

ANNUAL REPORT 2022

Aquaculture Research Institute

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DIRECTOR'S LETTER

With each passing year, I gain more appreciation for the amazing people I work with and the impact they have on our world. With a reduction in COVID, the world opened back up in 2022 and our faculty presented, ran workshops, and conducted research in eight countries across the globe. The return to “normal” also meant we were open to international students and visiting scholars again. Last year, ARI hosted students and scholars from Mexico, Taiwan, Sierra Leone, Italy, Nigeria, South Korea, Spain, and India. It is truly a joy to see the renewed energy that has come with the diversity of people and ideas.



Last year also provided several opportunities for us to showcase our work. ARI hosted the 38th Fish Feed and Nutrition Workshop in Moscow and the Idaho Coldwater Fish Culture Course in Hagerman. It was great to see colleagues, talk about research, and train agency and industry personnel in best management practices for cold water aquaculture. Our faculty also engaged trout farmers in the Republic of Georgia through a new USDA-Foreign Agricultural Service project, working with colleagues in Georgia to develop extension support for their budding trout industry. While this report highlights the many accomplishments of ARI's faculty, staff, students and researchers, there is much more going on behind the scenes. Our people are active across a range of service work institutionally, regionally, and nationally.

Administratively, we were successful in paying off a substantial institutional debt in 2022, negotiated more favorable F&A returns, made critical infrastructure improvements, and secured a substantial investment from the Vice President for Research and Economic Development for administrative support and research positions. Our industry partners also stepped up to provide philanthropic gifts for graduate student scholarships and research. Together, these achievements set ARI on stronger path forward. I look forward to seeing the payoffs in 2023 and the great things yet to come.

Go Vandals!

A handwritten signature in black ink, appearing to read "B. Small". The signature is fluid and cursive.

Brian C. Small, ARI Director
Professor, Fish and Wildlife Sciences
Affiliate Professor, Animal, Veterinary & Food Sciences

BY THE NUMBERS

2022

IMPACT

- 23 workshops, meetings, extension events
- 40 peer-reviewed journal articles
- 2 patent & invention disclosures
- 83 abstracts & presentations
- 5 technical & trade articles
- 12 books & book chapters
- 12 invited presentations

TRAINING

- 6 research scientists & postdocs
- 13 Ph.D. students (3 completed)
- 10 M.S. students (3 completed)

FUNDING

- >\$6.6 million in newly funded sponsored projects
- >\$6.8 million in continuing sponsored projects
- 6 tribal and governmental cooperative agreements
- \$100K in philanthropic gifts

RESEARCH HIGHLIGHTS

Feeds and Nutrition

- Evaluated optimal diet formulations for white sturgeon grow-out.
- Used modified fecal binders to reduce fish farm effluents across the industry.
- Evaluated soybean meal oral tolerance and immune response in Atlantic Salmon.
- Evaluated encapsulated micro-gel/particle diets for improved shrimp larval quality.
- Evaluated feed additives to improve performance and mitigate the metal toxicity.
- Evaluated health-promoting properties of organic acids and essential oils.
- Evaluated novel insect products as ingredients for aquafeeds.
- Investigated novel distillers' products as feed ingredients.
- Developed a climate smart resource utilizing sorghum in aquatic feeds.
- Filed a patent application for a high plant-PUFA fish food that improves trout growth.

Genetics and Genomics

- Published award winning paper on Pacific lamprey recolonization.
- Examined heat tolerance and epigenetic modifications in arctic grayling.
- Evaluated genetic and epigenetic effects of hatchery rearing and supplementation.
- Extensively supported genetic monitoring of salmonids in the Columbia River.
- Discovered and validated candidate genes associated with salmon migratory traits.
- Developed genetic markers for ongoing genetic monitoring of octoploid white sturgeon.
- Conducted functional microbiome research in rainbow trout.
- Determined nonspecific pathogen resistance in HFCES select line of rainbow trout.

Physiology, Health, and Management

- Conducted extensive monitoring of water conditions across fourteen trout facilities.
- Transferred key technology on Burbot aquaculture to private industry partners.
- Initiated project on Pacific lamprey sexual maturation.
- Conducted studies on sustainable aquaculture engineering for the novel remediation of water contamination from fish farms.
- Completed trials for regulatory approval of Coldwater disease vaccine for trout.
- Filed patent application for new attenuated vaccine strain that protects Atlantic salmon from Coldwater disease.
- Developed two new monoclonal antibodies for commercialization.

2022 Coldwater Fish Culture Course



ABOUT ARI

Established in 1988, the Aquaculture Research Institute (ARI) is an interdisciplinary entity at the University of Idaho designed to provide a focus for aquaculture and related fisheries research by faculty throughout the University. Aquaculture is a highly diverse activity involving food production, fisheries enhancement, and fisheries stock restoration, and involves application of an array of scientific disciplines, including fish nutrition, genetics, physiology, immunology, and water quality. The Institute leads and facilitates research and education across scientific disciplines involving several Departments and Colleges across the University. ARI works closely with the commercial sector, as well as with federal, state, and tribal agencies, having formal collaborative partnerships with the US Department of Agriculture and the Columbia River Inter-Tribal Fish Commission.

ARI facilitates basic and applied research in aquaculture, fisheries, and aquatic resources. While much of this research focuses on rainbow trout, ARI researchers also conduct research with other native and non-native species, including Pacific salmon and trouts, Atlantic salmon, sturgeon, lamprey, burbot, tilapia, catfish, shrimp, and zebrafish. Research involves fish rearing studies but also basic research into the molecular, cellular, and organismal regulation of phenotypic responses to environment, diet and pathogens. ARI scientists use modern techniques and technology, such as next-gen sequencing, proteomics, metabolomics, and bioinformatics, to address research questions.

Research is primarily conducted at the Hagerman Fish Culture Experiment Station, located in south-central Idaho. However, ARI facilities on the Moscow campus expand research and education opportunities to include marine fish and shrimp for on-campus faculty and students. ARI research is supported by funding from a range of sources, including competitive grants, cooperative agreements, gifts, and by contracts with industry. ARI has a strong commitment to assist companies as they develop new aquaculture and fisheries products, including ingredients and supplements for aquaculture feeds.

Fish nutrition and selective breeding are important aspects of ARI's research programs. Reducing the levels of fishmeal and fish oil in fish feeds is a high priority area. A long-term effort, in collaboration with the USDA, has been made to selectively breed rainbow trout that exhibit high growth performance when fed all plant-protein feeds. Reducing the environmental impacts of fish farming and understanding how the genome and environment drive phenotypic expression are other focuses of ARI research. Overall, ARI is committed to the development of environmentally sustainable aquaculture and fisheries management through advanced research and by training tomorrow's leaders in the aquaculture and fisheries fields.

