Sustainable aquaculture: development of new quantitative metrics for use in marketing aquaculture products

Theme D: Emerging Opportunities/Issues
Sustainability

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Funding Request: $98,686 (This number is inconsistent w/ below budget –QZ)

Duration: 2 years (September 1, 2021 – August 31, 2023)

Objective:

The objective of this project is development of Life Cycle Assessment metrics from existing aquaculture operations in the North Central Region (NCR).

Deliverables:

1. A video will be created to explain LCA as it relates to aquaculture.
2. A video will be created to explain the LCA results of our proposed project.
3. Multiple presentations discussing research results will be delivered in at least two NCR states.
4. At least one peer-reviewed article will be submitted to the Journal of Extension.
5. At least one peer-reviewed journal article will be submitted to an scientific journal.

Proposed Budgets:

Institution	Principal Investigator	Objective	Year 1	Year 2	Total
Purdue University	Paul Brown and Jen-Yi Huang, and Brian MacGowan	1	$43,958	$44,498	$88,456
University of Wisconsin	Rob Anex	1	$5,539	$5,691	$11,230
Totals			$49,497	$50,189	$99,686

Non-Funded Collaborators:

Facility	Collaborator(s)
The Ohio State University	Matthew A. Smith

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Project Summary

Aquacultural production in the NCR has not been increasing. However, changing consumer trends (locally produced, fresh, low environmental impact, support local farmers, decrease imports, etc.) offer an opportunity for increased production of fresh fish and shellfish in the NCR. These trends fall under the broad heading of sustainability. Sustainable food production is a market trend that might create pull through the supply chains. At the same time, there are changing definitions of the term sustainability. Our objectives are to develop quantitative metrics for use in marketing locally grown fish and shellfish. Recently completed research from us indicated aquaculture and aquaponic systems exerted low impacts, and both fit well within the definition of sustainability. Specific objectives addressed in this project will be working with existing fish farms in the NCR to develop sustainability metrics from real world situations. We will strategically target production systems (raceway, pond and recirculating systems) and species (trout, walleye, perch, bass, bluegill, catfish and koi) within the NCR with our analyses. Data developed in this project will be valuable marketing tools for existing farmers and help new producers sort through their options regarding system and species choices for new operations.

Justification

This project specifically addresses **Theme D Emerging Opportunities/Issues, Sustainability** in the current Request for Application from the North Central Regional Aquaculture Center (NCRAC). Quantitative data demonstrating the positive economic impact, low environmental impact and social opportunities derived from aquaculture might alleviate the disturbing trends in the United States (US) aquaculture industries and stimulate increases in production and consumption within the US market.

One of the better depictions of sustainability is shown on Figure 1. The three overlapping spheres and their interactions seem to apply in most, if not all situations. From the standpoint of food production systems, including aquaculture, the Economic sphere must be considered first in most cases. Commercial food production systems must be economically viable, else they would not exist for long. The Environmental sphere has become an important consideration among consumers and is part of the changing food consumption trends. The Social sphere is the newest in contemporary thinking in food production systems. Aquaculture producers are, for the most part, not taking advantage of changing consumer trends and communicating with consumers using the topics listed within the spheres and their interactions.

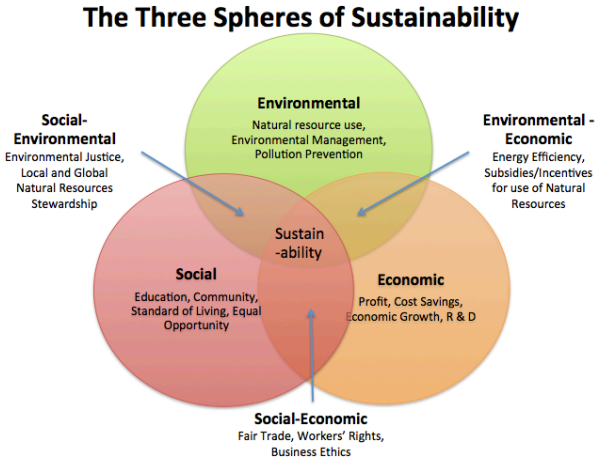

Figure 1. The three spheres of sustainability (University of Michigan Sustainability Assessment, 2002).

In a recent review of consumer trends, Arenas-Jal et al. (2020) argued three overarching issues

were impacting consumer choices of foods; climate change, health and social responsibility, which correspond to the Environmental and Social spheres of sustainability. Within these three broad headings, clean labels (not adding chemicals consumers are unfamiliar with), naturally healthy, and high protein foods were identified as the predominant issues driving food choices. Further, these three categories (clean labels, healthy and proteins) account for the largest global shares of the food market; over $700 billion globally in 2017. Fish and shellfish easily meet the expectations of consumers. In fact, fish and seafood were listed as one of the top five preferred protein sources in the US in 2017 (Nielsen. 2017. US Homescan Panel Protein Survey, cited in Arenas-Jal et al., 2020). However, this is not the sole reason increased aquaculture production in the US appears promising.

Basic supply/demand considerations indicate a strong argument can be made for increasing aquaculture production in the US. Currently, total US production ranks 17th globally. However, the US market is the largest importer of seafood. According to the most recent Fisheries Report from the National Oceanic and Atmospheric Administration (NOAA), "(by) weight, approximately 90 percent of the seafood we eat comes from abroad, over half of it from aquaculture". This imbalance between domestic production and imports results in a trade deficit of over $16 billion (US) (NOAA 2020). This imbalance between relatively low production and high imports is not a new scenario; it has not changed in over 2 decades. The strong justification for increased production based on economic opportunity has not resulted in increased domestic production. Figure 2 shows the total US production from aquaculture from 1992-2014. At best, domestic production appears stagnant. Another indication of this stagnation is the total number of farms producing seafood products. Total number of farms decreased between 2012 and 2017, from 6493 to 6266 (USDA 2018). Again, at best, total number of farms is stagnant. While the number of farms producing selected aquatic organisms (mollusk and crustaceans) increased (NOAA 2020), it seems clear aquaculture is not attracting new farmers or entrepreneurs. Thus, the Economic sphere and the apparent opportunities are not enticing new farmers into aquaculture despite stable demand for products.

