledge needed to avoid bringing infested oysters into currently uninfested areas. We have identified the most effective interventions that growers can use to reduce transmission and mitigate the negative impacts of infection on product value. Three treatments are suitable for killing shell-boring polychaetes without negative impacts on oysters (drying at room temperature, freshwater dip + drying, drying in a refrigerator). All results are being shared with our industry advisory group, the Healthy Oysters Steering Committee, and through on-farm outreach and presentations at industry conferences to allow growers to immediately begin using this newly acquired knowledge to benefit their businesses.



Photos: Courtesy of Kenneth Cain



Emerging and Re-emerging Flavobacterial Pathogens in Aquaculture

Annual Progress Report

Principal Investigators: Kenneth Cain, Timothy Bruce, Jie Ma, and Brent Buglar, *University of Idaho*; Esteban Soto and Taylor Heckman, *University of California, Davis*

Outreach Representative: Robert Durborow, *Kentucky State University*

Industry Advisor: Tom Van Tassel, *Evaqua Farms*

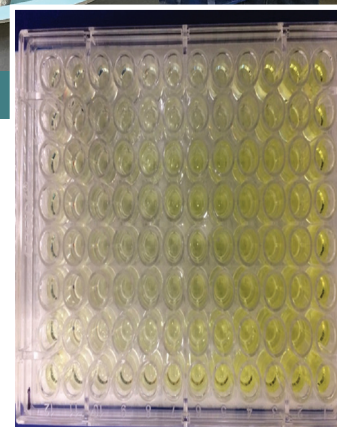
Project Monitor: Stephen Reichley, *Mississippi State University (formerly at Clear Springs Foods, Inc.)*

ISSUE: The incidence of clinical disease linked to emerging (and re-emerging) pathogens in the *Flavobacteriaceae* family has increased, and there is a need to better define distribution in the western region. Bacteria within this group can easily be mistaken as *Flavobacterium psychrophilum* or *F. columnare*, causative agents of bacterial cold water disease (BCWD) and columnaris, respectively. Such misdiagnosis has implications for treatment efficacy and disease management. Effective diagnostic, disease control, and prevention tools for these pathogens are needed.

RESPONSE: The goal of this project is to identify and further characterize—at the genetic, antigenic, and virulence level—*F. columnare* strains along with other pathogenic *Flavobacteriaceae* members collected from clinical disease cases. We will provide baseline information on clinical outbreaks associated with these emerging pathogens within aquaculture facilities in the western states. Antibiotic sensitivity following screening with 18 antibiotics will assist in determining potential treatment options. Pathogenic *F. columnare* and novel-flavobacterial strains will be selected to determine if a live attenuated BCWD vaccine can provide cross-protection and minimize disease impact.

RESULTS: A total of 184 isolates of suspected *Flavobacterium* and *Chryseobacterium* were collected from clinically affected fish in six western states and then identified and characterized: 53 were identified as *Chryseobacterium* and 131 as *Flavobacterium*. Genetic clades were established, and all but one included reference strains, many of which have been linked to published reports of fish disease outbreaks. Antimicrobial susceptibility profiles were investigated for three representative isolates from each of the major clades of atypical *Flavobacterium* and *Chryseobacterium* recovered. At least one representative strain from every clade displayed an MIC for oxytetracycline that was higher than the established breakpoint for *F. psychrophilum*, indicating potential resistance to this drug. Antigenic diversity has shown that serum antibodies from fish vaccinated with a live attenuated BCWD vaccine recognize multiple antigens from *F. columnare* and other flavobacterial isolates. Based on clade and clinical history, seven isolates were selected for virulence testing; of those, four were found to be highly virulent in laboratory challenges. These isolates are currently being used in cross-protection trials with our attenuated BCWD vaccine. Earlier testing has shown protection to some non-*F. psychrophilum* isolates; however, minimal protection against *F. columnare* was observed.

IMPACTS: This project has demonstrated that novel bacteria in the *Flavobacteriaceae* family are causing clinical disease at aquaculture facilities and provides baseline information on bacterial species diversity, treatment, and prevention options, and distribution range of *F. columnare* and other novel Flavobacterial strains within the western region. This information is important when identifying emerging disease problems and developing practical fish health management strategies aimed at reducing the impacts of Flavobacteriosis.



