Novacq is the Solution to Overfishing for Forage Fish by Replacing Fishmeal in Aquaculture Feed

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Table of Contents

Acknowledgments

First and foremost, I have to thank Ms. Katie Manbeck and Mr. Mike Cargill for spurring me on this journey of a lifetime. Mr. Cargill and I grew to have not just a teacher-student relationship, we became close friends. My sophomore year at Stafford High School Mr. Cargill and I started a class called Research in Agriculture. It was designed to be an exploration of solutions to world food security and testing what solutions we had the means to test. Over time we built an aquaponics system in the school greenhouse which is still operational to this day. Last year in my absence Mr. Cargill brought 8 students to the Kansas State Youth Institute in Manhattan, KS on the campus of Kansas State University. The Research in Ag class at Stafford High School continues to grow and opens new pathways to students seeking to know more about sustainable agriculture and securing the food system worldwide.

Ms. Manbeck was the Stafford High School Vo-Ag teacher my junior year of high school. While Mr. Cargill and I were working in the Research in Agriculture class we had no idea about the youth programs that the World Food Prize offered. One day Ms. Manbeck approached me in the hall at school and told me that I should get involved in the World Food Prize Global Youth Institute. Without her drive to bring this program to my attention, I would probably not know about it to this day.

I cannot thank the World Food Prize Foundation enough for the opportunity that they gave me to have the once in a lifetime opportunity that is the Borlaug-Ruan International Internship. I am exceedingly grateful for people like Ambassador Kenneth M. Quinn and Lisa Fleming When my parents came for orientation day prior to me leaving for my internship, they were only slightly worried for my safety overseas. After Ambassador Quinn got up and addressed the group and insured the safety of all the interns my parents were relieved. Lisa worked around the clock to ensure all 24 of the Borlaug-Ruan interns made it to their locations safely. It is because of great people like Lisa and Ambassador Quinn, that the World Food Prize is a great organization that it is.

Introduction

My name is Luke Alpers from Stafford High School in Stafford Kansas. I first became involved in The World Food Prize by way of the Kansas State Youth Institute in May of my Junior year of high school. After participating in that I was selected to participate in The World Food Prize Global Youth Institute (GYI) in 2016 as a senior in high school. During my time attending the Global Youth Institute, I did not have much interest in applying to be a Borlaug-Ruan International Intern. I have always had the desire to travel outside the US, but I had a feeling that this internship simply was not for me. It was the last day of the 2017 GYI when the 2016 Borlaug-Ruan International Interns were giving their presentations that I was inspired to apply for the internship.

As they were giving their presentations I knew that was something unique that I wanted to be a part of. I saw the once in a lifetime experience that these individuals had, and I wanted to have it too. I was also influenced to apply by my science teacher, Mr. Mike Cargill, who was also my GYI mentor. He told me that it would be an excellent experience and that I needed to apply. I knew that this internship could provide me with knowledge about food security that I would be hard pressed to find elsewhere.

During my interview to be placed at a research center, I expressed interest in aquaculture and as a result, I was placed at WorldFish in Penang, Malaysia. Over the course of my internship, I worked with professionals in aquaculture and genetics to complete our research objective which was to determine if Novacq could successfully replace fishmeal as the protein source in aquaculture feed. Then, if Novacq could not successfully replace fishmeal, at what ratio could Novacq be substituted for fishmeal to still achieve an effective protein content in the fish feed.

The WorldFish Center

During my internship, I was located at The WorldFish Center headquarters in Penang, Malaysia. WorldFish is an international nonprofit organization that works to benefit the lives of people around the world through more sustainable aquaculture practices. “The WorldFish mission is to strengthen livelihoods and enhance food and nutrition security by improving fisheries and aquaculture. We pursue this through research partnerships focused on helping those who stand to benefit the most—poor producers and consumers, women and children.”

The WorldFish Center began in 1975 as The International Centre for Living Aquatic Resources Management (ICLARM) at the University of Hawaii as a Rockefeller-funded program. In 1977 WorldFish became fully operational as an independent center in the Philippines. ICLARM continued to grow up into the 1990's when it was first admitted into The Consultative Group for International Agricultural Research (CGIAR). In 1997 ICLARM and its partners introduced Genetically Improved Farmed Tilapia (GIFT) and to this day continues to operate that project. In 2002 ICLARM finally took on its present name of WorldFish. The WorldFish Center now has 7 country offices employing 321 research staff, 373 global staff, and conducting roughly 149 research projects.