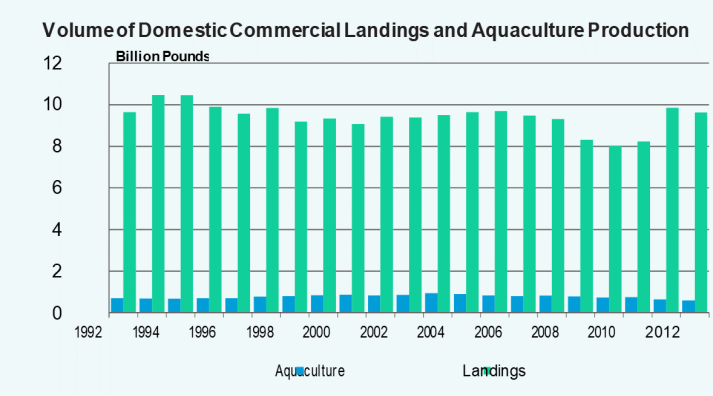

Figure 2. Volume of domestic commercial landings and aquaculture 1992-2014 (NOAA 2020).

Per capita consumption of fish and shellfish has been stable in this century. Since about 1985, consumption of seafood in the US has oscillated between 15 and 16 pounds (6.8 – 7.2 kg) per person per year (Figure 3). This stability should facilitate producer confidence and act as encouragement into aquaculture production. However, it does not seem to be a major factor. Small farms continually indicate they sell all their fish into targeted markets, particularly Asian live markets, who readily accept multiple species, many of which were culturally unknown prior to presentation to buyers (Personal communications from multiple fish farmers over the past 25 years).

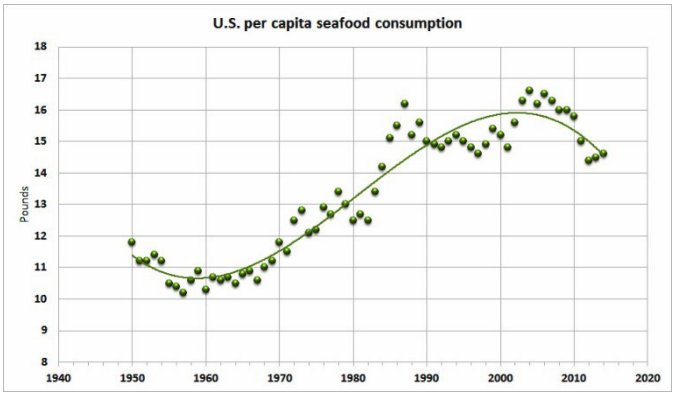

Figure 3. US per capita seafood consumption, 1950-2016

Many industries, when presented with the overarching conditions in domestic aquaculture (low domestic production, high imports, stable demand, and high small farm sales), would expand rapidly, but aquacultural production has not increased. Aquaculture is somewhat of an enigma. We posit that a broader view of the domestic seafood supply is needed; one that recognizes fish and shellfish as an integral component of the overall food supply, and one that recognizes and takes advantage of current consumer trends. This proposal is focused on developing quantitative data targeted toward the newer consumer trends that fall under the broad heading of sustainability; locally produced, fresh, low environmental impacts (carbon (C) footprint, land and water demands), and healthy foods. These might be the requisite data that will stimulate expansion by existing farms, entrance by new farmers, and help aquaculture producers stimulate consumer pull through the supply lines. Use of Life Cycle Assessment (LCA) is an accepted tool for quantifying the necessary metrics in aquaculture (Samuel-Fitwi et al. 2012).

Life Cycle Assessment (LCA)

Life cycle assessment has been defined as a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system" (ISO, 2006). Methods and values used have been standardized by the International Organization for Standardization (ISO) and regularly complemented and updated by subsequent guidelines (ISO, 2006). Therefore, LCA is a science-based approach to systematically and comprehensively analyze the life cycle of a product, process, or service from multidisciplinary perspectives, including environment, human health, and resources. In this project, a LCA model will be developed conforming to ISO 14040/44 standards (ISO, 2006) as described below.

The metrics associated with LCA are those directly related to the Environmental sphere of sustainability, but also incorporating the Economic sphere. Fish producers must initially focus on the Economic sphere. The Environmental sphere is one of the foundations for current consumer trends and one that has not received much focus in aquacultural marketing. A recent search (10/2020) through the Journal of the World Aquaculture Society identified no marketing publications incorporating the Environmental sphere of sustainability. The specific metrics commonly determined for LCA analyses are shown in Table 1. The metrics presented are those of primary concern when considering environmental impact of human activities and are the most relevant to aquaculture (Henriksson et al. 2011). GWP is a measure of generation and release of greenhouse gases that contribute to global warming, AD is a measure of how much energy is used in the process, EP quantified P release into receiving streams and AP measures the potential of pH changes in surface soils and waters. There are several other measures of environmental impact including non-fossil fuel abiotic depletion (AD non-fossil fuels, kg Sb (antimony) eq), ozone layer depletion (ODP, kg CFC-11 (chlorofluorocarbon)

Table 1. Common metrics used to characterize the environmental impact of activities.

Metric	Units
Global warming potential (GWP)	kg CO_2 equivalents
Fossil fuel abiotic depletion (AD)	mega joules
Eutrophication potential (EP)	kg PO_4 equivalents
Acidification potential (AP)	kg SO_2 equivalents

eq), human toxicity (HTP, kg 1,4-DB (dichlorobenzene eq), freshwater aquatic ecotoxicity (FAE, kg 1,4-DB eq), marine aquatic ecotoxicity (MAE, kg 1,4-DB eq), terrestrial ecotoxicity (TE, kg 1,4-DB eq), and photochemical oxidation (PO, kg C2H4 (ethylene) eq)

Related Current and Previous Work

The first publications using LCA analysis to quantify the impacts of aquaculture operations in aquaculture was in 2004 (Papatryphon et sl. 2004), and there has been a steady series of publications examining the impact of aquaculture activities since. Bohnes et al. (2019) presented a graphical presentation of the number of LCA analyses in aquaculture through 2017. They reported 10, 9, and 11 publications globally in 2015, 2016 and 2017, respectively. We extended that graphical relationship and found 11 and 12 in 2018 and 2019, respectively, and 9 publications so far in 2020. Thus, this is a relatively new area of research within aqauaculture; a line of research being applied to operations globally. Figure 4 shows the countries in which LCA analyses in aquaculture have been conducted and the number of publications originating from those countries. Based on this figure, it seems clear LCA has been adopted in a wide range of countries, from developed countries in Europe where most of the studies have been conducted to developing countries across the globe. The studies listed as US are worth noting.

