



ANNUAL REPORT 2021

Aquaculture Research Institute

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DIRECTOR'S LETTER

I am happy to report 2021 was a good year for ARI, with many successes. That is not to say there aren't any challenges, but I am optimistic we will continue to overcome our challenges with the support of our university, partners, and stakeholders.

The collaborative efforts with the College of Agriculture and Life Sciences to fill the vacant Aquaculture extension position was a success. Thanks to the contributions of CALS Dean Michael Parella and VPRED Chris Nomura we were able to advertise for a tenure-track Aquaculture Research and Extension Specialist. We had a very robust candidate pool, which was reviewed by a diverse committee representing the College of Agriculture and Life Sciences, College of Natural Resources, and ARI. In the end, we were fortunate to hire Dr. Jacob (Jake) Bledsoe. Jake has a background in aquaculture with research rooted in solving industry problems around fish performance and environmental quality, and Dr. Bledsoe is a University of Idaho alumnus!

Under President Green's leadership, the University of Idaho successfully addressed a critical budget shortfall and has set a course to achieve R-1 status, the highest Carnegie classification for research universities. ARI did its part to address the budget shortfall by shoring up deficit accounts, securing new revenue streams, and, unfortunately, giving up some positions. With University and State revenue exceeding expectations, there is optimism in the air, and I am hopeful our central role in building research capacity around aquaculture, fisheries, and water will be looked upon favorably by our partner Departments and Colleges as they look to fill faculty positions. In the short term, I am happy to report that our successes have been recognized by the Office of Research and Economic Development, which awarded ARI with 2-years of funding for two Research Scientists to expand our industry research partnerships and increase sponsored projects and graduate student recruitment.

ARI's associated faculty, staff, and students continue to advance the science around fish production and management, addressing both basic and applied research problems. Two of our faculty were recognized for their achievements, Ken Cain with the University of Idaho's Distinguished Professor Award and Gary Fornshell with the Idaho Governor's Award for Excellence. In 2021, ARI associate faculty and researchers brought in over \$6.1M in new sponsored projects and published 51 scientific journal articles. The true measure of our accomplishments, however, is through our regional and national impact. At this year's World

Aquaculture Society Conference in San Diego, I overheard two trout farmers (representing California and Pennsylvania) discussing the importance and applicability of the research coming out of “Hagerman.” There isn’t a higher compliment than that. From water quality to genomic sequencing, our people conduct competitive cutting-edge research to solve real-world problems. But they don’t stop there; all those associated with ARI work closely with our industry, agency, and tribal partners. What I mean to say is ARI is truly engaged in these partnerships, and the people I work with are some of the most passionate “fish people” I know. If you know “fish people,” that’s no small complement.

In addition to internally lobbying for new aquaculture faculty, my focus in the coming years is to ensure the financial sustainability of our program. For over two decades the Hagerman Fish Culture Experiment Station has been partially funded through a USDA-ARS cooperative agreement to support selective breeding and the development of sustainable feeds for the US Trout Industry. Over the 20+ years, this agreement has not received an increase in funding, and increases in research costs and salaries now threaten to diminish the capacity of ARI research and that of our in-house partnership with the USDA-ARS Trout Grains Program. I am working with University of Idaho administration, the Idaho congressional delegation, trout farmers and aquaculture industry groups to get our story out and request a federal infusion of new funds to continue the vital research our stakeholders and partners have come to depend on. I challenge anyone to show me another research group in the United States with the level of real-world impact on coldwater aquaculture and fish nutrition and feeds as the University of Idaho’s Aquaculture Research Institute in partnership with the USDA-ARS Trout Grains Program. ARI is recognized as one of the top aquaculture programs in the world, and I am proud of the research our faculty, students, staff, and partners conduct to deliver solutions and strategies for sustainable aquaculture, fisheries, and water use.

Go Vandals!



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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 water 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.

2021

>\$6.1M in newly funded sponsored projects

>\$7.9M in continuing sponsored projects

51 peer-reviewed journal articles

4 patent/invention disclosures

9 technical or trade articles

6 book chapters

1 book

15 Ph.D. students

5 M.S. students

7 postdoctoral fellows



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.

2021 RESEARCH HIGHLIGHTS

Feeds and Nutrition

- Maintained position as top-ranked university for fish nutrition
- Continued research to increase the sustainability of fish feeds
- Highly sought after by commercial industry to evaluate novel feeds and ingredients
- Characterized commercial strains in their response to dietary soybean meal
- Evaluated dietary modifications to reduce waste and improve water quality
- Characterized proteome of Hagerman fish vs non-selected fish reared on fish meal and plant-based diets, pre- and post-enteritis

Genetics and Genomics

- Extensive genetic monitoring programs for salmon returning to Columbia River
- Long-term pedigree studies to examine effects of hatchery programs on wild populations of Chinook salmon
- Discovery and validation of candidate genes associated with phenotypic traits such as migration timing, age at maturity, and thermal adaptation
- Development of novel techniques in octoploid white sturgeon for individual ploidy estimation and genotyping
- Genetic monitoring of Pacific lamprey translocation and recovery efforts by tribal fisheries programs

Physiology, Health, and Management

- Characterization of precocious male maturation rate in juvenile spring Chinook salmon
- Development of new monoclonal antibodies; a new attenuated Atlantic salmon Coldwater disease vaccine; and a new fish vaccination system
- First report of enhanced non-specific pathogen resistance in fish selected on plant-based feeds
- Described symmetry of tissue-specific immune expression and microbiota profiles across mucosal tissues of Atlantic salmon
- Industry scale evaluation of Biochar to remove phosphorous from aquaculture production water
- Addressed sensitivity of Idaho fishes to climate warming



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.