FACILITIES



Hagerman Fish Culture Experiment Station

The Hagerman Fish Culture Experiment Station is in south-central Idaho approximately 90 miles southeast of Boise, Idaho, the state capital. The University of Idaho leased the facility from the US Fish & Wildlife Service in 1996 and took possession of the 4-acre property in 1998. In 2006, a new 14,000 ft² building was dedicated, and included offices, a classroom, and analytical laboratories. A six-bedroom dormitory and additional fish rearing buildings were also constructed, augmenting existing fish rearing facilities and providing housing for trainees and visiting scholars.

Hagerman Station features a 6000 ft² wet lab supplied with 2000 gpm, 14.5°C, gravity-fed, first-use spring water. The wet lab contains 142 38-gallon (145-liter) and 42 152-gallon (450-liter) tanks for conducting comprehensive experimental procedures. Egg incubators and hatchery small troughs are used for incubating eggs and start-feeding trout fry. Quarantine facilities with the capacity to heat or chill water and to sterilize the effluent are in a separate, biosecure building. Physiological and behavioral studies can be conducted in a common garden environment consisting of three recirculating aquaculture systems and utilizing state-of-the art swimming, respirometry, and cardiac output chambers. Thirty covered outdoor tanks utilize second-use water and are suitable for raising groups of fish to maturity. Outdoor, 1/3 scale raceways (8 total) complete the fish rearing facilities. The Hagerman Station also has extensive analytical laboratories used to support research in feeds, molecular biology, population genetics and genomics, including next-generation sequencing.

Cold Water Laboratory

The 8000 ft² Cold Water Laboratory operates on the Moscow campus as a water-limited recirculating facility. There are currently seven independent recirculating systems on backup power that can accommodate a variety of cold-water species, including salmonid species and sturgeon. The facility also



maintains one warmwater system for rearing tilapia. Each system has independent chilling/heating, biofiltration, and UV treatment. The largest system has four four-meter diameter tanks for rearing of large populations or broodstock. The other systems are high-replicate systems, comprised of as many as 66 tanks. The Cold Water Lab has capabilities to incubate eggs in Heath tray incubators and McDonald jars. Fry can also be held in fiberglass troughs and fed with either single pass or recirculating water. Temperatures in the systems can be maintained between 4 °C and 20 °C. The Moscow Cold Water Lab facilities are available to researchers across the University for a nominal fee.

Aquatic Animal Research Facility



In 2019, the University completed construction of the Aquatic Animal Research Facility (AARF) on the Moscow campus. Adjacent to the Cold Water Laboratory, this two-story facility boasts office and classroom space coupled with a state-of-the-art 4000 ft² wet lab. The AARF also operates as a water-limited recirculating facility. There are currently four independent recirculating systems with backup power. Three of these systems were

specifically designed to facilitate new species development. A live-feed room to produce artemia and rotifers supports this work. The fourth system is a dedicated, high-replicate marine system suited for shrimp and marine fish research.

Bozeman Fish Technology Center

Through a cooperative agreement with the USDA/ARS Trout Feeds Program, ARI researchers have access to state-of-the-art diet manufacturing equipment for making fish feeds at the Bozeman Fish Technology Center, Montana. This includes a variety of equipment including a hammer mill, air swept pulverizer, mixers of various sizes and types, pelleting equipment including a Buhler twin screw extruder, feed drier, and a vacuum coater for oil addition.



PEOPLE

Administration



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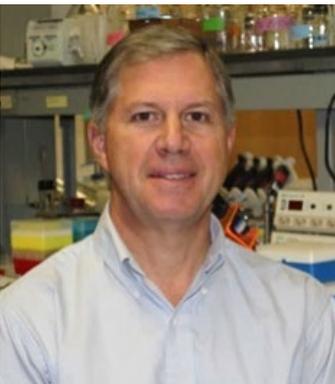
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Sharla Anita Smith (1946 - 2023)

Missed by so many.

MOSCOW AQUATIC ANIMAL RESEARCH FACILITY

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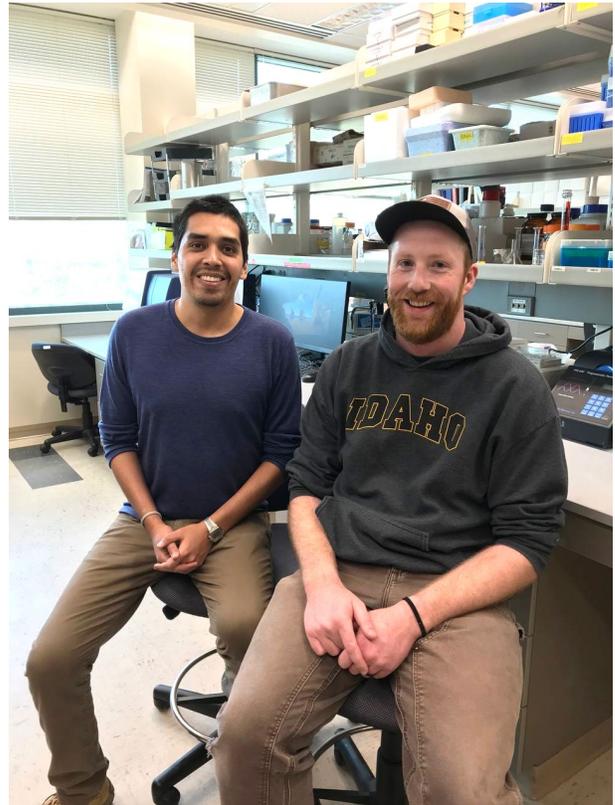
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Trainees

Postdocs and Research Scientists

Dr. Zhongqi Chen

Dr. Luke Oliver

Dr. Lea Medeiros

Dr. Md. Hossain Sakhawat

Dr. Travis Seaborn

Dr. Hui (“William”) Wang



Graduate Students

Alonso Longoria, Ph.D. in Animal Physiology

Amit Kumar Yadiv, Ph.D. in Animal Physiology (completed 2022)

Brent Vulgar, M.S. in Natural Resources

Carlie Sharpes, M.S. in Environmental Sciences (completed 2022)

Clayton Mabey, M.S. in Animal Physiology

Daniel Assan, Ph.D. in Natural Resources

David Arthaud, Ph.D. in Natural Resources

Elaine Harvey, Ph.D., Natural Resources

Ethan Struhs, Ph.D. in Biological Engineering

Evan Jones, M.S. in Natural Resources (completed 2022)