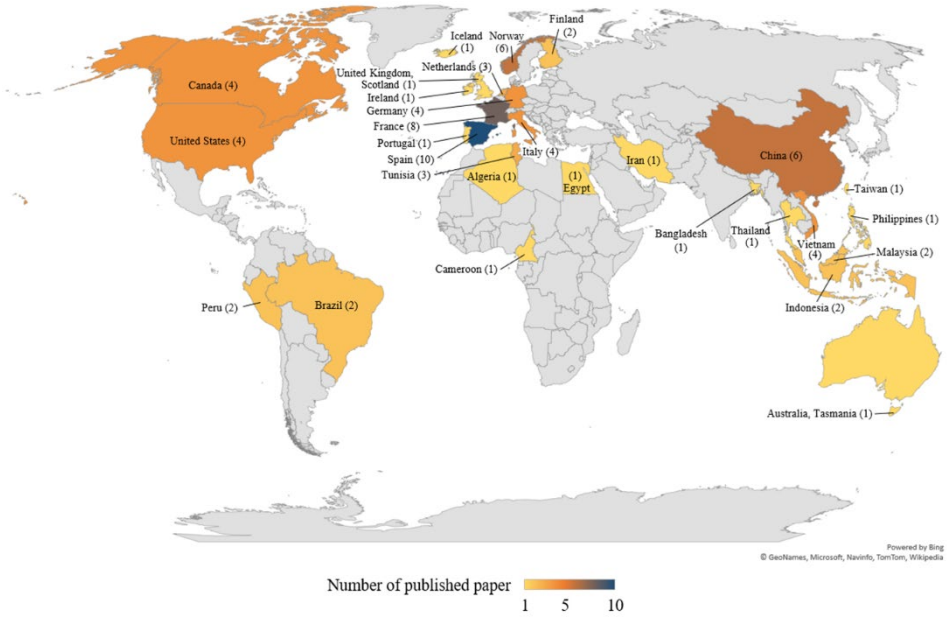

Figure 4. Countries in which LCA analysis focused on aquaculture has been conducted and the number of published papers from those countries ().

Most of the published papers on LCA in aquaculture originating from the US are from colleagues from the University of Michigan and their students. One of those papers was focused on shrimp farming in China (Cao et al. 2011), one was a review of LCA in aquaculture (Cao et al. 2013), and one was focused on shrimp farming in the US (Sun 2009). The fourth completed LCA study in aquaculture was a recent examination of biofloc marine shrimp aquaculture completed at Purdue (Al Eissa, 2020). ***Thus, there are few applications of LCA in aquaculture in the US and none focused on the culture of fish.*** Extrapolation of data from other countries to US conditions does not provide an accurate measure of impacts (Silvenius et al. 2017). There will be differences in feed costs, availability and transportation impacts; differences in electrical sources (coal, natural gas, solar, wind) supplying local grids as well as costs associated with electricity; and, differential labor costs. LCA data have been used to ***quantify environmental impacts of aquaculture*** (for examples, see Dullah et al. 2020, Song et al. 2019, Aubin et al. 2015, Munkung et al. 2013). However, these expanded to consider specific impactful components of aquaculture including ***feeds*** (for examples, see Maiolo et al. 2020, Basto-Silva et al. 2019, Llagostera et al. 2019, Boissy et al. 2011), and ***energy*** (Badiola et al., 2017, Nhu et al., 2016, Draganovic et al. 2013), ***for comparisons of production systems*** (for examples, see Philis et al. 2019, Tacout et al. 2016, Samuel-Fitwi 2013, Ayer and Tyedmers 2009, d'Orbcastel et al. 2009), ***evaluations in advance of new aquaculture facilities*** (Filgueira et al. 2019), and ***use as a predictive tool exploring the possibility of intensifying current production operations*** (Henriksson et al. 2018). While many of the applications of LCA analysis have been focused on environmental impacts of aquaculture, LCA data are not limited to that sphere. Tsakiridis et al. (2020) linked environmental and economic impacts of multiple food production systems in Ireland and reported "(a)quaculture (was) found to have the highest output multiplier and a low to medium carbon footprint compared to pastoral livestock products (beef and veal, sheep meat, dairy)". Kruse et al. (2009) proposed a series of metrics for inclusion of the Social sphere in LCA analysis. Thus, LCA analyses offer the promise of linking all three spheres of sustainability.

Statement of Duplication of Research

The USDA Current Research Information System (CRIS or REEport) was accessed to review related or relevant research projects and it was found that the proposed work is original research and does not duplicate any previously funded projects in the CRIS. Using the search terms LCA and aquaculture, 14 projects were identified, but none of these were focused on developing the metrics associated with aquaculture production in the US. Most were focused on new feed ingredients for animals (broadly) and one was specific for cattle production. The National Sea Grant Office Funding page and NOAA Office of Aquaculture Funding Opportunities Page were also consulted. The following NOAA databases of previously funded projects were also accessed to ensure that the proposed work does not duplicate previous research: 1) National Sea Grant Office Funding Page (http://www.seagrant.noaa.gov/funding/rfp.html); 2) website of state Sea Grant Program (http://www.seagrant.noaa.gov/other/programsdirectors.html); and 3) NOAA Office of Aquaculture Funding Opportunities Page (http://www.nmfs.noaa.gov/aquaculture/funding/funding.html). This project is a unique evaluation and does not duplicate prior research efforts.

Anticipated Benefits

Development of quantitative metrics from existing aquaculture operations in the NCR should benefit three separate, but related groups; existing producers seeking data that supports marketing efforts, new aquaculturists considering new operations, and consumers seeking sustainable foods for their families. Aquaculture production in the US should be increasing, but is stagnant. Data of this nature might be the stimulus for increased domestic production.

Objective

Develop quantitative metrics from existing aquaculture farms in the NCR and compare these values to other food production systems producing competing protein foods.

Deliverables

1. A video will be created to explain LCA as it relates to aquaculture.
2. A video will be created to explain the LCA results of our proposed project.
3. Multiple presentations discussing research results will be delivered in at least two NCR states.
4. At least one peer-reviewed article will be submitted to the Journal of Extension.
5. At least one peer-reviewed journal article will be submitted to an aquaculture journal.

Procedures

The goal of the proposed LCA model is to assess the cradle-to-market environmental sustainability of existing fish farms in the NCR. This LCA aims to provide verified and quantified values of the environmental impacts associated with the target gamut of system/species combinations. The results obtained will also be applied to help identify the components of the analyzed aquaculture operations that contribute most to the environmental impacts (i.e., hotspots) for further improvement. The intended audience of this LCA includes (i) fish farmers who are seeking an objective and quantitative metric for marketing the sustainability of their products, (ii) new producers who are sorting through options of system/species combinations for their operations, and (iii) consumers who attempt to make purchases with consideration of the sustainability of the production of their food.

As a quantified description of the function of a product that serves as the reference basis for all the calculations regarding inventory analysis and impact assessment, this LCA will be performed based on the functional unit (FU) of 1 kg (live weight) of fish produced by each system/species combination. Furthermore, in order to incorporate the economic impact of product into the LCA,

a monetary FU defined as $1 US dollar (market price) of fish produced by each system/species combination will be used. The results obtained will represent the environmental impacts per kg of product weight or per USD of product economic value, respectively.