Development of Oral Vaccine Delivery Methods for Prevention of Disease in Finfish Culture

Annual Progress Report

Principal Investigators: Matt Hawkyard, *Oregon State University/University of Maine*; Kenneth Cain, *University of Idaho*; Mary Arkoosh, *NOAA*; Joseph Dietrich, *NOAA*; Evan Jones, *University of Idaho*; Cameron Schuster, *Oregon State University/Cooperative Institute for Marine Resources Studies*

Outreach Coordinator: Angie Doerr, *Oregon State University/Oregon Sea Grant*

Industry Advisor: Jim Parsons, *Jamestown-S'Kallam Tribe*

Project Monitor: Wendy Sealey, *USDA*

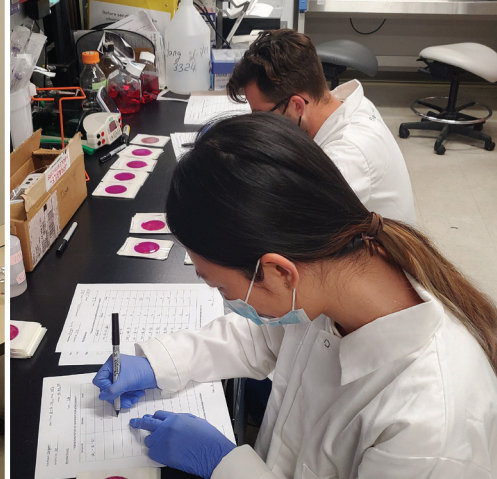
ISSUE: The development of marine and freshwater finfish aquaculture in the western United States is dependent upon a stable and robust supply of juveniles. However, significant disease-associated mortality occurs during commercial culture, requiring disease control and prevention. Current vaccination methods for bacterial pathogens generally rely on one of two methods. Firstly, farmers may use injection vaccines, which are labor intensive, costly, and involve high degrees of fish handling. Alternatively, farmers may vaccinate fish using immersion (bath) vaccines that are less labor intensive than injections, but still require transferring the fish into a crowded and stressful environment designed specifically for the bath vaccination process.

RESPONSE: The goal of this project is to develop and evaluate novel complex particles as a platform for oral vaccination of marine and freshwater finfish. Specifically, we aim to immunize sablefish and trout for resistance against *Aeromonas salmonicida*. The development of oral vaccination methods would have several major benefits by: 1) allowing smaller fish to be vaccinated than would be typically

permitted using injection methods; 2) reducing the labor (and cost) associated with administering injection-based vaccines; and 3) providing a tool for vaccination boosters, which could work in conjunction with more traditional vaccines. This project will also result in the development of an ELISA (enzyme-linked immunosorbent assay) for measuring the immune response to experimental vaccines in sablefish and trout.

RESULTS: The oral vaccines produced in this project appear to confer protection to trout exposed to *Aeromonas salmonicida* and perform similarly to bath vaccination methods. Similar levels of protection have been observed in sablefish vaccinated with the novel oral vaccine. An oral vaccine offers several benefits to the farmer when compared to bath vaccinations in that they can be offered directly to the fish in their culture environment without additional handling or crowding. Current efforts are aimed at evaluating the use of the oral vaccines in combination with bath vaccines. This project has also resulted in two new ELISAs that will allow researchers to measure the immune response of sablefish and trout to the pathogen *Aeromonas salmonicida* as well as experimental vaccines.

IMPACTS: We anticipate that upon completion of this project, the methods and technologies developed will be transferred to industry and other stakeholders and will ultimately improve the economy and application of vaccinations in the finfish industry.



Optimization of Pre- and Post-Harvest Factors to Extend the Shelf Life and Improve the Quality of Whole Fish and Fillets of Salmonids and White Sturgeon

Annual Progress Report

Principal Investigators: Xiang Yang, *University of California, Davis*; Robert McGorin, *Oregon State University*

Outreach Representative: Jackson Gross, *University of California, Davis*

Collaborators: Katie Harris, *Mt. Lassen Trout Farm*; Ali Bolourchi, *Tsar Nicolai Caviar*

Industry Advisor: Auggie Wilms, *Tsar Nicolai Caviar*

Project Monitor: Sean Nepper, *Riverence LLC*

ISSUE: Given the many challenges of increasing domestic finfish supply, reducing loss by extending the shelf life and improving the quality of fresh and frozen fish products is critical to maintaining the growth of finfish aquaculture and the profitability of fish producers in the western region of the United States. Several factors, such as slaughtering methods, processing practices, and packaging technologies, are generally considered important in extending shelf life and improving fish quality, yet they have not been systematically investigated on large finfish.