Jacob Styhl, M.S. in Biological Sciences

Jeongwhui Hong, Ph.D. in Natural Resources

Jonathan Massingale, Ph.D. in Natural Resources

Jose Ortiz, M.S. in Natural Resources

Kimia Kajbaf, Ph.D. in Animal Physiology

Krishna Singha, Ph.D. in Animal Physiology

Luke Oliver, Ph.D. in Natural Resources (completed 2022)

Madeline Piper Evans, M.S. in Animal Physiology

Matthew Dunkle, Ph.D. in Natural Resources (completed 2022)



Marina Rubio Benito, Ph.D. in Animal Physiology
Melanie Regan, Ph.D. in Natural Resources
Mosope Abanikanda, Ph.D. in Animal Physiology
Moureen Matuha, Ph.D. in Natural Resources
Neil Ashton, Ph.D. in Natural Resources
Nicholas Hoffman, Ph.D. in Biological Sciences
Nicole Nance, M.S. in Animal Physiology
Niloufar Nourmohammadi, Ph.D. in Animal Physiology
Rance Bare, Ph.D. in Biological Engineering
Susana Frias-Gomez, PhD, UNAM
Tsung-Yu (Daniel) Tsai, M.S. in Animal Physiology (completed 2022)
Veronica Myrsell, M.S. in Natural Resources

Undergraduate Interns

Victor Azevedo, Aquaculture intern, University of Idaho
Tawa Giwa, SARE intern College W. Idaho
Autumn Herrington, SARE intern, University of Idaho
Hannah Kemp, SARE intern, University of Idaho
Veronica Valdez, SARE intern, College of Southern Idaho
Rebekah Windover, SARE intern, University of Idaho



OUTPUTS AND ACCOMPLISHMENTS

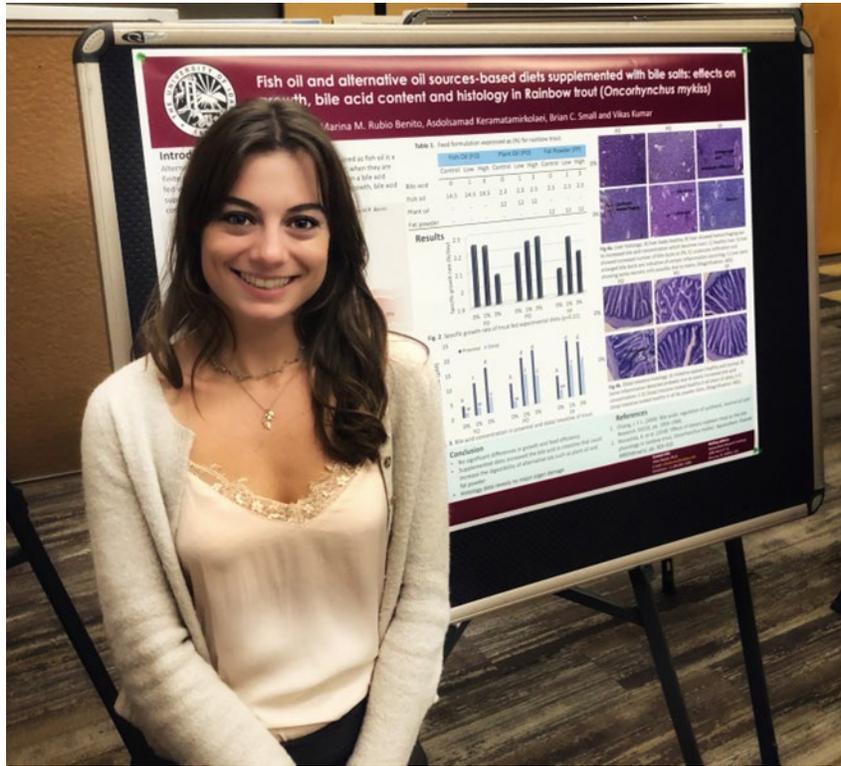
Formal Agreements

1. B.C. Small; Columbia River Inter-Tribal Fish Commission (Memorandum of Understanding); Est. 2000.
2. Small, B.C.; USDA Agricultural Research Service, Franklin, ME (Cooperative Agreement); Est. 2017.
3. Small, B.C.; USDA Agriculture Research Service, Aberdeen, ID (Cooperative Agreement); Est. 1999.
4. Nagler, J.; Columbia River Inter-Tribal Fish Commission (CRITFC) (Formal agreement on multiple projects (steelhead trout, Chinook salmon, Pacific lamprey) with Dr. Andrew Pierce [CRITFC research scientist] and Mr. Neil Graham [CRITFC field technician], both on-site at the UI Moscow campus, Est. 2009.
5. Overturf, K. coPI Sealey, W.; US Fish and Wildlife Service. Bozeman Fish Technology Center (Cooperative Agreement); Est. 2005. .
6. Overturf, K. coPIs: Welker, T., Liu, K., Sealey, W.; USDA Agricultural Research Service, Hagerman, ID. (In-House Appropriated project); Est. 1999.

New Sponsored Projects

1. Engle, C. *et al.* 2021-2023: Professional Aquaculture Services, providing administrative support. Cooperative Agreement between USDA-NIFA and National Aquaculture Association for programmatic review of the five US Department of Agriculture supported Regional Aquaculture Centers (**\$478,150**).
2. Ovissipour, R. & Sealey, W. 2021-2024: United Sorghum Check-off Program. Value-added Sorghum Protein Evaluation and Development. (**\$752,141**).
3. Sealey, W., Powell, M. S. & Gross, J. A. 2021-2025: Western Regional Aquaculture Center. Mixing up an optimal diet for white sturgeon grow-out. (**\$423,921**).
4. Mirlkoui. 2022: Molecular Characterization of used char filters after fish farm downstream water treatment: Multi-level chemical analyses and fractionation scheme. National High Magnetic Field Laboratory (MagLab). (**\$5,000**).
5. Mirlkouis, A. 2022: USA-ARS Sustainable aquaculture engineering: novel remediation of water contamination from fish farms. (**\$4,900**).