Aquaculture production systems consist of several life cycle stages. Figure 5 depicts the process flow diagram of the proposed LCA, which describes all the flows (arrows) among different unit processes (i.e., life cycle stage; solid boxes) within the boundary of the system analyzed (dashed box). This cradle-to-market LCA starts from production of feed, energy, chemicals, infrastructures and equipment through farming, processing and packaging to distribution, each of which requires resource inputs and generate waste and emission outputs, hence exerting environmental impacts.

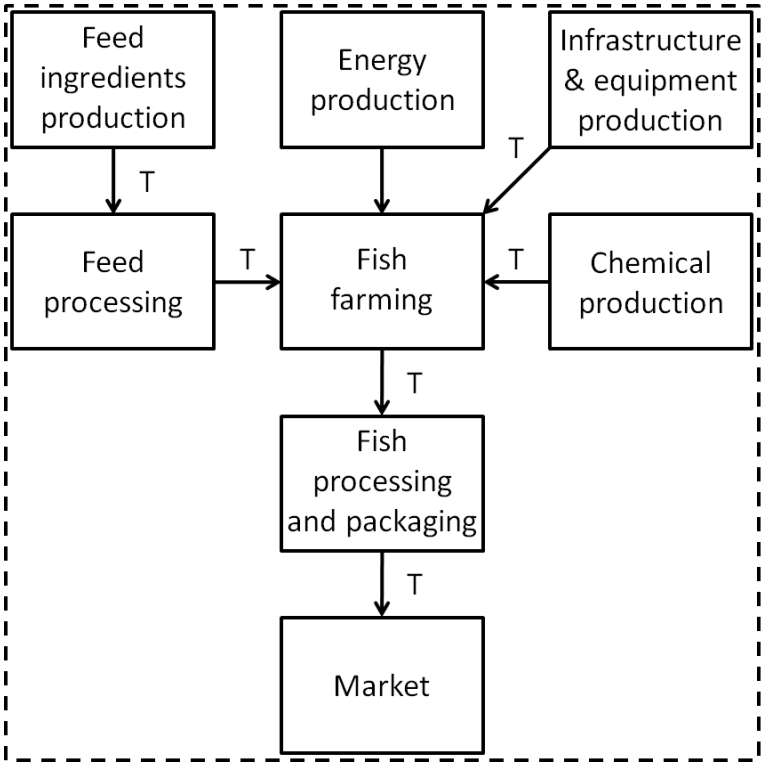

Figure 5. Process flow diagram for aquaculture production in the NCR.

Life cycle inventory data acquisition and analysis

To ensure an accurate and reliable LCA, all the input and output data for each of the unit processes need to be acquired for a complete life cycle inventory (LCI). For example, feed is one of the main sources of environmental impacts within aquaculture based on our recently completed research (Al-Eissa, 2020; Chen et al., 2020). The inputs for production of plant-based feed ingredients include all the fuel, electricity, water and materials uses for seed acquisition, fertilizer and pesticide manufacturing, transportation to planting site, planting activities, harvesting, transportation to processors, and milling and processing into feedstuffs. As the other most impactful unit process, the inputs for fish farming include (i) electricity; (ii) water; (iii) chemicals added to culture tank to maintain water quality; and, (iv) waste treatment and disposal. The LCI data will be acquired from multiple sources. Primary on-site operation data on fish farming will be collected from the participating fish farms in the NCR, which includes:

1) Construction inputs - land use, tank material, numbers and sizes, oxygen supplement equipment, heating and cooling equipment, and transporting equipment;
2) Operation inputs - consumption of fresh water, electricity, and chemicals;
3) Feed - feed composition, supplier, and feed conversion ratio; and,
4) Farming - culturing cycles, culture temperature, water quality, fish survival rate, weight of fish per cycle.

To further expand our LCI database with fish-specific processes, we will refer to articles published in peer-reviewed journals and publicly available peer-reviewed LCA reports using the

same pool of LCA studies as Bohnes et al. (2019). In addition to the primary data provided by the participating farms, information about upstream (e.g., crop cultivation) and downstream (e.g., waste disposal, wastewater treatment) processes will be based on publicly available operations, reference materials from government agencies and cooperatives, and published scientific articles and technical reports. Where data is not available, various LCI databases will be sourced, but modified based on current agriculture and aquaculture operations in the NCR. For example, commercial databases such as Ecoinvent (Swiss Centre for Life Cycle Inventories, Switzerland) and Gabi (PE International, Germany) provide over 10,000 scientifically sound, transparent, and quality-assured inventory datasets on products or processes with extensive datasets pertaining to different agriculture supply chains. Moreover, Federal LCA Commons, an open source database, coordinates LCI data between the United States Department of Agriculture, Department of Energy, and Environmental Protection Agency, which can provide more US- or NCR-specific data. Table 2 shows the LCI for production of 1000 kg shrimp in the NCR created in our recent research (Al-Eissa, 2020), that is compared to semi-intensive shrimp farm on the Gulf Cost of the US and a pond shrimp facility in Vietnam.

Table 2. LCI of shrimp production employing different farming systems (Al Eissa 2020).

Item	Unit	IPS (closed farming)	SPS (semi-closed farming)	EPS (open farming)
		Feed production		
Total	kg	1500	1120	0
		Feed processing		
Steam	kg	480	358	0
Electricity	kWh	195	146	0
Fresh water	m^3	1.95	1.46	0
Land area	m^2	2.1	1.57	0
		Feed transportation		
Diesel truck	tkm	1509	1012	0
		Larvae transportation		
Airplane	tkm	140	62.3	0
Diesel truck	tkm	0	0	50.3
Boat (diesel)	L	0	0	3
		Farming		
Input				

Land use	m2	84	NA	28000
Water use	m3	75	NA	NA
Seawater	m3	0	13	0
Electricity	kWh	921	548	0
Diesel	L	0	24	0
Baking Soda	kg	110	0	0
Chlorine	kg	0	3.8	0
CaCO3	kg	0	909	0
CaO	kg	0	318	0
Triple superphosphate	kg	0	28	0
Urea	kg	0	21	0
Poultry manure	kg	0	283	0
Output				
Live shrimp	kg	1000	1000	1000
N emission	kg	0.0028	38	−70
P emission	kg	NA	3.5	−7
		Processing and packaging		
Input				
Live shrimp	kg	1000	1000	1000
Water	L	0	10413	10413
Plastic bag	kg	10.5	8.75	8.75
Paper box	kg	135	112	112
Ice	kg	1500	1250	1250
Electricity	kWh	0	458	458
Output				
Shrimp product	kg	1000; whole shrimp	833; headless shell-on shrimp	833; headless shell-on shrimp
		Transportation of final product to Chicago		
Refrigerator diesel truck	tkm	456	0	0