My Assigned Program

I was involved in an experiment that would be used for WorldFish to compete in the Blue Economy Challenge. The challenge that our experiment was submitted for was called the Rethinking Feed for Aquaculture challenge. Competitors are given the task of redesigning current aquaculture feed methods. WorldFish partnered with CSIRO to use Novacq as a new, sustainable aquaculture food alternative. The program called for newly designed aquarium systems to be built into the aquarium building at WorldFish. The first step to initiating the Blue Economy Challenge Experiment was to build these aquarium systems to CSIRO's specifications. The Blue Economy experiment was one of the biggest on-site experiments WorldFish conducted in 2017. Figure 1 on page 13 shows the research team that I was included in.

Colleague Background

Khairul Rizal Abu-Bakar and Nurulhuda Ahmad Fatan (Nurul) were the two researchers I worked the closest with. They both earned their degree at the local university, the University of Science Malaysia (USM). Nurul is currently doing Ph.D. research at WorldFish in hopes of earning her doctorate's degree from USM. Kairul is the head researcher of Aquaculture and Genetics at WorldFish and was my greatest mentor throughout my internship. Sharon Suri was my host for the majority of my internship. Sharon is the project coordinator for Sustainable Aquaculture at WorldFish. Her primary goal is to receive a project, assemble the most effective research team to complete the project, and then work as the catalyst for organizing and sharing information as the project progresses. Prof. John Benzie is the Acting Program Leader of Sustainable Aquaculture at WorldFish. "He has more than 25 years of research experience in government, university and private sectors worldwide, applying genetics to natural resource management and aquaculture. He has led programs in aquaculture and marine biotechnology for Australian Government agencies, the University of New South Wales, and a multi-national shrimp breeding company. He is also currently

Professor of Marine Molecular Biodiversity at University College Cork, Ireland and an Editor of the journal Aquaculture." (John Benzie)

For the project I was a part of, WorldFish had partnered with the Commonwealth Scientific and Industrial Research Organization (CSIRO) which is the Australian federal government agency for scientific research.

My Position and Jobs at WorldFish

During the day I would work what would be typical office hours from about 9:00 am until 5:00 pm. The WorldFish office in Penang is not primarily a research office, although some research is done there. Most of the other buildings are for meetings and extension work as well as money handling and paperwork processing. My office was located in the sustainable aquaculture building, which is where all the scientists for WorldFish had their offices. This in itself was a memorable experience, as I was able to surround myself with highly intelligent individuals who were experts in aquaculture and fish genetics. I was assigned to work with Khairul and Nurul, research assistants in the sustainable aquaculture building. I primarily worked with Khairul on the project that we were assigned. The three of us ran the experiment under the supervision of Dr. John Benzie.

During the day I would usually stay busy between assisting Khairul and Nurul in the aquarium room. My primary task was to construct a second aquarium system identical to the one which the 2016 Borlaug-Ruan International Intern helped design. In total there are four rooms in the aquarium building. The first room houses the original aquarium system, the second housed the system that I assisted in building, and the third and fourth were both empty. The end goal was to complete the entire aquarium building with varying aquarium systems to expand the capabilities of WorldFish's research facilities. While working on the aquarium system was my job during the day, I also spent my personal time doing research on Novacq and the Blue Economy Challenge and reading up on the research WorldFish and CSIRO had done up to the point that I had joined the research team.

I also had some auxiliary jobs that Khairul assigned to me. At 8:30 am and at 3:30 pm every day I would take a pH reading and a temperature reading of the aquarium system to be sure the biofilter and temperature regulator was working properly. Then after taking those readings, I would feed the fish to satiation. It was important that I counted the fish at this time to be sure that the correct population was in each tank. During a 10-minute feeding time, I would feed the fish until they would no longer accept food. After the 10 minutes was up I had to leave a little bit of food floating in the water in case any were still hungry after I left. After waiting about an hour, I would return to the aquariums and siphon out any leftover

food and fecal material from the tanks that weren't carried to the filter by the current of the system. After the afternoon feeding and water testing, I would clean the media screen which collected any large food particles or fecal material as the water was finishing its cycle through the system. While conducting these small jobs, I learned valuable information on how to care for an aquarium system.

Because my position was working in an aquarium room with 2 other researchers there wasn't much input for me to give. I simply worked on the jobs we needed to get done as far as constructing the aquarium systems was concerned. Sometimes I would give input as to how I thought the design of the aquarium system could be improved. For example, I had come up with a way to use a siphoning system. Khairul and I tested the idea and showed it to John, but the decision was made to stay true to the first system. Overall, I just worked with Khairul and Nurul spending the greatest portion of my time learning rather than making suggestions.

