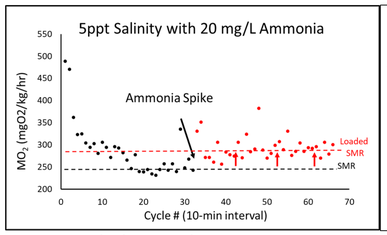
CPS: Medium: Integrating sensors, controls, and ecotoxicology with decoupled aquaponics using brackish groundwater and desalination concentrate for sustainable food production.

NIFA Award # 2023-67022-38976

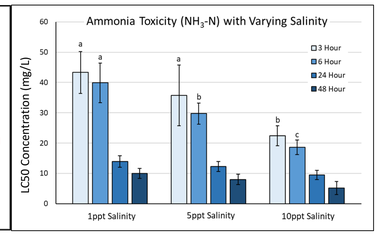
Miguel Acevedo[1,3] (PI), Xinrong Li[1] (Co-PI), Edward Mager[2,3] (Co-PI), Breana Smithers[1] (Res. Sci.), [1]Electrical Engineering Dept. [2]Biological Sciences Dept., [3]Advanced Environmental Research Institute, University of North Texas, Denton, TX

Challenge:

- Demonstrate that brackish groundwater desalination costs can be offset by using its byproducts for profitable food production.
- Separating nutrients from RAS allows to improve water quality for aquaculture and use nutrient rich water for hydroponics where it is needed.
- Develop an early alert system to detect and correct toxic stress conditions affecting the aquaculture organisms, thus optimizing growth and survival.

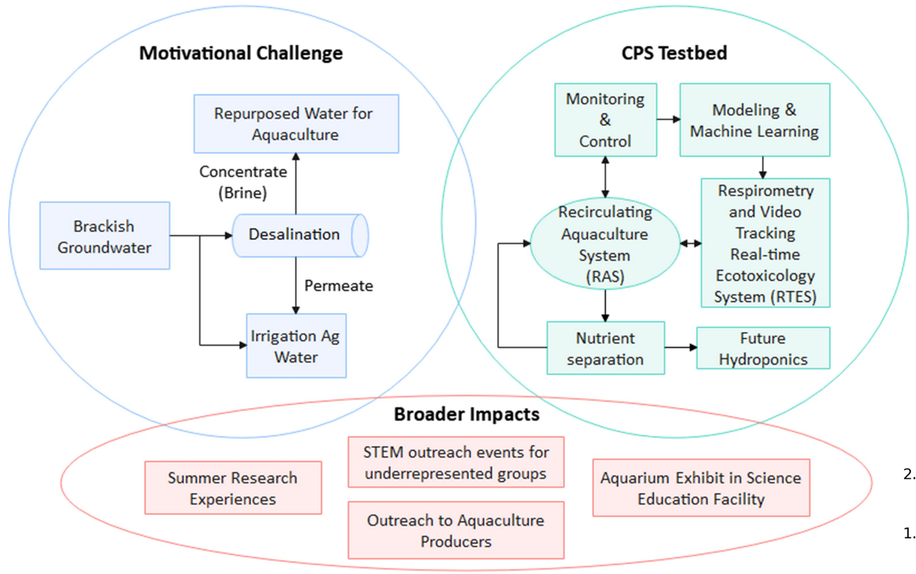


Metabolic Rate by Respirometry



LC-50 Toxicity Bioassays

Emadi C., Neto F., et al. 2023. Desalination Concentrate as a Potential Resource for Inland Aquaculture Presentation at 6th Annual WIN Workshop BGNDRF, Alamogordo, NM. US Bureau of Reclamation.

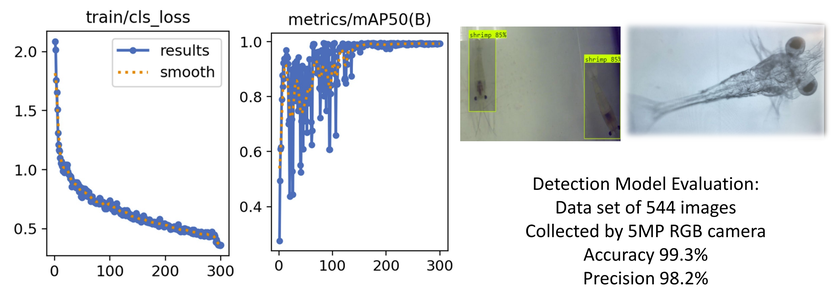


Three RAS installed in the lab with the Giant River Prawn

Gasperin A, Padilla C., and Roloff, J. 2023. Water Quality Monitoring System for Crustacean Based Aquaponics. EE Senior Design Project.

Scientific Impact:

- A substantial innovation of this research is the development of real-time respirometry, which has value beyond the specifics of this project.
- Combined with video tracking for behavioral assessment of toxicity into a RTES, powered by artificial intelligence (AI), is a unique contribution of this research.
- Consolidating all variables in the AI to assist in developing models useful to design and operate production-scale systems, represents an advance in CPS technology.



Detection Model Evaluation:
Data set of 544 images
Collected by 5MP RGB camera
Accuracy 99.3%
Precision 98.2%

Dang T., Li X., et al. 2024, Computer Vision and Deep Learning for Real-Time Aquatic Behavioral Assessment and Toxicity Prediction. Poster presentation EE Dept.

Giant River Prawn
(*Macrobrachium rosenbergii*)

Solution:

- Advancing real-time monitoring and control, aided by data analysis and machine learning, to implement RAS operating under optimal conditions.
- Implementing desalination system for nutrient distribution between the RAS and a future hydroponics loop (HP).
- Developing a real-time ecotoxicology system by integrated respirometry and behavioral assessment (via video tracking and machine learning) and apply it to the RAS
- Modeling organism growth and survival linked with nutrient distribution and water quality dynamics.
- Integrating all systems into a CPS testbed that includes networking, computing, and opportunities for education and outreach.

Broader Impact, Societal Benefits:

- Demonstrate that it is possible to repurpose desalination byproducts to produce food, offsetting the costs of treatment, while reducing environmental impacts from those byproducts.
- Benefits populations in many areas with semi-arid and arid climate, brackish groundwater, and scarcity of surface water, as well as saline aquaculture producers worldwide.

Broader Impact, Education and Outreach:

- Developing an exhibit and activity emphasizing interdisciplinary CPS research conducted during the academic year.
- Offering summer research experiences to students from underrepresented groups.
- Participating in STEM outreach events targeting underrepresented groups.

Broader Impact, Quantification of impacts:

- Economic impacts will be quantified by life-cycle cost-benefit analysis of the integrated water and food production, including costs of treated water and concentrate disposal, market price of shrimp, and revenues.
- This analysis will indicate the feasibility of recovering the desalination concentrate for profitable food production as well as using water efficiently for multiple purposes.

Contact information:
Miguel Acevedo, PI Miguel.Acevedo@unt.edu; Edward Mager, Co-PI Edward.Mager@unt.edu; Xinrong Li, Co-PI Xinrong.Li@unt.edu; Breana Smithers, Research Scientist Breana.Smithers@unt.edu