6. Small, B. 2022: UI Hagerman Fish Culture Experiment Station Laboratory Supplies. Columbia River Inter-Tribal Fish Commission (**\$1,013,161**).
7. Small, B. 2022: . Task Order #5: Blind Feed Evaluations. Small Private Feed Company. (**\$23,904**).
8. Nagler, J. 2022: The physiology of kelt reconditioning XIV: developing strategies to increase iteroparity in Snake River steelhead. Columbia River Inter-Tribal Fish Commission. (**\$254,210**).
9. Nagler, J. 2022: Effect of parent age on rate of minijack production among male progeny of spring Chinook Salmon VIII. Columbia River Inter-Tribal Fish Commission. (**\$203,479**).
10. Powell, M., Gaylord, G., Sealey, W. & Overturf, K. 2022: Improving utilization of alternate protein and oil sources in rainbow trout. USDA-NIFA (Hatch Project). (**\$2,125**).
11. Powell, M. 2022: Comparative thermal tolerance and metabolic responses in arctic grayling and rainbow trout. NSF-EPSCoR GEM3. (**\$5500**).
12. Caudill, C. C. & Nerkowski, S. 2022: Stream and Lake Invertebrate Molecular Ecology and Biomonitoring. NSF Idaho EPSCoR GEM3 program. (**\$11,780**).
13. Small, B. 2022-2023: Evaluation of ProCap Gold DDGS as a fishmeal replacement for Atlantic salmon. Private Ingredient Company. (**\$69,310**).
14. Small, B. 2022-2023: Banbury Springs Limpet Captive Holding & Rearing Project. US Fish & Wildlife Service. (**\$22,000**).
15. Small, B. 2022-2023: Aquaculture technician support. USDA Agricultural Research Service. (**\$62,018**).
16. Small, B. 2022-2023: Research Towards Precision Salmonid Feeds. USDA Agricultural Research Service. (**\$18,000**).
17. Bledsoe, J. 2022-2023: Exploring the adaptive potential of mucosal microbiomes to increased temperature regimens in rainbow trout (*Oncorhynchus mykiss gairdneri*) populations locally adapted to disparate ecotypes. NSF Idaho EPSCoR GEM3 SEED program. (**\$49,959**).
18. Bledsoe, J. 2022-2023: Evaluating inclusion of commercial pistachio by-product as functional ingredients in rainbow trout fishmeal and plant-meal based diets. University of Kansas Center for Research Inc. (**\$61,769**).



19. Eya, J. & Sealey, W. 2022-2023: Characterization of phenotypic/genetic relationship between digestive efficiency and gut microbiome composition in rainbow trout fed vegetable- or insect-based ingredient sources. West Virginia State University. (\$499,997).
20. Cain, K. D. & Ma, J. 2022-2023: Coldwater vaccine optimization for licensing and commercialization. Private Animal Health Company. (\$256,523).
21. Cain, K. D. & Ma, J. 2022-2023: Evaluation of immune response and survival of single or dual pathogens in juvenile rainbow trout fed commercial health-promoting diets. Private Feed Company. (\$29,741).
22. Cain, K. D. 2022-2023: Production of juvenile burbot for support of commercial aquaculture venture. Private Aquaculture Company. (\$179,719).
23. Powell, M. 2022-2023: Mandela Washington Fellowship for Young African Leaders, Reciprocal Collaborator Program. (\$5000).
24. Schwarz, M. & Sealey, W. 2022-2023: Evaluate nutritional value of Sorghum in Hybrid Striped Bass. Virginia Tech/ United Sorghum Check-off Program. (\$34,010).

25. Small, B., Bledsoe, J. & Powell, M. 2022-2023: Bolstering fish culture education, extension, and outreach in the Republic of Georgia. USDA, Foreign Agricultural Service. (**\$94,295**).
26. Welker, T. 2022-2023: Evaluation of Corn DDGS in Practical Feeds of Tilapia. US Grains Council (Kuala Lumpur, Malaysia) and Ohio Corn and Wheat Council Project. (**\$32,879**).
27. Kumar, V. 2022-2023: Optimizing the soybean meal (SBM) inclusion in different life stages of Atlantic salmon (*Salmo salar*) diet and increasing the SBM level in Yellow Perch (*Perca flavescens*) diet. Ohio Soybean Council. (**\$105,031**).
28. Kumar, V. 2022-2023: Impacts of dietary inositol and phytase enzyme on performance and gut microbiome of white-leg shrimp, *Litopenaeus vannamei*. Private Ingredient Company. (**\$61,675**).
29. Kumar, V. 2022-2023: Proteomics investigation of oxidized feed on the robustness and muscle quality of juvenile white-leg shrimp, *Litopenaeus vannamei*. Private Ingredient Company. (**\$55,732**).
30. Roe, A. & Powell, M. 2022-2023: Fish and Family: cooking and eating trout with your child. UI Seed Grant. (**\$5000**).
31. Cain, K. D. & Ma, J. 2022-2024: Efficacy and immunomodulatory properties of the probiotic *Enterobacter* C6-6 for early life stage management of coldwater and columnaris disease and related co-infections. USDA-NIFA. (**\$295,930**).
32. Sealey, W. & Gaylord, G. 2022-2025: Engineering-Scale Validation of Novel Algae CO2 Capture and Bioproducts Technology. Department of Energy/Helios-NRG. (**\$73,634**).
33. Kumar, V., Small, B. & Overturf, K. 2022-2026: Indirect criteria to select the farmed fish lines to enhance the efficiency of soybean meal utilization in their diet. Soy Aquaculture Alliance. (**\$315,648**).
34. Kumar, V. 2022-2026: Evaluation of additive effects of fish soluble protein in plant protein-based diets on growth performance, feed utilization and gut/liver histology of Rainbow trout. Private Ingredient Company. (**\$13,245**).
35. Dhar, A. & Sealey, W. 2023-2025: Development of PCR-based diagnostic assays in support of disease-free attestations of formulated aquafeed. USDA-NIFA-AFRI, Aquaculture. (**\$231,600**).
36. Narum, S. R. 2023-2025: Genetic Assessment of Columbia River Stocks. S.R. Bonneville Power Administration, Accords Grant. (**\$1,400,00**).



Continuing and/or Terminating Sponsored Projects

1. Nelson, J., Baxter, C., Forbey, J. & Hardy, R. 2018-2023: Linking genome to phenome to predict adaptive responses of organisms to changing landscapes. Contributing senior personnel and contributors to original proposal concept. 2018-Present: Caudill, Small: Co-leads for Trout Mechanisms Workgroup. 2020-present: C. Caudill; coPI for the University of Idaho (replacing R. Hardy). Year four funding (Federal FY22). NSF Total: (\$3,792,708). University of Idaho (\$2,296,575). State of Idaho (\$800,000). UI (\$447,986). Year 4 Total **(\$2,744,471)**.
2. Cain, K. D., Soto, E., Fornshell, G., Bruce, T. J. & Ma, J. 2019-2023: Emerging and Re-emerging Flavobacterial Pathogens in Aquaculture. Western Regional Aquaculture Center (WRAC). **(\$417,000)**.
3. Welker, T., Powell, M. & Gaylord, G. 2019-2023: Waste management and water quality improvement on commercial trout farms through nutritional strategies. USDA-NIFA. **(\$299,369)**.
4. Caudill, C. C., Bellmore, J. R. & Dunkle, M. 2019-2023: Investigating the influence of watershed variability on meta-food web dynamics and salmonid growth in southeast Alaskan streams. Joint Venture Agreement with USFS, Pacific Northwest Research Station. **(\$277,741)**.
5. Small, B. C. 2019-2024: Improving the Competitiveness of Rainbow Trout Production by the Integrated Development of Improved Feedstuffs, Feeds, and Trout. USDA Agricultural Research Service. **(\$1,446,600)**.