Abstract

A product of Microorganisms Capable of Nearly Replacing Fishmeal in Aquaculture Systems

Fishmeal is currently the primary protein source in aquatic feeds; due to the growing aquaculture industry, there is also an increased need for fishmeal. Currently, the fishmeal used for aquatic feed is made with fish harvested from marine environments. This increased need for fishmeal has put pressure on the marine environments because of overfishing. This unsustainable method of producing fishmeal for aquatic feed is what inspired the research project that I am involved in. The goal of this project is to provide a sustainable aquatic food source to small-scale aquaculture operations. WorldFish has partnered with CSIRO, to test a product called Novacq. The research team and I believe that Novacq may be able to nearly, or entirely, eliminate the need for fishmeal in aquatic feeds, thereby making the aquaculture industry more sustainable. We will test this hypothesis by utilizing a traditional recirculating aquarium system. This will allow us to be able to observe the fish without having to worry about water contamination skewing the results. We hope to be able to determine how effective Novacq is in replacing fishmeal and sustainably producing larger harvest weights in aquaculture operations. If Novacq can replace fishmeal it will affect small-scale aquaculture farms because they will no longer have to buy expensive fishmeal. They will retain more of their profit and will be able to contribute back to the local economy. We hope to see a substantial difference between the aquatic feeds that use Novacq, and those that don't. If Novacq can replace fishmeal and our experiment proves true, our goal is to implement Novacq in all fishing operations. This would allow aquaculture farms to operate more sustainably, efficiently, and retain more profit.

Experiment Preface

The goal of the experiment was to redesign current aquaculture feed methods in order to eventually identify a more sustainable option for commercial fish food. An article written by the Permaculture Research Institute states "A growing body of scientific evidence suggests that current fishing levels are dangerously high—both for the forage fish themselves and for the predators and industries that depend on them." (Roney 2013) For this project, WorldFish and CSIRO combined their resources and worked together to research Novacq. In the late 1990's CSIRO identified the vital role that marine microorganisms played in the diet of prawn. After this discovery, researchers at CSIRO began heavily studying these microorganisms and began trying to manipulate them to increase their efficiency as a prawn feed as well as to cause the microbes to produce a bioactive product that would increase prawn growth. As a result of this research, CSIRO created a bioactive product called Novacq that is capable of increasing prawn growth by up to 40%. CSIRO then partnered with WorldFish in order to test Novacq on WorldFish's own GIFT tilapia. Essentially, CSIRO had extreme success with Novacq on prawn and wanted to see if the same results would occur in the GIFT tilapia.

To make fishmeal large fishing boats cast nets into the ocean and gather large amounts of fish, then the fish are ground up into a powder that is mixed in with all the other ingredients the producer wants in their feed. This mixture is then extruded to form an aquatic food product. Novacq would provide a more sustainable solution to aquatic food protein, which had been proven in the prawn experiment conducted by CSIRO and what results we were looking to have in the WorldFish Novacq trials.

The research WorldFish and CSIRO did over the course of this project was not simply for the Blue Economy Challenge. This research is necessary for the future of the aquaculture industry and in securing the wellbeing of the world's marine environments. Currently, most aquaculture feeds use fishmeal as the primary protein source. For example, according to a report published by Greenpeace in July 2017, 76 percent of China's aquaculture species require trash fish as feed, and in 2014, aquaculture demanded at least 7.17 million tons of China domestic marine fishery resources, accounting for over 55 percent of the country's total marine catch production. Fishmeal is an unsustainable fish food protein source. Usually, this fishmeal comes from trash fish, or forage fish, these types of fish are not suitable for human consumption. According to an article written by Zhang Hongzhou "While higher aquaculture production might relieve pressure on wild fish stocks, the sector's overdependence on fishmeal and trash fish for feed opens it to ecological risks." The demand for fishmeal has increased to the point that the marine environments where the fish used to

make fishmeal are located have been put under intense pressure due to the disruption in their ecological system.

Overfishing does not solely affect the trash fish populations, it also affects the rest of the species that live in the marine environments where these trash fish live. “It also indirectly diminishes wild fisheries through habitat modification, wild seedstock collection, food web-interaction, nutrient pollution, and the introduction of exotic species and pathogens that harm the wild fish population." (Hongzhou). By removing a key component in the natural system of these marine environments it is nearly impossible for them to continue thriving as they were when the forage fish were prevalent. The smaller forage fish consume plankton, they are then consumed by larger fish or birds. Often times organisms on the bottom end of the food chain are overlooked when in fact it is those organisms that are the foundation of the entire marine ecosystem.