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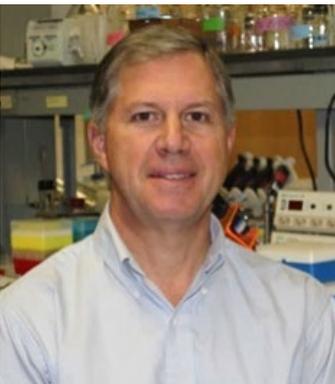
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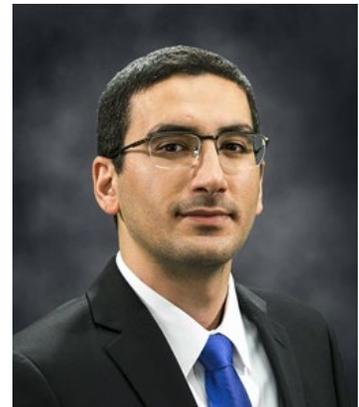


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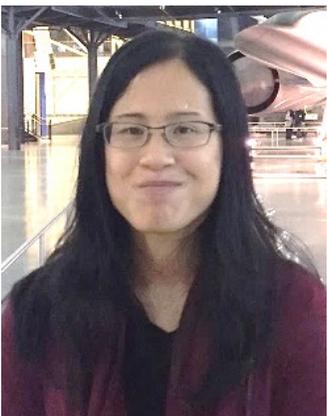
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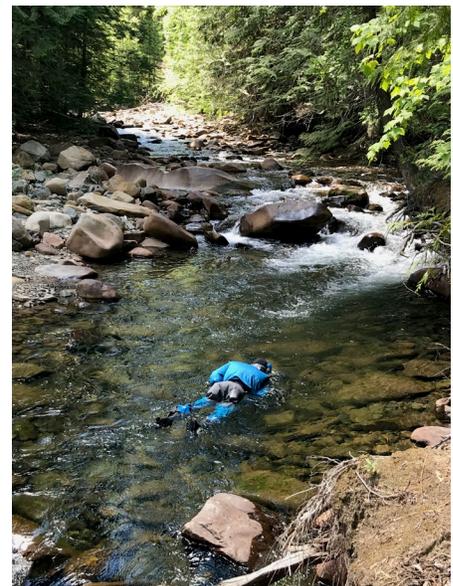
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Dr. Lea Medeiros

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Dr. Hui (“William”) Wang

Graduate Students

Mosope Abanikanda, Ph.D. in Animal Physiology

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Jonathan Massingale, Ph.D. in Natural Resources

Moureen Matuha, Ph.D. in Natural Resources

Niloufar Nourmohammadi, Ph.D. in Animal Physiology

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Amit Kumar Yadiv, Ph.D. in Animal Physiology

Tsung-Yu (Daniel) Tsai, M.S. in Animal Physiology



Undergraduate Interns

Victor Azevedo, Aquaculture intern, University of Idaho

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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



BY THE NUMBERS

Formal Research Collaboration

1. PI: B.C. Small; USDA Agriculture Research Service, Aberdeen, ID (Cooperative Agreement); Est. 1999
2. PI: K. Overturf, coPIs: T. Welker, K. Liu, W. Sealey. USDA Agricultural Research Service, Hagerman, ID. (In-House Appropriated project); Est. 1999
3. PI: B.C. Small; Columbia River Inter-Tribal Fish Commission (Memorandum of Understanding); Est. 2000
4. PI: K. Overturf, coPI: W. Sealey. US Fish and Wildlife Service Bozeman Fish Technology Center (Cooperative Agreement); Est. 2005.
5. PI: B.C. Small; USDA Agricultural Research Service, Franklin, ME (Cooperative Agreement); Est. 2017

New Sponsored Projects

1. 2021-2023; PI: C.R. Engle, coPIs: J. van Senten, G. Fornshell. 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. 2021; PI: S. Narum. *Bonneville Power Administration (BPA)*. Genetic Assessment of Columbia River Stocks.(\$1,600,000).
3. 2021; PI: S. Narum. *Bonneville Power Administration (BPA)*. Genetic Monitoring of Snake River Stocks. (\$640,000).
4. 2021-2022; PI: K.D. Cain. *Private Animal Health Company*. Determining host safety, antimicrobial activity, antiviral activity, and duration of activity of Armatrex against select fish pathogens and bio-fouling. (\$51,854)
5. 2021; PI: K.D. Cain. *Private Feed Company*. Cain, K. Utilization of copepods as alternatives to rotifers and/or Artemia for weaning of larval burbot (*Lota lota maculosa*). (\$12,480).
6. 2021-2022; PI: K.D. Cain. *Private Animal Health Company*. Coldwater vaccine optimization for licensing and commercialization. (\$433,572).

7. 2021-2202; PI: W.M. Sealey, coPI: T.G. Gibson; *Department of Energy/Helios-NRG Engineering-Scale Validation of Novel Algae CO2 Capture and Bioproducts Technology*. (\$73,634).
8. 2021-2202; PI: W.M. Sealey, coPI: T.G. Gibson; *Private Feed Ingredient Company*. Examination of GDDY products ability to replace fishmeal in rainbow trout diets. (\$73,634).
9. 2021-2202; PI: W.M. Sealey, coPI: Michael Schwarz; *Sorghum Checkoff Board*. Sorghum Digestibility. (\$17,835).
10. 2021-2025; PI W.M. Sealey, coPIs: M.S. Powell, J.A. Gross. *Western Regional Aquaculture Center*. Mixing up an optimal diet for white sturgeon grow-out. (\$423,921).
11. 2021-2022; PI: V. Kumar. *Private Feed Ingredient Company*. Evaluation of Black soldier fly larvae meal (full fat and defatted) in plant protein-based diets for improving the growth and health of rainbow trout (*Oncorhynchus mykiss*). (\$65,864).
12. 2021-2022; PI: V. Kumar. *Ohio Soybean Council*. Bile acid as a functional feed additive to enhance the growth, and mitigates intestinal inflammation induced by high level of soybean meal in Rainbow trout. (\$60,984)
13. 2021 – 2024; PI: V. Kumar. *Soy Aquaculture Alliance*. Indirect criteria to select the farmed fish lines to enhance the efficiency of soybean meal utilization in their diet. (\$290,543).
14. 2021-2022; PI: V. Kumar. *Private Feed Company*. Dietary evaluation of different levels of protein and lipid on the performance of Nile tilapia. (\$35,776).
15. 2021-2022; PI: V. Kumar. *Private Feed Company*. Appraisal of novel GSL encapsulated micro-gel diets and/or enhanced particle diets on growth performance, nutrient retention, gut histology and health of white-leg shrimp, *Litopenaeus vannamei*. (\$90,000).
16. 2021-2022; PI: J. Nagler. *Columbia River Inter-Tribal Fish Commission*. The physiology of kelt reconditioning XIII: developing strategies to increase iteroparity in Snake River steelhead. (\$224,261).
17. 2021-2022; PI: J. Nagler. *Columbia River Inter-Tribal Fish Commission*. Effect of parent age on rate of minijack production among male progeny of spring Chinook Salmon VII (\$213,789).
18. 2021; PI: H.H. Hernandez, coPI: M. Powell. Estudio sobre el uso de proteínas, lípidos y carbohidratos en la dieta del langostino *Macrobrachium acanthurus*, PAPIIT