6. Cain, K. D., Hawkyard, M., Bruce, T. J. & Ma, J. 2019-2024: Development of oral vaccine delivery methods for prevention of disease in finfish culture. Western Regional Aquaculture Center (WRAC). **(\$479,000)**.
7. Small, B. C. 2021-2022: Determination of oxygen bioavailability using new technology for oxygen delivery in aquaculture systems. Private Animal Health Company. **(\$38,043)**.
8. Small, B. C. 2021-2022: Utilization of Corn Ethanol byproduct in Atlantic Salmon feeds. Illinois Corn Marketing Board, National Corn Ethanol Research Center subaward. **(\$57,174)**.
9. Small, B. C. 2021-2022: Evaluation of meal worm protein digestibility and efficacy as a fish meal replacement for rainbow trout. Private Ingredient Company. **(\$63,748)**.
10. Small, B. C. 2021-2022: Safety Assessment of Canola meal from Event NS-B50027-4 in Rainbow Trout (*Oncorhynchus mykiss*). Private Ingredient Company. **(\$57,523)**.
11. Small, B. C. 2021-2022: Aquaculture technician support. USDA Agricultural Research Service. **(\$62,018)**.
12. Small, B. C. 2021-2022: Aquaculture technician support. USDA Agricultural Research Service. **(\$59,998)**.
13. Small, B. 2022-2023: Research Towards Precision Salmonid Feeds. USDA Agricultural Research Service. **(\$18,000)**.
14. Nagler, J. 2021-2022: The physiology of kelt reconditioning XIII: developing strategies to increase iteroparity in Snake River steelhead. Columbia River Inter-Tribal Fish Commission. **(\$224,261)**.
15. Nagler, J. 2021-2022: Effect of parent age on rate of minijack production among male progeny of spring Chinook Salmon VII. Columbia River Inter-Tribal Fish Commission. **(\$213,789)**.
16. Cain, K. D. 2021-2022: Determining host safety, antimicrobial activity, antiviral activity, and duration of activity of Armatrex against select fish pathogens and bio-fouling. Private Animal Health Company. **(\$51,854)**.
17. Kumar, V. 2021-2022: Bile acid (functional feed additive) to enhance the growth, and mitigates intestinal inflammation induced by high level of soybean meal in Rainbow trout. Ohio Soybean Council. **(\$60,948)**.
18. Kumar, V. 2021-2023: Implementing integrated approaches to select for feed efficient rainbow trout families to enhance the soy protein utilization in salmonid aquaculture. Soy Aquaculture Alliance. **(\$290,543)**.



Gifts

1. Small, B. C. 2021-2023: Research Excellence in Sustainable Aquaculture Fund. (\$75,000).
2. Bledsoe, J. 2022: Advancing Sustainable Aquaculture Through Research & Extension. (\$10,000).
3. Small, B. C. 2022: UI Sustainable Aquaculture Student Fund. (\$15,000).

Peer-Reviewed Papers

1. Amirkolaie, A. K., Small, B. C. & Kumar, V. Bile acid supplementation in alternative lipid (soybean oil and fat powder) based diets: Effects on growth, histology (liver and intestine) and digestibility in Rainbow trout (*Oncorhynchus mykiss*). *Anim Feed Sci Technol* (2022).

2. Andrews, K. R. *et al.* Whole genome resequencing identifies local adaptation associated with environmental variation for redband trout. *Mol Ecol* **32**, 800-818 (2023).
3. Bledsoe, J. W., Pietrak, M. R., Burr, G. S., Peterson, B. C. & Small, B. C. Functional feeds marginally alter immune expression and microbiota of Atlantic salmon (*Salmo salar*) gut, gill, and skin mucosa though evidence of tissue-specific signatures and host-microbe coadaptation remain. *Anim Microbiome* **4**, 20 (2022).
4. Bledsoe, J. W. *et al.* Multi-tissue RNAseq reveals genetic and temporal differences in acute response to viral (IHNV) infection among three selected lines of rainbow trout with varying resistance. *Fish Shellfish Immunol* **124**, 343-361 (2022).
5. Cain, K. The many challenges of disease management in aquaculture. *J World Aquac Soc* **53**, 1080-1083 (2022).
6. Collins, E. E., Romero, N., Zendt, J. S. & Narum, S. R. Whole-Genome Resequencing to Evaluate Life History Variation in Anadromous Migration of *Oncorhynchus mykiss*. *Front Genet* **13**, (2022).
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10. Hess, J. E. *et al.* Pacific Lamprey Translocations to the Snake River Boost Abundance of All Life Stages. *Trans Am Fish Soc* **151**, 263-296 (2022).
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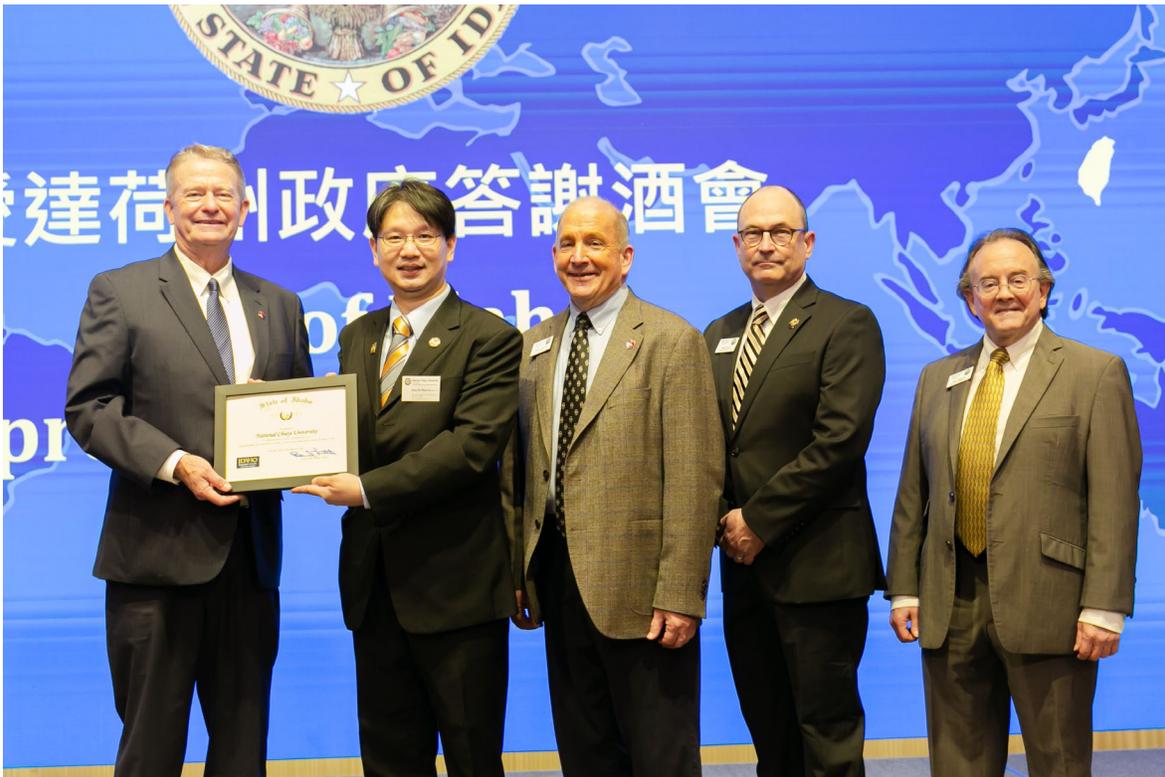
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15. Hossain, Md. S., Zhang, Y. & Small, B. C. Evaluation of a corn fermented protein with solubles (CFPS) as a complete soybean meal replacer in practical diets for Atlantic salmon (*Salmo salar*). *Aquaculture* **566**, 739198 (2023).
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2. Hardy, R. W. History of fish nutrition, Part 1: 1900 to 1958. *Aquafeed Magazine*. *Aquafeed Magazine* **14**(2) 28-32 (2022).
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5. Keefer, M. L., Yuksel, M. K. & Caudill, C. C. *Decision support modeling for outplanting adult Chinook Salmon in the Santiam River basin*. (2022).