RESPONSE: The overall goal of this study is to fill the gap of knowledge and provide finfish producers valuable processing strategies to produce the highest quality whole fish and fish fillets with sustainable aquaculture systems. We propose to evaluate the effects of traditional and alternative slaughtering methods, different processing methods, and numerous packaging technologies on the retail shelf life and quality of trout, steelhead, and white sturgeon. We will also develop a technical document with standard operating

procedures and video for fish slaughter and a guidance document covering fish processing in English and Spanish.

RESULTS: To date, we have performed a number of method validations. These include; texture profile analysis, microbial sampling, sensory evaluation training, and sampling procedures for sturgeon fillets, steelhead trout fillets, and whole trout. We have also validated different slaughtering methods based on the advice from industrial partners. To validate the physiochemical and nutritional assays for fish freshness, we have procured the necessary chemicals, reagents, and GC capillary columns for physiochemical and nutritional analyses to have on-hand for a beginning MS graduate student to commence research in Fall 2022. We have also validated suitability of selected analytical methods to measure total volatile basic nitrogen, trimethylamine, fatty acid distribution, etc., and ordered NOVOCIB PRECICE enzymatic freshness assay kits to have on-hand for preliminary screening runs using retail fish samples.

POTENTIAL IMPACTS: All the analytic methods related to the shelf life and quality assessment for fish products have been validated. Ultimately, the findings of the actual experiments could be beneficial to producers by providing them with information on how these factors impact the quality and shelf life of their respective products. This will allow fish producers to make informed decisions regarding their production practices and help provide consumers with high quality products with a longer shelf life.



Characterization of Aquaculture in the Western U.S.

Annual Progress Report

Principal Investigators: Jonathan van Senten, *Virginia Tech*, Carole R. Engle, *Engle-Stone Aquatic\$ LLC*, Rafael Cuevas Ruibe, *Cal Poly Humboldt*, Quentin Fong, *University of Alaska*

Outreach Representative: Quentin Fong, *University of Alaska*

Industry Advisor: Ken Beer, *The Fishery Inc.*

Project Monitor: Jackson Gross, *UC Davis*, and Jacob Bledsoe, *University of Idaho*

ISSUE: Aquaculture in the western region has a rich heritage, with farms that date back more than a century. This region's aquaculture operations include a wide variety of warmwater and coldwater species that are raised in diverse production systems in both saltwater and freshwater. Nevertheless, aquaculture is as poorly understood by many individuals in the western region as it is in the rest of the country. Myths and inaccurate information abound and have led to overly burdensome regulatory programs, adverse policies, and a lack of adequate social license to support a rate of growth commensurate with the resources and skill sets available. There is a strong need to provide ready access to accurate, science-based information on aquaculture in the western region in a non-technical format.

RESPONSE: We will develop and make available a series of fact sheets, infographics, and video vignettes that are science-based and factually correct on the farming practices used, supply chains created and sustained, interactions with the environment, and the economic contributions of aquaculture in the western region. The materials developed will be made available on the WRAC web site. Consumers increasingly wish to develop a sense of connection with

local farmers and food suppliers, often through digital media. This project seeks to provide the necessary information and deliverables to help characterize the industry in an approachable and factual manner.

RESULTS: To date, 158 supply chains for aquaculture have been identified and mapped across six states in the western region (California, Colorado, Idaho, Oregon, Utah, and Washington). Draft fact sheets have been sent to industry representatives for content review and feedback in each of the six states. Data used for the supply chain analysis included previous surveys of major aquaculture sectors in the region, a new survey of shellfish producers in Alaska, new interviews of additional producers in California to fill in gaps, and current state-level data where available. The project has identified several unique supply chains within the western region that have not been well described before now. We are developing disaggregated economic impact models of these different supply chains to estimate the contribution of the various aquaculture sectors in these six states and across the region through the IMPLAN modeling framework. We are using the Analysis-by-Parts approach to construct aquaculture-specific sectors to link into the IMPLAN regional economic matrices for each of the six states and the western region. Video recording and photography activities have been initiated, following the first trip to visit several farms in California.

IMPACTS: Survey instruments to assess economic cost structures of baitfish and sportfish, ornamental fish, shellfish, and seaweed production have been developed. Cal Poly Humboldt graduate student, Brian Donovan, has been trained in survey recruitment and survey interview techniques.