- (Programa de Apoyo a Proyectos de Investigación e Innovación Tecnológica) Mexico (\$10,000).
19. 2021; PI: A. Villasante, coPI: M. Powell. *Science, Technology Knowledge and Innovation Ministry of Chile*. Evaluating the effect of supplementing bile acids to the diet in flesh pigmentation in rainbow trout (*Oncorhynchus mykiss*) fed on a high plant protein diet: a potential role of bile acid gut microbiota crosstalk? (\$40,000).
 20. 2021-2022; P.I. B.C. Small. *Private Animal Health Company*. Determination of oxygen bioavailability using new technology for oxygen delivery in aquaculture systems. (\$38,043).
 21. 2021-2022; P.I. B.C. Small. *Private Feed Ingredient Company*. Safety Assessment of Canola meal from Event NS-B5ØØ27-4 in Rainbow Trout (*Oncorhynchus mykiss*). (\$57,523)
 22. 2021-2022; P.I. B.C. Small. *Private Feed Ingredient Company*. Evaluation of meal worm protein digestibility and efficacy as a fish meal replacement for rainbow trout. (\$63,748).
 23. 2021-2022; P.I. B.C. Small. *USDA Agricultural Research Service*. Research Towards Precision Salmonid Feeds. (\$18,000).
 24. 2021-2022; P.I. B.C. Small. *Illinois Corn Marketing Board, National Corn Ethanol Research Center subaward*. Utilization of Corn Ethanol byproduct in Atlantic Salmon feeds. (\$57,174).
 25. 2021; P.I. B.C. Small. *Columbia River Inter-Tribal Fish Commission*. UI Hagerman Fish Culture Experiment Station Laboratory Supplies. (\$1,013,161).
 26. 2021-2022; P.I. B.C. Small. *USDA Agricultural Research Service*. Technician Support. (\$59,998).

Continuing and/or Terminating Sponsored Projects

1. 2019-2023; PI: C.C. Caudill, coPI: J.R. Bellmore, M. Dunkle. *Joint Venture Agreement with USFS, Pacific Northwest Research Station*. Investigating the influence of watershed variability on meta-food web dynamics and salmonid growth in southeast Alaskan streams. (\$277,741).
2. 2017-2021; coPI: K.D. Cain. *USDA-NIFA*. Understanding the duration and mechanisms of long-lasting protection of nasal vaccines in rainbow trout. (\$500,000).

3. 2017-2021; PI: K.D. Cain, coPI: G. Fornshell. *Western Regional Aquaculture Center*. Developing “freshwater cod” or burbot (*Lota lota*) into a viable commercial aquaculture species in the United States. (\$444,783).
4. 2018-2021; P.I. V. Kumar; Private feed company. Dietary requirements and metabolic roles of organic and inorganic mineral (Zinc) in a commercial strain of RBT and effects on fillet quality. (299,790); P.I. V. Kumar, co-PI's R. Hardy, B. Small
5. 2018-2021; PI: V. Kumar. *Soy Aquaculture Alliance*. Indirect criteria to select the farmed fish lines to enhance the efficiency of soybean meal utilization in their diet. (\$169,159).
6. 2018-2023; coPI: Chris Caudill, coLead: B.C. Small; NSF-EPSCoR. RII Track-1: Linking Genome to Phenome to Predict Adaptive Responses of Organisms to Changing Landscapes. (\$24,000,000 total; >\$1M to Caudill and Small).
7. 2019-2020; PI: V. Kumar. *Private feed company*. Metabolomics investigation of dietary effects on growth performance and survival in white-leg shrimp, *Litopenaeus vannamei*. (\$23,046).
8. 2019-2021; PI: A. Bockus, coPI: W.M. Sealey, T.G. Gibson. Louisiana Board of Regents. Feed Formulation for Marine Fish. (\$16,000).
9. 2019-2021; PI: T. Welker, coPI: M.S Powell. *USDA-NIFA Aquaculture Program*. Waste Management and Water Quality Improvement on Commercial Trout Farms through Nutritional Strategies. (\$299,369 total).
10. 2019-2021; PI: T. Welker, coPI: W.M. Sealey, M.S. Powell, T.G. Gaylord. K. Overturf. USDA Antimicrobial Resistance (AMR) or Alternatives to Antibiotics (ATA). The use of organic acids and essential oils in rainbow trout and hybrid striped bass feeds to alleviate the use of antibiotics. (\$67,000).
11. 2019-2022; PI: C.C. Caudill. *USFS, Pacific Northwest Research Station*. Investigating the influence of watershed variability on meta-food web dynamics and salmonid growth in southeast Alaskan streams. (\$262,746).
12. 2019-2023; PI: K.D. Cain; Cain, coPI: T. Bruce, J. Ma. Western Regional Aquaculture Center. Development of oral vaccine delivery methods for prevention of disease in finfish culture, (\$479,000).
13. 2019-2024; P.I. B.C. Small; USDA Agricultural Research Service. Improving the Competitiveness of Rainbow Trout Production by the Integrated Development of Improved Feedstuffs, Feeds, and Trout. (\$1,446,600).
14. 2020; PI: K.D. Cain; *Private feed company*. Evaluation of commercial and experimental