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3. Hardy, R. W. & Kaushik, S. J. *Fish nutrition*. (Academic press, 2021).
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5. Krogdahl, Å., Kortner, T. M. & Hardy, R. W. Antinutrients and adventitious toxins. in *Fish nutrition* 775-821 (Elsevier, 2022).
6. Kumar, V. Bio Feedstocks in Aquafeed. in *Bio Products: Green Materials for an Emerging Circular and Sustainable* (ed. Vijayendran, B.) (De Gruyter, 2022).
7. Kumar, V. Introduction: Importance of analysis in seafood and seafood products, variability and basic concepts. in *Handbook of Seafood and Seafood Products Analysis* (eds. Toldra, F. & Nollet, L.) (CRC Press, Taylor & Francis Group, 2022).
8. Ragaza, J. A., Hossain, M. S. & Kumar, V. The Potential of Invasive Alien Fish Species as Novel Aquafeed Ingredients. in *Sustainable Aquafeeds* 57-76 (CRC Press, 2021).
9. Small, B. C. Nutritional Physiology. in *Fish Nutrition* 593-642 (Academic Press, 2022).
10. Kumar, V. *Feed and Feeding for Fish and Shellfish: Nutritional Physiology*. (ELSEVIER Academic Press, 2023).
11. Kumar, V. *Nutrition and Physiology of Fish and Shellfish: Feed Regulation, Metabolism, and Digestion*. (ELSEVIER Academic Press, 2023).
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Abstracts and Presentations

1. Abanikannda, M. *et al.* Interactive effects of temperature and diet on growth, mitochondrial function, and gut microbiome in rainbow trout. in *38th Meeting of Fish Feed & Nutrition Workshop, University of Idaho* (2022).

2. Abanikannda, M. *et al.* Whole insect larval meal improves the utilization of soy based diets and reduces the mortality of rainbow trout challenged with *Flavobacterium psychrophilum*. in *The 2022 US Trout Farmers Association Fall Conference* (2022).
3. Abernathy, J. W. *et al.* White bass broodstock and genome resources development in support of hybrid striped bass aquaculture. in *North Carolina Aquaculture Development Conference* (2022).
4. Andrews, K. *et al.* Whole genome resequencing identifies local adaptation for redband trout. in *Annual National Meeting of the American Fisheries Society* (2022).
5. Andrews, L., Gaylord, T. G. & Powell, M. Climate changes elevates stress and reduces food efficiency in arctic grayling (*Thymallus arcticus*). in *Idaho Conference on Undergraduate Research* (2022).
6. Biasato, I. *et al.* Efficacy of utilization of all-plant-based and commercial low-fishmeal feeds in two divergently selected strains of rainbow trout (*Oncorhynchus mykiss*): focus on growth performance, whole-body proximate composition, and intestinal microbiome. *Frontiers in Physiology, Section on Aquatic Physiology*. in *Frontiers in Physiology, Section on Aquatic Physiology* (2022).
7. Bledsoe, J. W. Molecular insights on nutritional physiology: Characterizing Adaptive Gains of Plant Based Diet Selection. in *38th Fish Feed and Nutrition Workshop* (2022).
8. Bledsoe, J. W., Powell, M. & Small, B. C. Water and Workforce: Early Priorities of a New Research and Extension Specialist. in *US Trout Farmers Association Annual Meeting* (2022).
9. Bledsoe, J. W., Powell, M. & Small, B. C. Introduction to US Extension and UI Aquaculture Research Institute. in *USDA-FAS Caucuses Agricultural Development Initiative Working Group*.
10. Bledsoe, J. W., Small, B. C. & Reichley, S. Aquaculture Research, Education, and Extension in the United States. in *Republic of Georgia Trout Farming Stakeholder Workshop. Georgian Agricultural Extension-Foreji* (2022).
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12. Bruce, T. *et al.* An Initial Evaluation Of Fishmeal Replacement With Soy Protein Sources On Growth And Immune Responses Of Burbot (*Lota lota maculosa*). in *International Symposium on Fish Nutrition and Feeding* (2022).