Freezer diesel truck	tkm	0	3316	64.6[1]
Ocean freight	tkm	0	0	41893

Impact assessment

To evaluate the environmental impacts based on the developed LCI, life cycle impact assessment (LCIA) will be carried out using the Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI 2.1). TRACI is an environmental impact assessment tool developed by the US EPA specifically for the US that provides characterization factors for LCIA, industrial ecology, and sustainability metrics. Characterization factors quantify the potential impacts that inputs and releases consistent with US locations have on specific impact categories in common equivalence units. Eight categories of midpoint environmental impacts will be assessed, including ozone depletion, climate change, acidification, eutrophication, smog formation, human health impacts (air pollutants, carcinogenics, non-carcinogenics), ecotoxicity and resource uses of fossil fuels. As an example, Figure 6 shows the LCIA results we obtained from the shrimp production in the NCR, which indicate that feed production and farming are the two environmental hotspots. Furthermore, midpoint impacts will be aggregated into endpoint environmental impacts on human health, ecosystem quality, or resources using the ReCiPe 2016 Endpoint (Egalitarian) v1.02 method, so that the environmental performance of an aquaculture operation can be presented by a single score. The results will also be presented as seen in Figure 7, a summary presentation of data based on human health, ecosystem quality and resource impact from our recent research (Chen at al., 2020). The final presentation of data will be new LCA values from aquaculture in the NCR in contrast to other protein sources commonly consumed in the US. As an example, Figure 8 displays the impact of several protein producing industries in Ireland (Tsakiridis et al. 2020). Based on

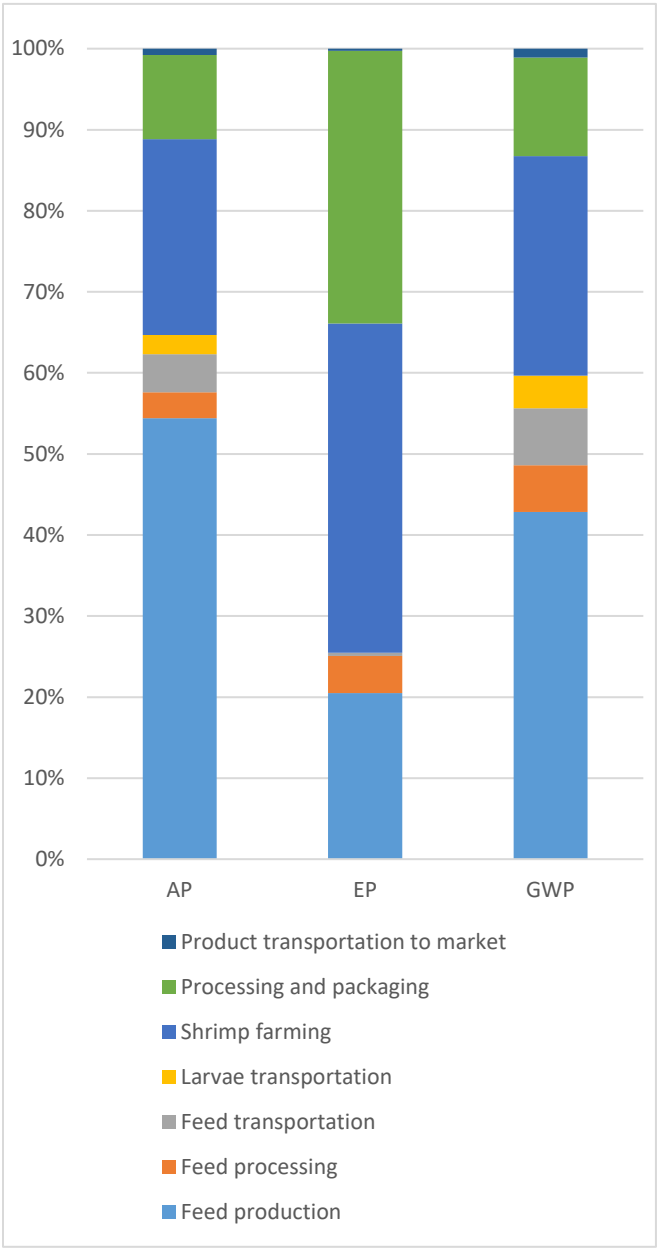

Figure 6. LCIA results from shrimp production in the NCR.

these data, aquaculture producers have a strong sustainability argument.

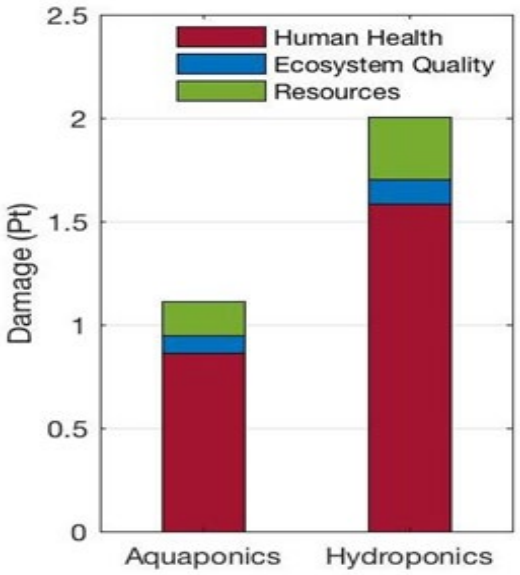

Figure 7. Composite midpoint values from hydroponics and aquaponics in Indiana.

Participating fish farms

We purposefully did not identify participating farms at this stage of project development. First, we, as a group, decided to collect data and present results anonymously. Our goal is not to claim one fish farm in the NCR has higher or lower impacts than another, but to summarize system/species data and compare to other protein sources. Further, any commitment now might change before the project start date (9/1/21). However, our approach has been finalized.

We will strategically target systems within the NCR (ponds, raceways and indoor recirculating systems) and species within those systems, particularly species commonly raised in the region (yellow perch, Perca flavescens, largemouth bass, Micropterus salmoides, rainbow trout, Oncorhynchus mykiss, tilapia, Oreochromis sp.). Additional species may be included, but those choices will be a function of potential participants. This approach was used in Europe to develop a broad view of impacts associated with multiple species and production systems (Aubin et al. 2009).