- starter (and grow out) diets for Atlantic Salmon. (\$25,880).
15. 2020-2021; PI: B.C. Small; *Illinois Corn Marketing Board*, National Corn Ethanol Research Center subaward. Utilization of Corn Ethanol byproduct in Atlantic Salmon feeds. (\$57,174).
 16. 2020-2021; PI: B.C. Small; *Private feed company*. Evaluation of ME-PRO digestibility and efficacy as a fish meal replacement in relation to other alternative protein feedstuffs for rainbow trout. (\$55,311).
 17. 2020-2021; PI: B.C. Small; *Private feed company*. Feed benchmarking during grow-out. (\$35,567).
 - 2020-2021; PI: B.C. Small; *USDA Agricultural Research Service*. Effect of trout strain on digestibility of alfalfa meal. (\$29,797).
 18. 2020-2021; PI: B.C. Small; *USDA Agricultural Research Service*. Research Towards Precision Salmonid Feeds. (\$18,000).
 19. 2020-2021; PI: J. Nagler; *Columbia River Inter-Tribal Fish Commission*. The physiology of kelt reconditioning X: developing strategies to increase iteroparity in Snake River steelhead. (\$254,000).
 20. 2020-2021; PI: J. Nagler; *Columbia River Inter-Tribal Fish Commission*. Effect of parent age in rate of minijack production among male progeny of spring Chinook IV. (\$218,547).
 21. 2020-2021; PI: K.D. Cain; *Private animal health company*. Coldwater vaccine optimization for licensing and commercialization. (\$222,250).
 22. 2020-2021; PI: K.D. Cain; *Private feed company*. Evaluation of survival and immune response to IHNv challenge in juvenile rainbow trout fed commercial health-promoting diets. (\$29,970).
 23. 2020-2021; PI: M.S. Powell, coPI: K. Overturf, W. Sealey. *Hatch*. Improving Utilization of Alternate Protein and Oil Sources in Rainbow Trout. (\$2,125).
 24. 2020-2021; PI: T. Bruce. *USDA NIFA Educational and Workforce Development* (Postdoctoral Fellowship; Project 2018-08177). Investigation of gut microbiota, physiological stress response and immune parameters in cultured burbot. (\$159,829).
 25. 2020-2021; PI: T.G. Gaylord, co-PIs: W.M. Sealey, Abigail Bockus. *USFWS Asian Carp Settlement*. Novel uses for Asian Carp. (\$23,000).
 26. 2020-2021; PI: V. Kumar. *Hawaii Feed & Fertilizer LLC*. (*National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce*). Assessing the feasibility of a local Hawaiian fishmeal for white-leg shrimp, *Litopenaeus vannamei* diet. (\$56,482).

27. 2020-2021; PI: V. Kumar. *Ohio Soybean council*. Functional feed additive to mitigate the gastrointestinal inflammation in commercial rainbow trout caused by high levels of dietary soybean meal. (\$30,000).
28. 2020-2021; PI: V. Kumar. *Private feed company*. Improving the plant ingredients utilization in Nile tilapia via dietary supplementation of xylanase. (\$35,000).
29. 2020-2021; PI: V. Kumar. *Private feed company*. Practical applications of commercial Jefe feed additives (AG175 and AQUANAT *Synergy*) to improve the gut health of rainbow trout. (\$75,614).
30. 2020-2021; PI: W.M. Sealey, coPI: T.G. Gibson. *Private Feed Ingredient Company*. Assessment of the protein digestibility and amino acid availability of 3 different Poultry Meal based ingredients for rainbow trout. (\$32,816).
31. 2020-2023; coPI: V. Kumar. *USDA NIFA Foundational Program*. Whole-genome analyses/selection to increase muscle yield and reduce fillet. (\$498,984).
32. 2020-2023; PI: K.D Cain; *Western Regional Aquaculture Center (WRAC)*. Emerging and re-emerging Flavobacterial pathogens in Aquaculture. (\$326,125)
33. 2020-2024; PI: W.M Sealey, coPI: M.S. Powell. *Western Regional Aquaculture Center*. Mixing up an optimal diet for white sturgeon grow out. (\$423,921).
Examination of Navita Performance Compared with Commodity Soybean Meal and Commercial Protein Sources in Rainbow Trout Diets. (\$59,740).



Peer-Reviewed Papers Published

1. Alshwairikh, Y. A., Kroeze, S. L., Olsson, J., Stephens-Cardenas, S. A., Swain, W. L., Waits, L. P., Horn, R. L., Narum, S. R., & Seaborn, T. 2021. Influence of environmental conditions at spawning sites and migration routes on adaptive variation and population connectivity in Chinook salmon. *Ecology and Evolution*, 11, 16890-16908.
<https://doi.org/10.1002/ece3.8324>
2. Amirkolaie, A.K., Small, B.C., and Kumar, V. 2021. 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*). *Animal Feed Science and Technology*. (In press).
3. Ashton, N.K., Ross, T.J., Hardy, R.S., Stephenson, S.M., Evans, V., Jensen, N.R., Young, S.P., and Cain, K.D. 2021. Effects of Temperature Fluctuation on Burbot Embryos: Implications Hydropower and Climate Change. *Transactions of The American Fisheries Society* (online early) <https://doi.org/10.1002/tafs.103>
4. Bockus, A.B., Rawles, S.D., Sealey, W.M., Conley, Z.B., and Gaylord, T.G. (2021) Effect of dietary additives Thermal Care, Bio-Mos, and GroBiotic A on rainbow trout (*Oncorhynchus mykiss*) performance at elevated temperature. *Aquaculture* 15: <https://doi.org/10.1016/j.aquaculture.2021.737084>.
5. Bowerman, T., M.L. Keefer, and C.C. Caudill. 2021. Elevated stream temperature and individual traits influence Chinook salmon prespawm mortality across the Columbia River Basin. *Fisheries Research*. 237: 105874.
<https://doi.org/10.1016/j.fishres.2021.105874>
6. Brezas, A., Kumar, V., Overturf, K., Hardy, R. 2021. Dietary amino acid supplementation affects temporal expression of amino acid transporters and metabolic genes in selected and commercial strains of rainbow trout (*Oncorhynchus mykiss*). *Comparative Biochemistry and Physiology Part B Biochemistry and Molecular Biology*. 255(7), 110589
7. Bruce, T.J., J. Ma, Sudheesh, P.S. and K.D. Cain. 2021. Quantification and comparison of iron regulation and metabolism in a virulent and attenuated strain of *Flavobacterium psychrophilum*. *Journal of Fish Diseases* DOI: 10.1111/jfd.13354
8. Bruce, T.J., L.P. Oliver, J. Ma, B.C. Small, R.W. Hardy, M.L. Brown, S.R. Craig, K.D. Cain. 2021. Evaluation of fishmeal replacement with soy protein sources on growth