Methods

The Novacq trials were designed to test what concentration of Novacq could replace fishmeal in an aquatic feed. The aquarium system that WorldFish used for the tests consists of 60 tanks that were 40 liters each. The tanks were situated on racks, 5 tanks per shelf with 12 shelves. On the top of each shelf, a large fiberglass tub is used as a reservoir tank to send water to all the smaller tanks on the shelves using gravity flow. The individual tanks are connected using PVC pipe and drain into large fiberglass tubs below the shelving unit. After the water has passed through the entire aquarium system and has reached the bottom reservoir tank, it goes through an extensive filtration system.

The first step in the filtration system is a large media screen that sits on top of the tubs underneath the shelving units. This screen is used to catch any excess food and fecal material that gets caught in the current going out of the system. After the drainage water passes through the screen it is sent through a series of filters including a sand filter, a biofilter, and a UV light. The sand filter is to catch any smaller solid particles that passed through the media screen. The biofilter had bacteria in it that would consume compounds that would be harmful to the fish, such as ammonia. Finally, the UV light destroyed any other harmful bacteria and microorganisms that may have remained in the water. Having such an extensive filtration system ensures that the fish remain in prime health over the course of the experiment. Healthy and stable water chemistry is also important to ensure that there are no variables in the aquarium system other than food.

Fish were selected to stock the tanks based on gram weight and estimated gram weight at the end of the experiment. We also decided to have a higher stocking density in the tanks with a lower gram weight fish. For each of the 3 test groups, we used 20 replicates so as to fill all 60 tanks in the aquarium system. In the first sample, there were 20 tanks with 12 fish in each tank weighing 8 grams per fish. The second sample was 20 tanks, each with 10 fish weighing 10 grams each. The last system had 20 tanks with 8 fish weighing 12 grams each. All other factors were kept at a constant. The fish were fed the same food at a constant time, water temperature remained constant, and all the tanks were cleaned at the same time. All fish were fed to satiation at 8:30 am and 3:30 pm. Before all the tanks were stocked with fish, the research team decided that it would be beneficial to do a trial run. Two replicates of each sample weight group were used to fill 6 total tanks with fish.

After the trial run was successfully completed, fish were selected from stock tanks on WorldFish campus. These fish were set apart and held until the water chemistry in the aquarium tanks were exactly set. This is as far as the experiment had reached during the time of my internship. The next phase was removing the trial run fish and replacing them with the fish selected for the experiment. After all the aquariums were cleaned and the water quality was correct the fish would be introduced into their respective aquariums. After moving the fish and allowing them to calm down they would be fed and treated just as the fish in the trial run were.

Results

Due to the lengthy process of setting up the experiment, I was unable to see the results. During my time preparing and conducting the experiment all that had been completed was observations taken on the trial run where not all the tanks were in use. As my internship came to an end Khairul, Nurul, and I had selected the fish that would be used for the experiment, but they had not been introduced to the aquarium system yet. We were also still making a few slight modifications to the aquarium system to ensure the best possible water quality. One of the additions that Khairul and I were exploring was a ribbed plastic cylinder that could act as a place to grow the same bacteria as what was in the biofilter. After filling one of the top reservoir tubs with the plastic cylinders, we built a PVC pipe frame with holes drilled in it to dissolve oxygen into the reservoir. The oxygen was used by the bacteria to establish itself on the plastic cylinders.

We also found during this trial run that the water current in the aquarium system was not strong enough to sweep away the fecal matter out of the tanks. This was not much of a problem for the tanks with the lower stocking density of fish, but for the tanks, with a higher stocking density, the water became clouded with all the fecal material. Khairul and I worked

to try and increase the current through the system. There is only so much the current can be increased, too high of a current can stress and overwork the fish in the aquariums.

I had also made the observation that the fish that were in the tank nearest to the door were smaller, lighter, and less active than all the other fish. We determined that the fish which lived in the tanks that were beside the door were constantly stressed as a result of constant activity happening by the door. To solve this problem, we blocked the side of the tank that faces the door with a sheet of cardboard. Within 24 hours the fish in that tank had gained coloration and were noticeably more active.