Mixing Up an Optimal Diet for White Sturgeon Grow-out

Annual Progress Report

Principal Investigators: Wendy M. Sealey, *USDA, ARS, Bozeman Fish Technology Center*; Madison Powell, *University of Idaho*; Jackson A. Gross, *University of California Davis*

Outreach Representative: Jackson A. Gross, *University of California Davis*

Collaborator: William T. Fairgrieve, *NOAA-Northwest Fisheries Science Center*

Industry Advisors: David Brock, *Rangen/Wilbur Ellis*; Iva Rooker, *Star Milling Feed Company*

Project Monitor: Sean Nepper, *Riverence LLC*

ISSUE: The diet-related issues of fatty ovaries and elevated visceral fat observed in white sturgeon at sexing indicate poor nutrient partitioning when existing commercial diets are fed to white sturgeon, which suggest that some of these feeds are not optimized for the sturgeon on-growing period. Limited data on the specific nutritional needs of these age classes may be the reason why commercial diets have generally yielded sub-optimal performance.

RESPONSE: Our study's objectives are to: 1) determine the effects of dietary protein, lipid, and carbohydrate levels on growth, feed utilization, nutrient retention, and deposition of mesenteric fat in Year 1 and Year 2 white sturgeon; 2) develop cost-effective feed formulated with optimal macronutrient levels by replacing fishmeal using the appropriate combination of alternative protein source mixtures with amino acid supplementation; 3) evaluate any long-term effects of diets on fish growth, ovarian health, meat product quality, and consumer preference.

RESULTS: To date, 14 diets containing fishmeal, fish oil, and wheat starch at various mixture levels were formulated and fed to 1.5-yr-old white sturgeon in California and 2.5-yr-old white sturgeon in Idaho. At the end of both feeding trials, a response surface was fitted to the results and the range of mixtures producing at least 90 percent of the optimum response to each variable.

POTENTIAL IMPACTS: The data generated by this study can be used by farmers to choose more appropriate, currently available commercial diets for use in on-growing white sturgeon.



Photo: Courtesy of Wendy Sealey

In The Press & At The Podium

JOURNAL PUBLICATIONS & MANUSCRIPTS

Considine M, Martinelli JC, Wood CL, King T, and Rumrill S. *In preparation*. Detection of mud blister worm infestations on Oregon oyster farms. Target journal: Aquaculture Research.

Jones EM, Oliver LP, Ma J, Leeuwis R HJ, Myrsell V, Arkoosh MR, Dietrick JP, Schuster CM, Hawkyard M, Gamperl KA, and Cain, KD. Production of a monoclonal antibody specific to sablefish (*Anoplopoma fimbria*) IgM and its application in ELISA, western blotting, and immunofluorescent staining. Fish and Shellfish Immunology (Accepted-in revision)

Martinelli JC, Lopes HM, Jimenez-Hidalgo I, Hauser L, King TL, Rawson P, Williams JD, Padilla-Gamiño JL, and Wood CL. *In preparation*. Distribution and prevalence of shell-boring polychaetes *Polydora* spp. (Annelida: *Spionidae*) in Washington State, USA. Target journal: Aquaculture.

Martinelli JC, Spencer LH, Alma L, Padilla-Gamiño JL, and Wood CL. 2022. Evaluating treatments for shell-boring polychaete (Annelida: *Spionidae*) infestations in Pacific oysters (*Crassostrea gigas*) from the US Pacific Northwest. Aquaculture 561:738639.

Vaage B and Myric CA. 2022. Growth, metabolism, and dissolved oxygen tolerance of juvenile burbot. Aquaculture. 552:737980.

DISSERTATIONS & THESES

Jones E. 2022. Evaluating a novel oral vaccine particle for use in disease prevention in rainbow trout (*Oncorhynchus mykiss*) and development of important tools for the study of immunity in sablefish (*Anoplopoma fimbria*). Master's Thesis, University of Idaho, Moscow, ID.

Oliver LP. 2022. Characterizing diet, reproduction, and fish health parameters important for commercial development of burbot (*Lota lota*) aquaculture. PhD Dissertation. University of Idaho, Moscow, ID.

WRAC-funded projects

September 1, 2021–August 31, 2022

PRESENTATIONS & POSTERS

Bruce T, Oliver L, Ma J, Small B, Hardy R, Brown M, Craig S, and Cain K. An initial evaluation of fish-meal replacement with soy protein sources on growth and immune responses of burbot (*Lota lota maculosa*). International Symposium on Fish Nutrition and Feeding. Sorrento, Italy. Jun. 5–9, 2022.