13. Bruce, T. *et al.* Characterization Of Stress Response And Gut Microbiota In Cultured Burbot *Lota lota* Maculosa Following Feeding With Plant-Based Diets. in *World Aquaculture Conference* (2022).
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16. Cain, K. D. Overview of feeding practices and dietary needs for production of burbot (*Lota lota*) at different life stages. in *38th Meeting of Fish Feed and Nutrition Workshop* (2022).
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18. Chen, Z. *et al.* Applying genomics in assisted migration under climate change: Framework, empirical applications and case studies. in *EPSCoR Annual meeting* (2022).
19. Chen, Z., Masingale, J., Caudill, C. C., Narum, S. R. & Small, B. Phenotypic plasticity in thermal tolerance and performance within and among redband trout populations. in *NSF-Idaho EPSCoR GEM3 Annual Meeting* (2022).
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45. Kumar, V. Nutrigenomics and Its Applications in Commercial Aquaculture. Aquaculture Success, Fisheries Sustainability, and Biodiversity Conservation: Towards Food Security in the Region Conference. in *ICAFB-2022* (2022).
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62. Powell, M. S. *et al.* Advances in understanding soybean meal induced distal enteritis in salmonids. in *Aquaculture America* (2022).
63. Rubio-Benito, M. M., Romano, N., Overturf, K. & Kumar, V. Mitigation of soybean meal-induced enteritis in rainbow trout *Oncorhynchus mykiss* using vitamin D and glutamine as dietary supplements. in *World Aquaculture Singapore* (2022).
64. Rubio-Benito, M. M., Romano, N., Overturf, K. & Kumar, V. Mitigation of soybean meal-induced enteritis in rainbow trout *Oncorhynchus mykiss* using bile salt dietary supplementation. in *World Aquaculture Conference* (2022).
65. Rubio-Benito, M. M., Romano, N., Overturf, K. & Kumar, V. Potential of additives to improve the soy utilization in salmonids diets. in *38th Meeting of Fish Feed & Nutrition Workshop, University of Idaho* (2022).
66. Rubio-Benito, M. M., Romano, N., Overturf, K. & Kumar, V. The potential role of bile salts in soybean meal-induced enteritis mitigation in rainbow trout *Oncorhynchus mykiss* fed two levels sbm diets over an 18-week feeding trial. in *Aquaculture* (2022).
67. Rubio-Benito, M. M., Romano, N., Overturf, K. & Kumar, V. The potential role of bile salts in soybean meal-induced enteritis mitigation in rainbow trout (*Oncorhynchus mykiss*) fed soybean meal diets over a long-term feeding trial. in *The 2nd International Symposium on Mucosal Health in Aquaculture 2022* (2022).
68. Schwarz, M. H. *et al.* United Sorghum Checkoff Program - SmartFeeds Programming. in *Virginia Aquaculture Conference* (Newport News, 2022).
69. Seaborn, T., Landguth, E. & Caudill, C. C. Climate change, behavioral plasticity, and local adaptation impact redband trout eco-evo dynamics. in *Annual National Meeting of the American Fisheries Society* (2022).

70. Sealey, W. M. Expanding use of Distillers products in aquaculture diets. in *Distiller's Grain Council Meeting* (2022).
71. Sealey, W. M. Understanding how modern feed formulation and manufacturing can create classical nutritional deficiencies in cultured aquatic animals. in *Western Fish Disease Workshop Nutrition Continuing Education Program Instructor* (2022).
72. Sealey, W. M. (Invited). Examination of corn fermented proteins to replace fishmeal in juvenile rainbow trout diets. in *US Korea JPA International Feeds Symposium* (2022).
73. Sealey, W. M. & Gaylord, T. G. Aquatic Nutrition Capacity and Feed Development at the Bozeman Fish Technology Center. in *Webinar for Colorado Department of Natural Resources* (2023).
74. Sealey, W. M., Tilton, S., Bockus, A. & Gaylord, T. G. Examination of corn fermented proteins to replace fishmeal in juvenile rainbow trout diets. in *Aquaculture America* (2023).
75. Singha, K. P., Yadav, A. K. & Kumar, V. Dispensable amino acid L-alanine can lower the lipid load in rainbow trout diet. in *38th Meeting of Fish Feed & Nutrition Workshop. University of Idaho* (2022).
76. Small, B. ARI and potential opportunities for industries. in *38th Meeting of Fish Feed and Nutrition Workshop* (2022).
77. Small, B. Evaluation of Mealworm Protein as a Fishmeal Replacement for Rainbow Trout. in *US Trout Farmers Association Fall Conference* (2022).
78. Small, B. C. & Bledsoe, J. W. Functional Feeds and Ingredients to Target Fish Health and Optimize Performance. in *50th Scientific Symposium of the US-Japan Natural Resources Aquaculture Panel* (NOAA-NMFS, 2022).
79. Small, B. C. & Bledsoe, J. W. Idaho Aquaculture Workforce Development. in *2022 Idaho Chapter of American Fisheries Association Fish Culture Section* (2022).
80. Vega, Y. G., Burnham, L. A., Tsai, T. Y., Longoria, J. A. C. & Powell, M. S. Does adding organic acids and essential oils in feeds promote fish health? in *Idaho INBRE Annual* (2022).
81. Vuglar, B. M., Ma, J., Heckman, T. I., Soto, E. & Cain, K. D. Virulence assessment of novel Flavobacteriaceae isolates collected from aquaculture facilities in the Western United States. in *Western Fish Disease Workshop* (2022).
82. Yadav, B. M., Sinha, A. K., Romano, H. & Kumar, V. Potential of Iron Toxicity in Fish Nutrition. in *38th Meeting of Fish Feed & Nutrition Workshop. University of Idaho* (2022).

83. Yadav, A. K., Sinha, A. K., Romano, H. & Kumar, V. The underlying physiological mechanism for mitigating the feed borne iron toxicity in rainbow trout via dietary supplementation of vitamin C and bentonite. in *Aquaculture* (2022).

Patent Applications and Invention Disclosures

1. Cain, K.D., Ma, J., and Loch, T. U.S. Patent Application No. 63/350,081 COLDWATER DISEASE VACCINE COMPRISING AN ATTENUATED FLAVOBACTERIUM PSYCHROPHILUM STRAIN, (Filed June 8, 2022).
2. Hong, J. Iasonova, D., and Small, B. U.S. Patent Application No.: PCT/US2022/079475. HIGH PLANT PUFA FISH FOOD (Filed November 8, 2022)