Timeline

While not requested, a quick consideration of the timeline seems appropriate. The scope of this project requires a more advanced graduate student (Ph.D.) and a typical duration for Ph.D. research is 4 years. The proposed data generation can be developed within the 2-year project period, but would be insufficient to support the entire graduate career of the student. We see this initial effort as a seed project and appear to have several options for continuation. First, a second 2-year project through NCRAC will be an option, if the topic rises to the level of funding through the objective selection process. A second option is funding from the Purdue Department of Forestry and Natural Resources (FNR). FNR maintains a substantial endowment that supports up to 30 graduate students at any given time. Having funding for 2 years of a 4-year project is considered valuable and the Department has a history of providing continuation support for graduate students in this scenario. A third option is the recently developed Great Lakes Sea Grant initiative focused on creating pull of seafood through the supply chain within the Great Lakes states. That initiative will be coalescing a second project shortly before this one ends (Brown is a member of the Great Lakes Advisory Committee and has introduced LCA to that group). A fourth option is USDA NIFA funding. Brown and Huang are in the process of developing a complimentary project to this one through NIFA this year. Thus, while the restricted timeline in this project appears to inhibit successful completion, we feel confident we can develop the dataset we are proposing and continue this work for a much longer time period.

Outreach and Evaluation Plan

Matt Smith, The Ohio State University, has agreed to serve as Extension Liaison on this project. Smith's role will be to guide the development phase of the project by helping identify participants, choice of systems/species, and provide introductions where appropriate. Smith will be involved in all phases of communication throughout this project. The best way of making these data available will be presentations at Regional Aquaculture Conferences and in publications. Publications will be in 2 forms, technical and popular. Brown and Huang are currently developing those 2 publications in association with the Al-Eissa thesis. However, we will also develop more contemporary methods of Outreach.

LCA is a relatively new scientific tool, but one with significant application in aquaculture. Our initial outreach activity will be development of a video explaining LCA, demonstrating data acquisition and resulting metrics, and how these data can benefit existing and new aquaculturists. A second video will be developed in Year 2 of the project showing our data collected in Year 1. Purdue recently purchased two HDR 4K video cameras that we will use to develop the video. A Purdue FNR extension intern will edit and render the video clips into final products. The edited videos will be uploaded to the NCRAC web site and YouTube. Results from this project will also be developed into a technical/extension documents for potential publication.

The project will be considered successful when data are developed and disseminated, and when a larger percentage of fish farmers and consumers understand these new metrics, and how they help the overall food production system and specifically high protein foods.

Facilities

Facilities required in this project are office space, computers and internet access. Both universities provide that to all employees, including graduate students. Travel funds were requested for face-to-face meetings between all parties and regular Zoom meetings will occur through the course of the project. Initially, monthly meetings will occur, established by the Graduate Student. Contemporary communications capabilities ensure active participation by colleagues at the University of Wisconsin.

Benefits

Sustainability is a broad concept with varying definitions, and use of LCA as a tool to develop quantitative values that could be used by fish farmers is a new concept for fish farmers in the NCR. We see the following benefits from this project: 1) provision of quantitative metrics for use by fish farmers as they market their products, reassuring their customers products are sustainable; 2) identification of impact areas within aquaculture operations that can be addressed and minimized; and, 3) critical information for new producers as they consider system/species combinations and their potential markets. Data of this nature have the potential of benefiting all those involved in aquaculture in the NCR, not just targeted system or species groups.

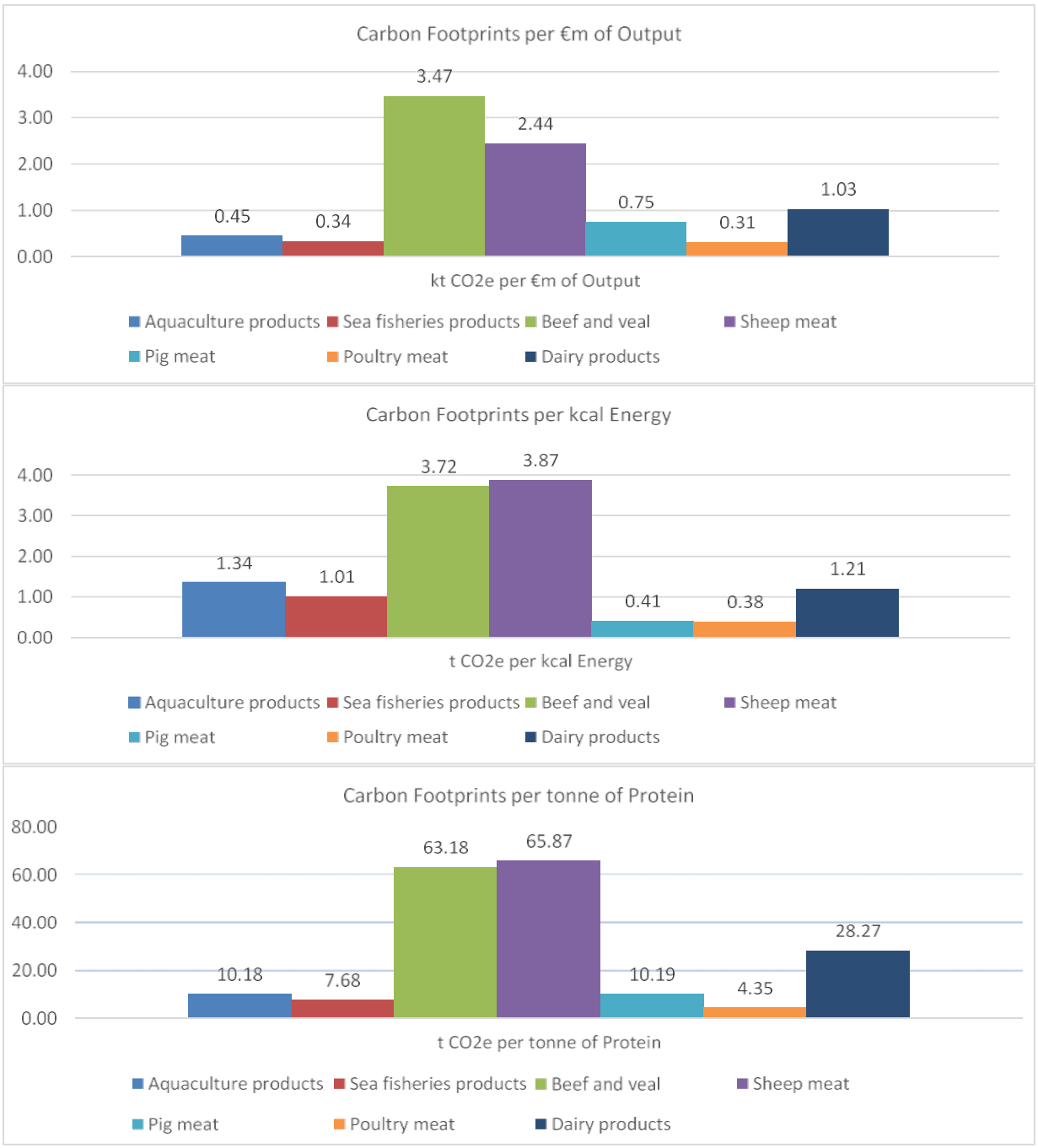

Figure 8. Impact of several protein producing industries in Ireland (Tsakiridis et al. 2020).