- and immune responses of burbot (*Lota lota maculosa*). *Aquaculture* 545. DOI: 10.1016/j.aquaculture.2021.737157.
9. Bruce, T.J., Ma, J., Jones, E.M., Vuglar, B.M., Oliver, L.P. Loch, T.P., Knupp, C. and Cain, K.D. 2021. Assessment of *Flavobacterium psychrophilum* strain virulence in Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*). *Journal of fish Diseases* DOI: 10.1111/jfd.13349
 10. Chen, Z., Grossfurthner, L., Loxterman, J. L., Masingale, J., Richardson, B. A., Seaborn, T., Smith, B., Waits, L. P., & S. R. Narum. 2021. Applying genomics in assisted migration under climate change: Framework, empirical applications, and case studies. *Evolutionary Applications*, 15:3-21. <https://doi.org/10.1111/eva.13335>
 11. Chupal, N., Singha, K.P., Sardar, P., Sahu, N.P., Shmana, S., Kumar, V. 2021. Probiotics and Antimicrobial Proteins Scope of Archaea in Fish Feed: a New Chapter in Aquafeed Probiotics? *Probiotics and Antimicrobial Proteins*. 13, 1668-1695
 12. Delomas, T.A., Willis, S.C., Parker, B.L., Miller, D., Anders, P., Schreier, A., and S.R. Narum. 2021. Genotyping SNPs and inferring ploidy by amplicon sequencing for polyploid, ploidy-variable organisms. *Molecular Ecology Resources* 21:2288-2298. <https://doi.org/10.1111/1755-0998.13431>
 13. Dunkle, M., R. Dunbeck, and C. C. Caudill. 2021. Fish carcasses alter subyearling Chinook salmon dispersal behavior and density but not growth in experimental mesocosms. *Ecosphere* 12(12):e03856. <https://doi.org/10.1002/ecs2.3856>
 14. Eaton, K.R., K.A. Tardy, S.R. Narum, J.H. Powell, C.A. Steele. 2021. Discovery of out-of-basin introgression in Pettit Lake Sockeye salmon: management implications for native genetics. *Conservation Genetics* 22:615-627. <https://doi.org/10.1007/s10592-021-01386-7>
 15. Fawole, J.F., Labh, S.N., Hossain, M.S., Overturf, K., Small, B.C., Walker, T., Hardy, R.W., Kumar, V. 2021. Insect (Black soldier fly larvae) oil as a potential substitute for fish or soy oil in the fish meal-based diet of juvenile Rainbow trout (*Oncorhynchus mykiss*). *Animal Nutrition*. 7(4), 1360-1370.
 16. Fischer, H., Romano, N., Renukadas, N., Kumar, V., Sinha, A.K. 2021. Comparing black soldier fly (*Hermetia illucens*) larvae versus prepupae in the diets of largemouth bass, *Micropterus salmoides*: Effects on their growth, biochemical composition, histopathology, and gene expression. *Aquaculture*. 546, 737323.
 17. Fuchs, N.T., C.C. Caudill, A.R. Murdoch, and B.L. Truscott. 2021. Overwintering distribution and post-spawn survival of Steelhead in the upper Columbia River Basin.

- North American Journal of Fisheries Management 41:757-774.
<https://doi.org/10.1002/nafm.10585>
18. Granados, Y.V., S.A.F. Gómez, L.H.H. Hernández, M.S. Powell and F. Vega-Villasante. 2021. Effects of manooligosaccharides and fructooligosaccharides on the growth and non-specific immune responses of juvenile freshwater prawn *Macrobrachium acanthurus*. Latin American Journal of Aquatic Research 49(2):299-306
 19. Hargrove, J., C.A. Camacho, W.C. Schrader, J.H. Powell, T.A. Delomas, J.E. Hess, S.R. Narum, M.R. Campbell. 2021. Parentage-based tagging improves escapement estimates for ESA-listed adult Chinook Salmon and Steelhead in the Snake River basin. Canadian Journal of Fisheries and Aquatic Sciences, 78:349-360. DOI: 10.1139/cjfas-2020-0152.
 20. Hess, J.E., R.L. Paradis, M.L. Moser, L.A. Weitkamp, T.A. Delomas, S.R. Narum. 2021. Robust recolonization of Pacific lamprey following dam removals. Transactions of the American Fisheries Society, 150:56-74. DOI: 10.1002/TAFS.10273.
 21. Hossain, M.S., F. Fawole, S. Labh, K. Overturf, B.C. Small, V. Kumar. 2021. Insect meal inclusion as a novel feed ingredient in soy-based diets improves performance of rainbow trout (*Oncorhynchus mykiss*). Aquaculture 544. DOI: 10.1016/j.aquaculture.2021.737096.
 22. Hossain, M.S., M. Peng, B.C. Small. 2021. Optimizing the fatty acid profile of novel terrestrial oil blends in low fishmeal diets of rainbow trout yields comparable fish growth, total fillet n-3 LC-PUFA content, and health performance relative to fish oil. Aquaculture 545. DOI: 10.1016/j.aquaculture.2021.737230.
 23. Hossain, M.S., S. Lee, B.C. Small, R.W. Hardy. 2021. Histidine requirement of rainbow trout (*Oncorhynchus mykiss*) fed low fishmeal-based diet for maximum growth and protein retention. Aquaculture Research. DOI: 10.1111/are.15224
 24. Keefer, M.L., M.A. Jepson, T.S. Clabough, and C.C. Caudill. Technical fishway passage structures provide high passage efficiency and effective passage for adult Pacific salmonids at eight large dams. PLOS ONE 16(9): e0256805
<https://doi.org/10.1371/journal.pone.0256805>
 25. Koch, I.J., and S.R. Narum. 2021. An evaluation of the potential factors affecting lifetime reproductive success in salmonids. Evolutionary Applications 14:1929-1957.
<https://doi.org/10.1111/eva.13263>