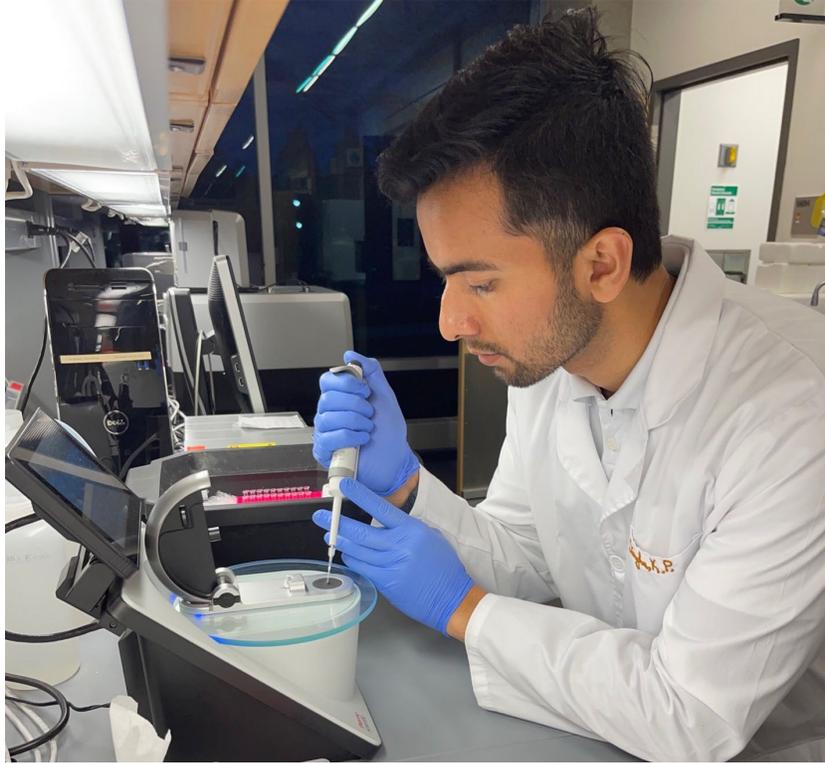
Awards

1. Hess, J. E. *et al.* Award for the Best Paper in the Transactions of the American Fisheries Society (TAFS), "Robust recolonization of Pacific lamprey following dam removals." *Transactions of the American Fisheries Society* (2021).
2. Rubio-Benito, M. "Best Abstract Award". (2022).
3. Rubio-Benito. "Soy Aquaculture Alliance Award". (2022).
4. Abanikannda, M. "Best Research Award - Feed for Future". (2022).



Invited Presentations

1. Kumar, V. "The potential role of feed additives in soybean meal-induced enteritis mitigation in rainbow trout *Oncorhynchus mykiss*". in *2022 US Trout Farmers Association Fall Conference (2022)*.
2. Kumar, V. "Overview of Shrimp farming emphasis on India and USA market: strategy to optimize the shrimp productivity via nutritional approach". in *Chinese Aquaculture Conference (2022)*.
3. Kumar, V. "Nutrigenomic approaches improve the efficiency of soybean meal utilization in salmonids aquaculture". in *XVI International Symposium on Aquaculture Nutrition (2022)*.
4. Kumar, V. "Roles of Fish Nutrition for Sustainable Aquaculture". in *University of Queensland, School of Agriculture and Food Science, Faculty of Science (2022)*.
5. Fornshell, G. Regional Aquaculture Center Programmatic Review Progress Report. in *National Aquaculture Association Board of Directors (2022)*.
6. Himes, K., Winford, E., Caudill, C. C. & Hatzenbuehler, P. Idaho Economic Climate Impacts Assessment: Key Findings and Panel Discussion. in *Renfrew Colloquium (2022)*.
7. Hoffman, N. F., Medeiros, L. R., Pierce, A. L., Nuetzel, H. M. & Nagler, J. J. Continuous light treatments reduce precocious maturation in age 1+ male spring Chinook salmon (*Oncorhynchus tshawytscha*). in *American Fisheries Society Annual General Meeting (2022)*.
8. Cain, K. D. History of burbot aquaculture in the us: moving from a conservation focus to a potential high value commercial species! in *International Congress on Fish Biology (Burbot Symposium). (2022)*.
9. Powell, M. S. Correlation of expression and enzyme activity among stress-related genes in Salmonids. in *XVI Simposium Internacional de Nutrición Acuícola (2022)*.
10. Powell, M. S. Genetic selection strategies to increase oral tolerance to alternative proteins. in *International Conference on Advanced Technologies in Aquaculture and Value-Adding Applications (2022)*.
11. Small, B. C. The gut-brain axis in fish and potential to develop targeted approaches to fish nutrition for aquaculture. in *PITIFC-VC. World Aquaculture Conference (2022)*.
12. Small, B. C. The Future of Trout Feeds, ARI and the USDA Trout Grains Program. . in *US Trout Farmers Association Fall Conference (2022)*.

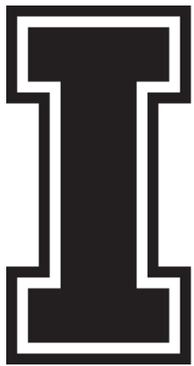


Extension and Outreach Activities

1. Bledsoe, J. & Wagner, M. Industry Tour: Jerome High School Forestry and Wildlife Class Trip. (2022).
2. Bledsoe, J. Assisted Bill Jones Jr. Trout Farm LLC in the certification process. (2022).
3. Bledsoe, J. College of Southern Idaho Aquaculture Tour. (2022).
4. Bledsoe, J. East Smart Idaho- Idaho Aquaculture. (2022).
5. Bledsoe, J. et al. Idaho Coldwater Fish Culture Workshop. (2022).
6. Bledsoe, J. Gooding County Science Fair (judge). (2022).
7. Bledsoe, J. Mackay High School's Fish Lab Public Grand Opening. (2022).
8. Bledsoe, J. Monterey Bay Aquarium Seafood Watch. (2022).
9. Bledsoe, J. US Grains Council Southeast Asia Regional Team's Idaho Aquaculture Tour. (2022).
10. Bledsoe, J., Lee, M. & Trushenski, J. USTFA Annual Fall Conference. (2022).
11. Bledsoe, J., Welker, T. & Sealey, W. US Grains Council Idaho Aquaculture Tour. (2022).

12. Caudill, C. C., Narum, S. & Griswold, K. Adaptation and Plasticity in Fishes in a Warming Environment. in Annual National Meeting of the American Fisheries Society (2022).
13. Caudill, C. GEM3 Modeling workshop co-organizer. in (2022).
14. Kumar, V. & Small, B. "The 38th Fish Feed and Nutrition Workshop". in Aquaculture Research Institute (ARI), University of Idaho.
15. Kumar, V. "Feed Ingredients/Fish Nutrition". in Aquaculture America 2023 (2023).
16. Link, T. & Caudill, C. C. Watershed panel. in the University of Idaho Challenges and Opportunities for Idaho Water Resources (2022).
17. Powell, M. Field trip for future Ag Ed classes. (2022).
18. Powell, M. Idaho Governor's Trade Mission. (2022).
19. Small, B. C. & Corazze, G. Alternative Lipid Sources session. in XX International Symposium on Fish Nutrition and Feeding: Towards Precision (2022).
20. Small, B. C. Western Regional Aquaculture Center Board Meeting. (2022).
21. Small, B. C. Western Regional Aquaculture Center IAC/TC meeting. (2022)
22. Small, B. C., Peterson, B. C. & Unniappan, S. Current Trends in Fish Growth and Metabolism Symposium. in International Congress on the Biology of Fishes (2022).
23. Small, B. Presentation on the Idaho aquaculture industry and research to Sandpoint Rotary club (2022).





University of Idaho

Aquaculture Research Institute

Advancing sustainable aquaculture and the conservation of aquatic resources