Bruce T, Bledsoe J, Oliver L, Ma J, Jones E, Vuglar B, Welker T, and Cain K. Characterization of stress response and gut microbiota in cultured burbot *Lota lota maculosa* following feeding with plant-based diets. World Aquaculture Conference. San Diego, CA. Feb. 28–Mar. 4, 2022.

Cain KD. History of burbot aquaculture in the US: Moving from a conservation focus to a potential high value commercial species! International Congress on Fish Biology (Burbot Symposium). Montpellier, France. Jun. 28–Jul. 1, 2022 (Invited).

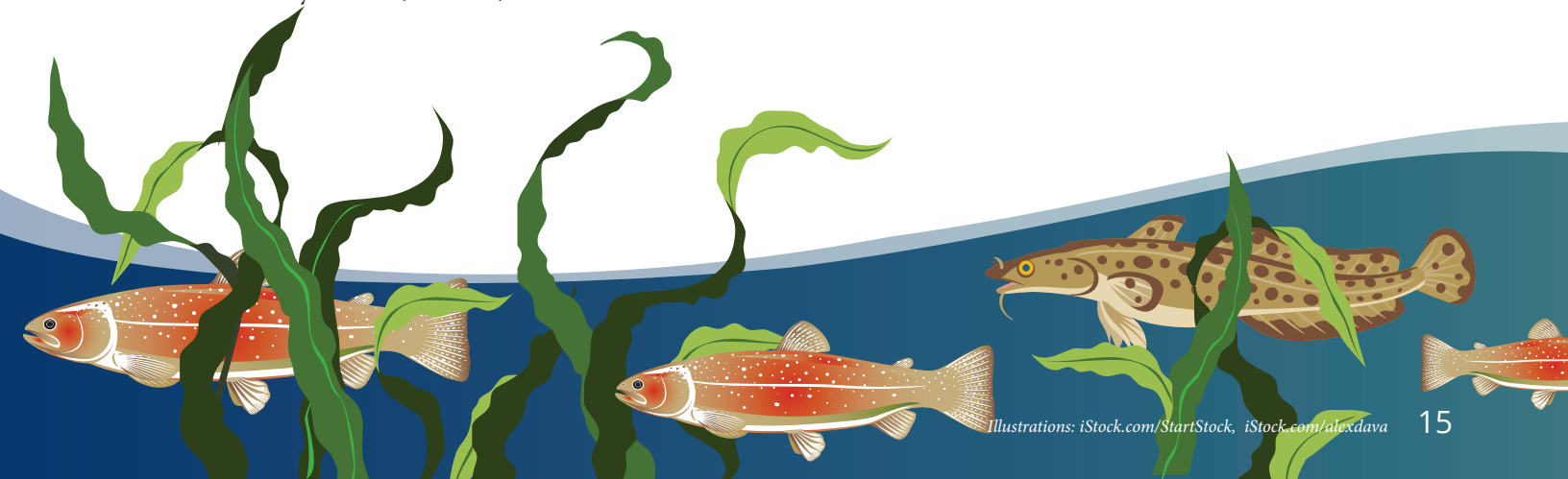
Cain KD. Overview of feeding practices and dietary needs for production of burbot (*Lota lota*) at different life stages. 38th Meeting of Fish Feed and Nutrition Workshop. Moscow, ID. Jul. 11–13, 2022.

Gross J. Upstream and downstream animal welfare considerations of fish in aquaculture fish farming (Invited Speaker). American College of Animal Welfare Short Course. Jun. 23–25, 2022.

Gross J and Deutsch Z. Increasing fish welfare of large finfish in California aquaculture. National Aquaculture Extension Conference, Portland, ME, Jun. 13–17, 2022.

Gross J and Deutsch Z. Welfare challenges associated with handling and slaughter of large caviar finfish (poster). Aquaculture 2022. Feb. 28–Mar. 4, 2022.

Gross J and Deutsch Z. Welfare of farmed fish at the time of slaughter (Poster). North American meeting of International Society of Applied Ethology. Davis, CA, Apr. 29–30, 2022.