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Project Leaders

Name and State	Institution	Specialization
Paul Brown, IN	Purdue University	Fish Nutrition
Jen-Yi Huang, IN	Purdue University	LCA
Rob Anex, WI	University of Wisconsin	LCA - energy
Brian MacGowan, IN	Purdue University	Extension

Sustainable aquaculture: development of new quantitative metrics for use in marketing aquaculture products

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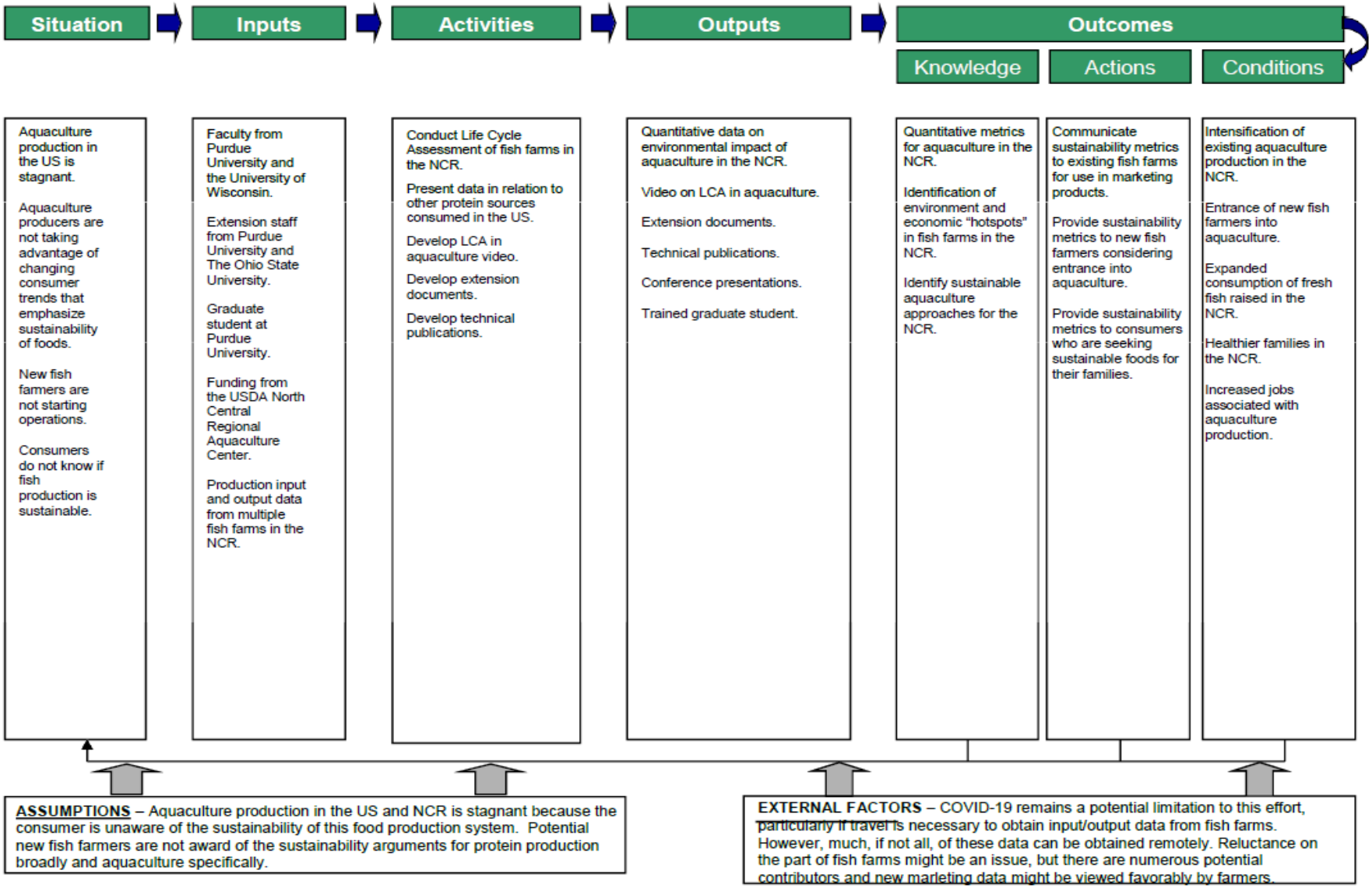

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Purdue University Sponsored Program Services 610 Purdue Mall West Lafayette, IN 47907-2040				**USDA AWARD NO.** Year 1: Objective 1 Duration Proposed Months: 12 **FUNDS REQUESTED BY PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
PRINCIPAL INVESTIGATOR (S)/PROJECT DIRECTOR (S) Paul Brown					
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. _1_ Graduate Students				$35,978	
Total Salaries and Wages . . . . . →				$35,978	
B. Fringe Benefits (If charged as Direct Costs)				$1,980	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$37,958	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$3,000	
F. Travel				$3,000	
1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.) Annual costs:					
J. Total Direct Costs (C through I) . . . . . →				$	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$43,958	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$	$
O. Cost Sharing (If Required Provide Details)					

NOTE: Signatures required only for Revised Budget This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
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BUDGET

ORGANIZATION AND ADDRESS Purdue University Sponsored Program Services 610 Purdue Mall West Lafayette, IN 47907-2040				**USDA AWARD NO.** Year 2: Objective 1	
				Duration Proposed Months: __12____	Duration Awarded Months: _____
PRINCIPAL INVESTIGATOR (S)/PROJECT DIRECTOR (S) Paul Brown				**FUNDS REQUESTED BY PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. _1_ Graduate Students				$36,479	
Total Salaries and Wages . . . . . →				$36,479	
B. Fringe Benefits (If charged as Direct Costs)				$2,019	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$38,498	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$3,000	
F. Travel				$3,000	
1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.) Annual costs:					
J. Total Direct Costs (C through I) . . . . . →				$	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$44,498	$
O. Cost Sharing (If Required Provide Details)					