Conclusion

In order for aquaculture to continue to be a sustainable protein source to people around the world and alternative for fishmeal must be found. Fish is only going to continue to be a growing source of protein in the world. According to an article by the FAO, 20Kg of fish is consumed per capita in the world every year. "With the production of farmed fish eclipsing that of wild fish, another major transition is also underway: Aquaculture's share of global fishmeal and fish oil consumption more than doubled over the past decade to 68 percent and 88 percent, respectively." The article continued by saying fishery products account for over 9 percent of total agriculture exports worldwide.

The Blue Economy Challenge research project that WorldFish and CSIRO participated in caused research organizations to rethink commercial aquaculture systems worldwide. Over the course of the experiment, we explored the hypothesis of replacing the industry standard protein source in fish food with Novacq. I believe that questioning the methods by which the world’s food is produced should be a constant conversation. In order to constantly be using the most up to date techniques and technology of producing food, there must first be a willingness to be cognizant of flaws in current food systems. Research organizations like WorldFish and CSIRO are prime examples of identifying an unsustainable flaw in the production chain and identifying a solution.

Program Mission

As is stated on the WorldFish website: The mission of the project that we were working on was to develop an alternative source of protein for commercial fish foods. Currently, fish food manufacturers use fishmeal as the protein source in their feed CSIRO and WorldFish identified the fact that the greatest ecological risk to continuing to use fishmeal as the primary source of protein in commercial fish food was the risk of killing entire marine ecosystems. WorldFish partnered with CSIRO to test their Novacq on a genetic strain of black tilapia specifically developed by WorldFish called Genetically improved farmed tilapia

or “GIFT.” The mission was to see if we could achieve the same growth rate and harvest weight increases in the GIFT as what was seen by CSIRO during their Novacq trials on prawn.

My experience at WorldFish was second to none. From the time I entered the airport in Kansas City, I was out of my comfort zone. I grew up in a small town in rural Kansas with a population of roughly 1,000 people. Prior to this internship, I had never flown in an airplane, never been in an airport, never seen the ocean, and never truly left home. By having such an overwhelming amount of new and foreign things happening to me at once, I felt that I should just take it all in and enjoy the experience to the fullest. When I got to Penang, I realized that not only was everything that happened there foreign to me, but I was much more foreign to them. Many times, I caught people staring at my blonde hair and making comments in their own language about it. I didn't mind though, I was taking in every bit of culture and knowledge that I could expose myself to. With this mindset, I believe I was able to fully experience the diverse culture of Penang. These experiences influenced me to have a much more open and accepting mindset to the people around me. Once I experienced what it was like to be "the foreigner" I had an entirely new outlook on foreigners in the US.

While in Malaysia, I grew in my ability to articulate my thoughts and ideas and share those with my peers. In a research institution setting, it was important for me to be able to communicate questions that I had with my mentors, as well as share ideas that I had that could possibly improve the results of the experiment. As I developed relationships with my colleagues, I felt comfortable asking any question that came to my mind. Many people think that it is a sign of low intelligence when someone asks lots of questions. I believe the smartest people in the world are the ones who never stop asking questions.

WorldFish is an excellent organization full of amazing people. The reason, I believe, WorldFish succeeds as much as it does in cutting edge aquaculture research is because everyone on WorldFish staff is working toward one common goal. Every employee of WorldFish is working to improve food security worldwide by improving aquaculture systems. This paradigm of working together to complete a common goal is the key to solving world food scarcity. For a long time, I thought that food security was nothing more than individual research projects by individual organizations all around the world. After seeing the collaboration between WorldFish and CSIRO, I can say that collaborating with other organizations is one of the most powerful moves an NGO can make. It made me realize the power of people working towards a goal.

Though some people may have different opinions on certain issues, that should not hinder them from working together. In my small town there tends to be lots of closed minds and growing up in that environment I was oblivious to it because I knew no other way. After experiencing so much culture and human diversity in Penang I was able to open my eyes to the diversity around me in my own community and see the uniqueness that I had never seen before. I cannot thank the World Food Prize enough for giving me the life-changing opportunity of the Borlaug-Ruan International Internship. I will never forget the Summer of 2017.

Pictures

Figure 1: The Blue Economy Challenge research team

From left to right- Nurul, Kabir, Dave, Sharon, Myself, Cedric. Dave and Cedric are the two scientists from CSIRO who came to consult with WorldFish for this project

Figure 2 (right) and Figure 3 (below) are pictures I took in a local restaurant. The ocean is the primary, and in most cases the only, source of food for the people of Penang. Seeing these tubs of prawn and crab made me remember that the work that I'm doing is for people who depend on the ocean for survival.

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