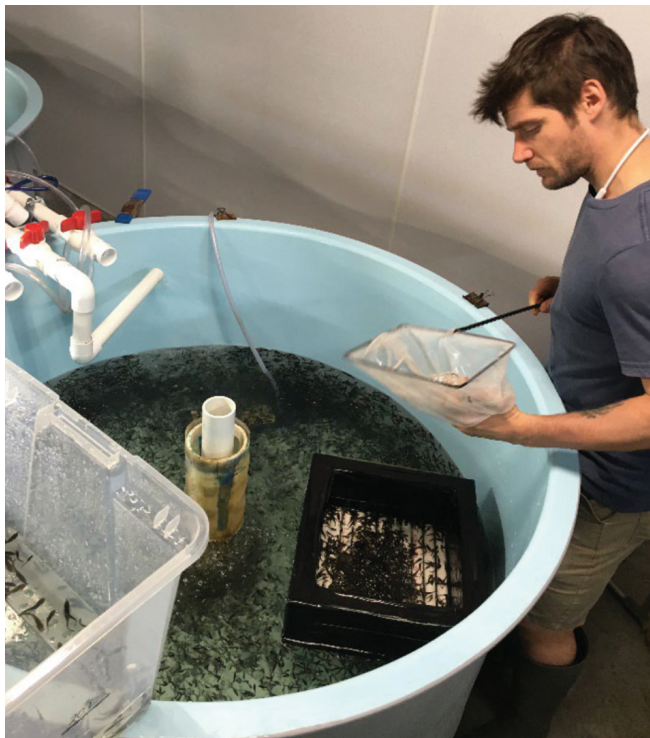
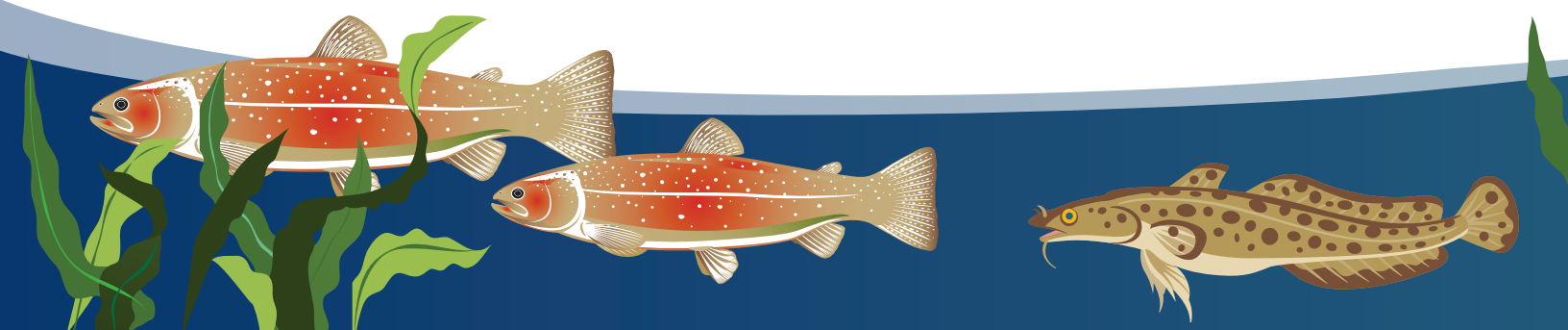


Photo: Courtesy of Kenneth Cain

- Hawkyard M, Stuart K, Drawbridge M, Laurel B, Dietrich J, Arkoosh M, Schuster C, Cain K, Jones E, and Langdon C. The development and evaluation of liposomes and liposome containing complex particles for improved health and nutrition of finfish. Northeast Aquaculture Conference and Exposition. Portland, ME. Apr. 27–29, 2022.
- Hawkyard M, Stuart K, Drawbridge M, and Langdon C. WRAC as a springboard for advancements in marine larval finfish nutrition. US Chapter of the World Aquaculture Association, San Diego, CA. Feb. 28–Mar 4, 2022.
- Heckman TI, Yazdi Z, Pomaranski EK, Sebastião FA, Vuglar BM, Cain KD, Loch TP, Soto E. Flavors of flavobacteriales: characterizing atypical flavobacterial pathogens in aquaculture. International Symposium on Aquatic Animal Health. Santiago, Chile. Sep. 4–8, 2022.
- Heckman TI, Yazdi Z, Pomaranski EK, Sebastião FA, Vuglar BM, Cain KD, Loch TP, Soto E. Flavors of flavobacteriales: characterizing atypical flavobacterial pathogens in aquaculture. Western Fish Disease Workshop. Hood River, OR. May 16–19, 2022.