26. Kotzamanis, Y., Fawole, J.F., Brezas, A., Kumar, V., Fontanillas, R., Antonopoulou, E., Kouroupakis, E., Ilia, V. 2021. Dietary lysine requirement of greater amberjack juvenile (*Seriola dumerili*, Risso, 1810). *Aquaculture Nutrition*. 27(2), 2107-2118.
27. Kumar, V., Fawole, N. Romano, M.S. Hossain, S. Labh, K. Overturf, B. Small. 2021. Insect (black soldier fly, *Hermetia illucens*) meal supplementation prevents the soybean meal-induced intestinal enteritis in rainbow trout and health benefits of using insect oil. *Fish and Shellfish Immunology*, 109:116-124. DOI: 10.1016/j.fsi.2020.12.008
28. Liu, K., Frost, J., Welker, T.L., and Barrows, F.T. 2021. Comparison of new and conventional processing methods for their effects on physical properties of fish feed. *Animal Feed Science and Technology*.
<https://doi.org/10.1016/j.anifeedsci.2021.114818>.
29. Ma, J., Casadei, E., Bruce, T.J., Sepahi, A., Cain, K.D., and Salinas, I. 2021. Long-term efficacy of nasal vaccination against enteric red mouth (ERM) disease and infectious hematopoietic necrosis (IHN) in juvenile rainbow trout (*Oncorhynchus mykiss*) Vaccine (In Press) <https://doi.org/10.1016/j.vaccine.2021.11.077>
30. Marden, E, Abbott, RJ, Austerlitz, F, et al S.R. Narum, and L. Rieseberg. 2021. Sharing and reporting benefits from biodiversity research. *Molecular Ecology* 30:1103-1107. doi.org/10.1111/mec.15702.
31. McCann, K.M., Rawles, S.D., Lochmann, R.T., McEntire, M.E. Sealey, W.M., Gaylord, T.G., Webster, C.D. 2021. Dietary replacement of fishmeal with commercial protein blends designed for aquafeeds in hybrid striped bass (*Morone chrysops* ♂ x *Morone saxatilis* ♀): Digestibility, growth, body composition, and nutrient retention. *Aquaculture Reports* 20:
32. Meiler, K., Kumar, V. 2021. Organic and inorganic zinc in the diet of a commercial strain of diploid and triploid rainbow trout (*Oncorhynchus mykiss*): Effects on performance and mineral retention. *Aquaculture*. 545, 737126
33. Naylor, R.L., Hardy, R.W., Bureau, D.P., Chiu, A., Elliott, M., Farrell, A.P., Forster, I., Gatlin, D.M., Goldberg, R.J., Hua, K., Nichols, P.D., 2009. Feeding aquaculture in an era of finite resources. *Proceedings of the National Academy of Sciences*, 106(36), pp.15103-15110.
34. Oliver, L.P., Evavold, J.T. Cain, K.D. 2021. Out-of-season spawning of burbot (*Lota lota*) through temperature and photoperiod manipulation. *Aquaculture* 543 2021. 736917 DOI: 10.1016/j.aquaculture.2021.736917

35. Palma, M., Bledsoe, J.W., Tavares, L.C., Romano, N, Small, B.C., Viegas, I., Overturf, K. 2021. Digesta and Plasma Metabolomics of Rainbow Trout Strains with Varied Tolerance of Plant-Based Diets Highlights Potential for Non-Lethal Assessments of Enteritis Development. *Metabolites*, 11:590. <https://doi.org/10.3390/metabo11090590>
36. Paul, J. and B.C. Small. 2021. Chronic exposure to environmental cadmium affects growth and survival, cellular stress, and glucose metabolism in juvenile channel catfish (*Ictalurus punctatus*).
37. Phulia, V., Sardar, P., Jamwal, A., Kumar, V., Shamna, N., Fawole, F., Sanap, B., Gupta, S. 2021. Identification of best detoxification strategies for sustainable valorization of waste from Jatropha-based biodiesel industry: Compounding the benefits of plant-based vehicular fuel. *Environmental Technology & Innovation*. 24, 101911
38. Pierce AL, Medeiros LR, Hoffman B, Koch IJ, Narum SR, Galbreath PF, Nagler JJ 2021. Dietary tetradecylthioacetic acid supplementation during the fall prevents an increase in body lipid levels but does not influence precocious male maturation rate in juvenile spring Chinook salmon. *Aquaculture Res*. 52: 5483-5492.
39. Ragaza, A.R., Hossain, M.S., Koshio, S., Ishikawa, K., Yokoyama, S., Kotzamanis, Y., Brezas, A., Kumar, V. 2021. Brown seaweed (*Sargassum fulvellum*) inclusion in diets with fishmeal partially replaced with soy protein concentrate for Japanese flounder (*Paralichthys olivaceus*) juveniles. *Aquaculture Nutrition*. 27, 1052-1064.
40. Rodríguez-Ezpeleta, N., Zinger, L., Kinziger, A., Bik, H.M., Bonin, A., Coissac, E., Emerson, B.C., Lopes, C.M., Pelletier, T.A., Taberlet, P., and S.R. Narum. 2021. Biodiversity monitoring using environmental DNA. *Molecular Ecology Resources* 21:1405-1409. <https://doi.org/10.1111/1755-0998.13399>
41. Romano, N., Fischer, H., Kumar, V., Francis, S.A., Sinha, A.K. (2021). Productivity, conversion ability, and biochemical composition of black soldier fly (*Hermetia illucens*) larvae fed with sweet potato, spent coffee or dough. *International Journal of Tropical Insect Science*. DOI: 10.1007/s42690-021-00532-5
42. Rubio-Benito, M.M., Bruce, T.J., Ma, J., Jones, E.M., Cain, K.D., Kumar, V. 2021. Insect protein as an additive in fish feeds: effects on growth and immune parameters in rainbow trout (*Oncorhynchus mykiss*) challenged with *Flavobacterium psychrophilum*. *Aquaculture*.