- Jones E, Ma J, Hawkyard M, Arkoosh M, Dietrich J, Schuster C, Oliver L, Vuglar B, Myrsell V, and Cain K. Evaluating a novel oral vaccine delivery platform in rainbow trout *Oncorhynchus mykiss*. World Aquaculture Conference. San Diego, CA. Feb 28–Mar.4, 2022.
- Jones E, Oliver L, Ma J, Leeuwis R, Myrsell V, Hawkyard M, Arkoosh M, Dietrich J, Schuster C, Gamperl K, and Cain K. Production of a monoclonal antibody against sablefish *Anoplopoma fimbria* IgM and its use in an ELISA to measure circulating antibodies. World Aquaculture Conference. San Diego, CA. Feb. 28–Mar. 4, 2022.
- Martin K. WRAC project update: Identification of genetic markers for disease resistance to IHNV in commercial populations of rainbow trout. US Trout Farmers annual meeting, World Aquaculture Society Conference, San Diego, CA. Feb. 28–Mar. 4, 2022.
- Martinelli JC, Casendino HR, Spencer LH, Alma L, King TL, Padilla-Gamiño JL, and Wood CL. 2021. Testing effective treatments to control infections by shell-boring polychaetes (*Polydora* spp) in the US Pacific Northwest. Pacific Coast Shellfish Growers Association, 75th meeting (online). Sep. 20–22, 2021
- Martinelli JC, Considine ME, Casendino HR, King TL, Spencer LH, Tarpey C, Alma L, Hauser L, Padilla-Gamiño JL, Rumrill S, and Wood CL. Prevalence, distribution, and control of shell-boring polychaetes on oyster farms from California to Alaska (poster). Salish Sea Ecosystem Conference. Apr. 26–28, 2022. (virtual)
- Martinelli JC, Considine ME, Casendino HR, King TL, Spencer LH, Tarpey C, Alma L, Hauser L, Padilla-Gamiño JL, Rumrill S, and Wood CL. Prevalence, distribution, and control of shell-boring polychaetes on oyster farms from California to Alaska. Washington Sea Grant Shellfish Growers Conference. (virtual) Mar. 7, 2022.
- Martinelli JC, Considine ME, Casendino HR, King TL, Spencer LH, Tarpey C, Alma L, Hauser L, Padilla-Gamiño JL, Rumrill S, and Wood CL. Prevalence, distribution, and control of shell-boring polychaetes on oyster farms from California to Alaska. World Aquaculture Society Meeting, San Diego, CA. Feb. 28–Mar 4, 2022.
- Matuha, M. Sustainable production of burbot: weaning techniques, optimal spawning, sensory analysis and production economics. University of Idaho College of Natural Resources, Department of Fish & Wildlife Sciences Graduate Seminar (Fish 501).



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Myrick CA and Vaage B. The effects of acute and chronic exposure to ammonia on juvenile burbot growth and survival. 7th International Burbot Symposium, 14th International Congress on the Biology of Fish. Montpellier, France (invited) Jun. 28–Jul. 1, 2022.

Oliver L, Bruce T, Ma J, Jones E, and Cain K. Development of an anti-burbot IgM monoclonal antibody and optimization of an ELISA to measure anti-aeromonas SP. antibody titers in burbot *Lota lota* following pathogen challenge. World Aquaculture Conference. San Diego, CA. Feb. 28–Mar. 4, 2022.

Soto E, Yazdi Z, Nguyen DT, Heckman TI, LaFrentz BR, Griffin MJ, Loch TP. Phenotypic and genetic diversity amongst the etiological agents of columnaris diseases. International Symposium on Aquatic Animal Health. Santiago, Chile. Sept. 5–8, 2022.

Vaage B and Myrick CA. 2021. Does acclimation to reduced dissolved oxygen increase hypoxia tolerance in juvenile burbot? Colorado-Wyoming Chapter AFS Annual Meeting (virtual). Feb. 23, 2021.

Vaage B and Myrick CA. 2021. The effects of acute and chronic exposure of ammonia on juvenile Burbot (*Lota lota*) growth and survival. American Fisheries Society Western Division Annual Meeting (virtual). Jun. 28, 2021.

Vallejo R. submitted a proceedings paper to the conference World Congress on Genetics. “Genetic architecture of resistance to infectious hematopoietic necrosis virus in three aquaculture rainbow trout strains.” Applied to Livestock Production, Rotterdam July 3–8, 2022. Unfortunately, COVID-19 associated travel restrictions prevented his presentation at the conference.

Vuglar BM, Ma J, Heckman TI, Yazdi Z, Soto E, and Cain, KD. Virulence assessment of novel Flavobacteriaceae isolates collected from aquaculture facilities in the western United States. Western Fish Disease Workshop. Hood River, OR. May 16–19, 2022.

IN THE MEDIA & ON THE WEB

Blogpost in collaboration with Valerie Partridge, Department of Ecology: “These worms are boring!... into oyster shells, that is.” Online: <https://ecology.wa.gov/Blog/Posts/September-2021/These-worms-are-booooring-into-oystershells-that>. Sep. 27, 2021.

Collaboration with reporter Carly Casella. A mystery worm is threatening the future of Washington’s oysters. High Country News, Apr. 1, 2022: Online: <https://www.hcn.org/issues/54.4/north-scientific-research-a-mystery-worm-is-threatening-the-future-of-washingtons-oysters>.

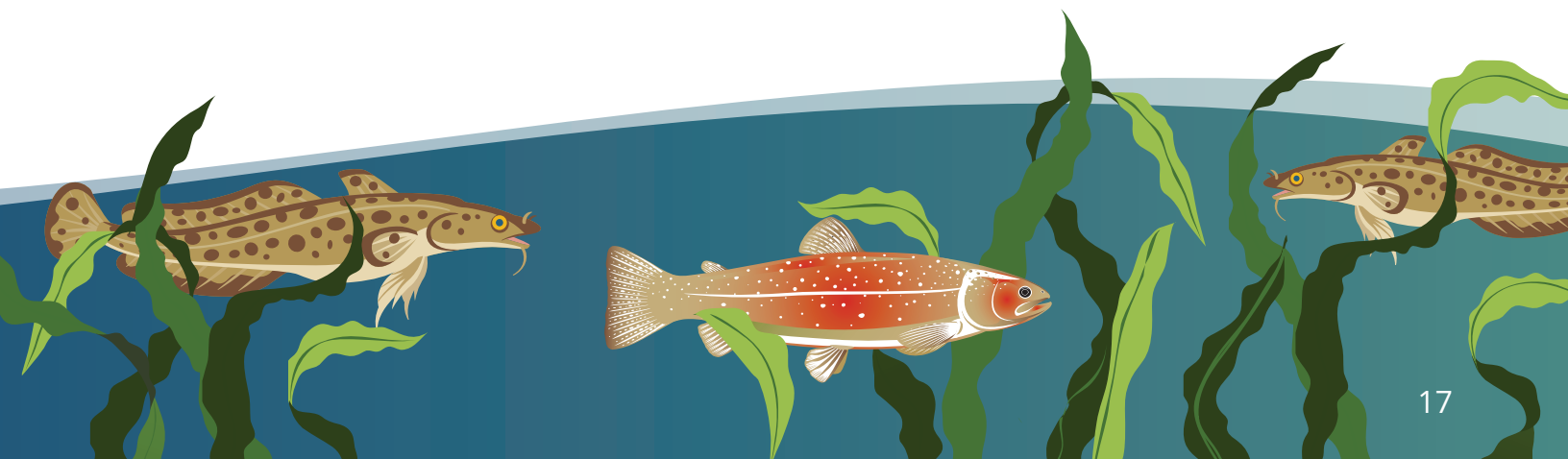
Martinelli J. “Prevalence, distribution, and control of shell-boring polychaetes on oyster farms from California to Alaska.” Pacific County Marine Resources Committee Board. May 12, 2022.

Martinelli J. “Mystery worm is affecting oysters in Washington.” Radio interview, *Think Out Loud*, Oregon Public Broadcasting. Online: <https://www.opb.org/article/2022/04/19/mystery-worm-is-affecting-oysters-in-washington/>. Apr. 19, 2022.

VIDEOS

In collaboration with Jackson Gross and the WRAC-funded project, Detection and Control of Mud Blister Worm (*Polydora* spp.) Infestation on Commercial Oyster Farms throughout the Pacific Northwest:

- How to recognize and treat a shell-boring marine worm pest in oyster aquaculture: <https://www.youtube.com/watch?v=-dGJn8r5Ysk>
- How to open oysters at home? How to shuck oysters? Sustainable Aquaculture at Taylor Shellfish: <https://www.youtube.com/watch?v=FF8heY54fcE>
- Cómo abrir ostras?:



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