43. Seaborn, T., D. Griffith, A. Kliskey, and C.C. Caudill. 2021. Building a Bridge Between Definitions and Concepts of Adaptive Capacity and Adaptive Potential. *Global Change Biology* 27:2656-2668 <https://doi.org/10.1111/gcb.15579>
44. Sealey, W.M., Conley, Z.B., Hinman, B.T., O'Neill, T.J., Bowzer, J., Block, S.S. 2021. Evaluation of the ability of *Pichia guilliermondii* to improve growth performance and disease resistance in rainbow trout (*Oncorhynchus mykiss*). *Journal of the World Aquaculture Society* <https://doi.org/10.1111/jwas.12872>
45. Syms, J.C., M.A. Kirk, C.C. Caudill, and D. Tonina. 2021. A biologically based measure of turbulence intensity for predicting Pacific lamprey passage behaviors. *Journal of Ecohydraulics*. DOI: 10.1080/24705357.2020.1856007
46. Wang, H., T. Seaborn, Z. Wang, C.C. Caudill, and T.E. Link. 2021. Modeling tree canopy height using machine learning over mixed vegetation landscapes. *International Journal of Applied Earth Observations and Geoinformation* 101. 102353. <https://doi.org/10.1016/j.jag.2021.102353>
47. Waters, C.D., A. Clemento, T. Aykanat, J.C. Garza, K.A. Naish, S.R. Narum, and C.R. Primmer. 2021. Heterogeneous genetic basis of age at maturity in salmonid fishes. *Molecular Ecology* 30:1435-1456. doi.org/10.1111/mec.15822
48. Welker, T.L., Liu, K., Overturf, K., Abernathy, J., and Barrows, F.T. 2021. Effect of soy protein products and gum inclusion in feed on fecal particle size profile of rainbow trout. 1(1): 14-25. <https://doi.org/10.3390/aquacj1010003>.
49. Whibley, A., J.L. Kelley, and S.R. Narum. 2021. The changing face of genome assemblies: guidance on achieving high-quality reference genomes. *Molecular Ecology Resources* 21:641-652. [doi: 10.1111/1755-1998.13312](https://doi.org/10.1111/1755-1998.13312).
50. Willis, S.C., J.E. Hess, J.K. Fryer, J.M. Whiteaker, and S.R. Narum. 2021. Genomic region associated with run timing has similar haplotypes and phenotypic effects across three lineages of Chinook salmon. *Evolutionary Applications* 14:2273-2285. <https://doi.org/10.1111/eva.13290>
51. Zhu, S., Portman, M., Cleveland, B., Magnuson, A.D., Wu, K., Sealey, W.M. and Lei, X. G. 2021. Replacing fish oil and astaxanthin by microalgal sources produced different physiological and biochemical responses in juvenile rainbow trout fed two types of practical diets. *Journal of Animal Science* 99:1-14.

Peer Reviewed Papers Submitted

1. Amirkolaei, A.K., V. Kumar, B. Adhami, N. Romano, B.C. Small. In review. Emulsifiers in Fish Nutrition and their Function in Dietary Change. *Reviews in Fisheries Science and Aquaculture*.
2. Bledsoe, J.W., B.C. Peterson, M. Pietrak, G. Burr, B.C. Small. Symmetry of tissue-specific immune expression and microbiota profiles across mucosal tissues of Atlantic salmon (*Salmo salar*) highlight host-microbe coadaptations that are marginally perturbed by functional feeds. *BMC Animal Microbiome*.
3. Bledsoe, J.W., Ma, J., Cain, K., Bruce, T.J., Rawles, A., Abernathy, J., Welker, T., and Overturf, K. 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 and Shellfish Immunology*.
4. Jeongwhui H., J.W. Bledsoe, K.E. Overturf, S. Lee, D. Iassonova, B.C. Small. I Latitude oil as a sustainable alternative to dietary fish oil in rainbow trout (*Oncorhynchus mykiss*): Effects on fillet fatty acid profiles, intestinal histology, and plasma biochemistry. *Frontiers in Sustainable Food Systems*, section Water-Smart Food Production.
5. Kajbaf, K., Overturf, K., Cleveland, B., Kumar, V. Regulation of the ω -3 fatty acid biosynthetic pathway and fatty acids bioconversion capacity in selected rainbow trout (*Oncorhynchus mykiss*) using alternative dietary oils. *Animal Feed Science and Technology*.
6. Powell, M.S., W.M. Sealey, L.H.H. Hernandez and C.M. Myrick. Lysine requirement for Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*). *Aquaculture Reports*.
7. Romano, N., Fischer, Sinha, A.K., Kumar, V. Different dietary combinations of high/low starch and fat with or without bile acid supplementation on growth, liver histopathology, gene expression and fatty acid composition of largemouth bass, *Micropterus salmoides*. *Comparative Biochemistry and Physiology Part B Biochemistry and Molecular Biology*.
8. Seaborn, T., D., E. Landguth, and C.C. Caudill. Simulating plasticity as a framework for understanding habitat selection and its role in adaptive capacity and extinction risk through an expansion of CDMetaPOP. *Molecular Ecology Resources*.
9. Struhs, E., W.R. Bare, and A. Mirkouei. "Engineered Biochar for Removing Phosphorus in Downstream Water of Aquaculture Facilities: A Case Study in

Hagerman Valley, Idaho,” *Proceedings of the ASME IDETC/CIE: 27th Design for Manufacturing and the Life Cycle Conference*.

Trade Articles and Technical Bulletins

1. Cain, K.D., 2021. Ken’s Corner, Aquaculture Opportunities and Education. *Aquaculture North America*. May/June Vol 23
2. Cain, K.D., 2021. Ken’s Corner, Sorting through the noise in the farmed-versus-wild debate. *Aquaculture North America*. July/August Vol 24
3. Cain, K.D., 2021. Ken’s Corner, Vaccines may be the biggest tool in the fish health toolbox. *Aquaculture North America*. March/April Vol 22 (2)
4. Caudill, C.C., J. Masingale, T. Seaborn, D. Hora, and D. Isaak. 2021. Sensitivity of Idaho fishes to climate warming. in *Idaho Climate-Economy Impacts Assessment*. <https://www.uidaho.edu/-/media/Uidaho-Responsive/Files/president/direct-reports/mcclure-center/iceia/iceia-fish-report-2021.pdf>
5. Engle, C.R., J. van Senten, and G. Fornshell. 2021. Enterprise Budgets for Trout Production in Idaho. Virginia Cooperative Extension, Virginia Tech, Virginia State University. AAEC-276NP.
6. Hatzenbuehler, P., C. Wardropper, A. Adjesiwor, E. O. Ansah, M. Burnham, M. de Haro-Martí, K. Dentzman, J. R. Findlay, J. B. Glaze, Jr., J. Hinds, V. Jansen, J. Karl, R. Lamichhane, R. Lew, N. Olsen, M. Powell, K. Running, J. Sagers, L. Schott, O. Walsh and B. Wilson. 2021. Impacts of Climate Change in Idaho, *Idaho Climate-Economy Impacts Assessment*, McClure Center for Public Policy Research, 42pp

Books and Book Chapters

1. Bai, S.C., Hardy, R.W. and Hamidoghli, A., 2022. Diet analysis and evaluation. In *Fish Nutrition* (pp. 709-743). Academic Press, London.
2. Davis, D.A. and Hardy, R.W., 2022. Feeding and fish husbandry. In *Fish Nutrition* (pp. 857-882). Academic Press, London.
3. Hardy, R.W. and Kaushik, S.J. eds., 2022. *Fish nutrition*. Academic press, London. pp. 922.
4. Hardy, R.W., Kaushik, S.J., Mai, K. and Bai, S.C., 2022. Fish nutrition—history and perspectives. In *Fish Nutrition* (pp. 1-16). Academic Press, London

5. Krogdahl, Å., Kortner, T.M. and Hardy, R.W., 2022. Antinutrients and adventitious toxins. In Fish Nutrition (pp. 775-821). Academic Press, London.
6. Ragaza, A.R., Hossain, M.S., Kumar, V. 2021. The potential of invasive alien fish species as novel aquafeed ingredients in the book “Sustainable Aquafeeds: Technological Innovation and Novel Ingredients”. Editors: Jesús Simal (University of Vigo, Spain) and Jose M. Lorenzo (Centro Tecnológico de la Carne, Spain). Publisher: CRC Press, Taylor & Francis Group, LLC. DOI: 10.1201/9780429331664-3
7. Small, B.C., 2022. Nutritional physiology. In Fish Nutrition (pp. 593-641). Academic Press, London.

Patent Applications and Invention Disclosures

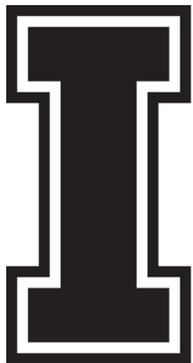
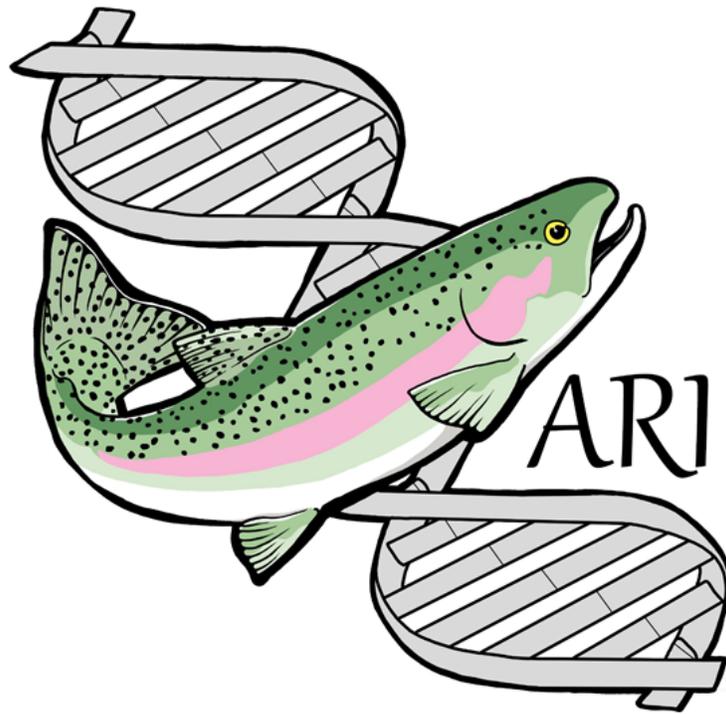
1. Cain, K.D. and Jones, E. “Mouse anti-sablefish IgM monoclonal antibody for use in detecting burbot antibody”. Invention Disclosure (Filed December 2021)
2. Cain, K.D., Ma, J., and Loch, T. “Coldwater Disease Vaccine: newly developed attenuated *Flavobacterium psychrophilum* strain that protects Atlantic Salmon, Rainbow trout, and possibly other fish species”. Invention Disclosure (Filed November 2021)
3. Cain, K.D. and Jones, E. “Mouse anti-sablefish IgM monoclonal antibody for use in detecting sablefish antibody”. Invention Disclosure (Filed November 2021)
4. Iassonova, D., B.C. Small, J. Hong. “High plant PUFA fish food.” US Provisional Patent Application (Filed November 2021)



Awards

1. Kenneth Cain, Distinguished Professor Award, University of Idaho, 2021
2. Gary Fornshell, Idaho Governor's Award for Excellence in Agriculture, 2021
3. Kimia Kajbaf (PhD student): "Best Abstract Award" by U.S. Aquaculture Society - Student Travel Award
4. Marina Rubio Benito (PhD student): "Best Abstract Award" by United States Aquaculture Society - Student Travel Award
5. Marina Rubio Benito (PhD student): "2nd place in the Spotlight competition" by United States Aquaculture Society





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