NOTE: Signatures required only for Revised Budget This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

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BUDGET

ORGANIZATION AND ADDRESS Purdue University Sponsored Program Services 610 Purdue Mall West Lafayette, IN 47907-2040				**USDA AWARD NO.** Years 1 and 2: Objective 1 Duration Proposed Months: 12	Duration Awarded Months: _____
PRINCIPAL INVESTIGATOR (S)/PROJECT DIRECTOR (S) Paul Brown				**FUNDS REQUESTED BY PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. _1_ Graduate Students				$72,457	
Total Salaries and Wages . . . . . →				$72,457	
B. Fringe Benefits (If charged as Direct Costs)				$3,999	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$76,456	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$6,000	
F. Travel				$6,000	
1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.) Annual costs:					
J. Total Direct Costs (C through I) . . . . . →				$	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$88,456	$
O. Cost Sharing (If Required Provide Details)					

NOTE: Signatures required only for Revised Budget

This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS The Board of Reagents University of Wisconsin System 240 Agricultural Hall 1450 Linden Drive Madison, WI 53706-1522				**USDA AWARD NO.** Year1 1 Objective 1 Duration Proposed Months: __12____	Duration Awarded Months: _____
PRINCIPAL INVESTIGATOR (S)/PROJECT DIRECTOR (S) Rob Anex				**FUNDS REQUESTED BY PROPOSER**	**FUNDS APPROVED BY CSREES** : (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. _1__ Senior Associates			0.05	$5,539	
c. _1_ Graduate Students					
Total Salaries and Wages . . . . . →				$5,539	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →					
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies					
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.) Annual costs:					
J. Total Direct Costs (C through I) . . . . . →				$	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$5,539	$
O. Cost Sharing (If Required Provide Details)					

NOTE: Signatures required only for Revised Budget This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS The Board of Reagents University of Wisconsin System 240 Agricultural Hall 1450 Linden Drive Madison, WI 53706-1522				**USDA AWARD NO.** Year 2: Objective 1 Duration Proposed Months: __12____ **FUNDS REQUESTED BY PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
PRINCIPAL INVESTIGATOR (S)/PROJECT DIRECTOR (S) Rob Anex					
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. _1__ Senior Associates			0.05	$5,691	
c. _1_ Graduate Students					
Total Salaries and Wages . . . . . →				$5,691	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →					
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies					
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.) Annual costs:					
J. Total Direct Costs (C through I) . . . . . →				$	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$5,691	$
O. Cost Sharing (If Required Provide Details)					

NOTE: Signatures required only for Revised Budget This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

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BUDGET

ORGANIZATION AND ADDRESS The Board of Reagents University of Wisconsin System 240 Agricultural Hall 1450 Linden Drive Madison, WI 53706-1522				**USDA AWARD NO.** Years 1 and 2: 1 Objective 1 Duration Proposed Months: __12____ **FUNDS REQUESTED BY PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** : (If Different)
PRINCIPAL INVESTIGATOR (S)/PROJECT DIRECTOR (S) Rob Anex					
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. _1__ Senior Associates			0.05	$11,230	
c. _1_ Graduate Students					
Total Salaries and Wages . . . . . →				$11,230	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →					
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies					
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.) Annual costs:					
J. Total Direct Costs (C through I) . . . . . →				$	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$11,230	$
O. Cost Sharing (If Required Provide Details)					

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME AND TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		

Budget Explanation
Purdue University
(Brown, Huang, MacGowan)

Objective 1

A. Salaries and Wages: $76,456

Year 1:

Funds are requested for 1 graduate student (Ph.D., 0.5 FTE). Student will be responsible for coordinating communication among participants, identifying participating farms, collecting data, developing LCA metrics, and initiating publications. $37,958.

Year 2:

Funds are requested for 1 graduate student (Ph.D., 0.5 FTE). Student will be responsible for coordinating communication among participants, identifying participating farms, collecting data, developing LCA metrics, and initiating publications. $38,498.

B. Fringe Benefits: $3,999

Fringe benefit rate for graduate students is 7.9%.
Year 1: $1,980.
Year 2: $2,019

E. Materials and Supplies:

Supply funds are requested for computer software, replacement ink cartridges, paper and laboratory notebooks, and color copying.

Items	Year 1	Year 2	Total
Computer software	$1,250	$1,250	$2,500
Ink, paper and lab notebooks	$750	$750	$1,500
Color copy and extension document production	$500	$500	1,000
Video editing	$500	$500	$1,000
Total	$3,000	$3,000	$6,000

F. Travel (Domestic): $6,000

Year 1:

Funds are requested for travel to the World Aquaculture Society Annual Meeting and the US Chapter Annual Meeting in each year (either Brown or Huang). Estimates of cost are $1200 for airfare, $500 for motel charges, and $500 for per diem, transport from airport to motel and registration. Funds are also requested for travel to farm sites (estimated costs are $175 vehicle rental, $150 motel, and $125 per diem)

Year 2:

Funds are requested for travel to the World Aquaculture Society Annual Meeting and the US Chapter Annual Meeting in each year (either Brown or Huang). Estimates of cost are $1200 for airfare, $500 for motel charges, and $500 for per diem, transport from airport to motel and registration. Funds are also requested for travel to farm sites (estimated costs are $175 vehicle rental, $150 motel, and $125 per diem).

Budget Explanation
University of Wisconsin
(Anex)

A. Salaries and Wages: $11,230

Year 1:

Funds are requested for 1 week of Dr. Anex's time. He will be responsible for helping the graduate student with the energy component of the LCA analyses and serving on the student's graduate committee.

Year 2:

Funds are requested for 1 week of Dr. Anex's time. He will be responsible for helping the graduate student with the energy component of the LCA analyses and serving on the student's graduate committee.

Budget Summary by Participating Institutions

Objective 1, Year 1

	Purdue (Brown, Huang and MacGowan)	**UW (Anex)**	**TOTAL**
Salaries, Wages, and Fringe Benefits	$37,958	$5,539	$43,497
Equipment	--	--	--
Materials and Supplies	$3,000	--	$3,000
Travel	$3,000	--	$3,000
All Other Direct Costs	--	--	--
TOTAL	$43,958	$5,539	$49,497

Objective 1, Year 2

	Purdue (Brown, Huang and MacGowan)	**UW (Anex)**	**TOTAL**
Salaries, Wages, and Fringe Benefits	$38,458	$5,691	$44,189
Equipment	--	--	--
Materials and Supplies	$3,000	--	$3,000
Travel	$3,000	--	$3,000
All Other Direct Costs	--	--	--
TOTAL	$44,458	$5,691	$50,189

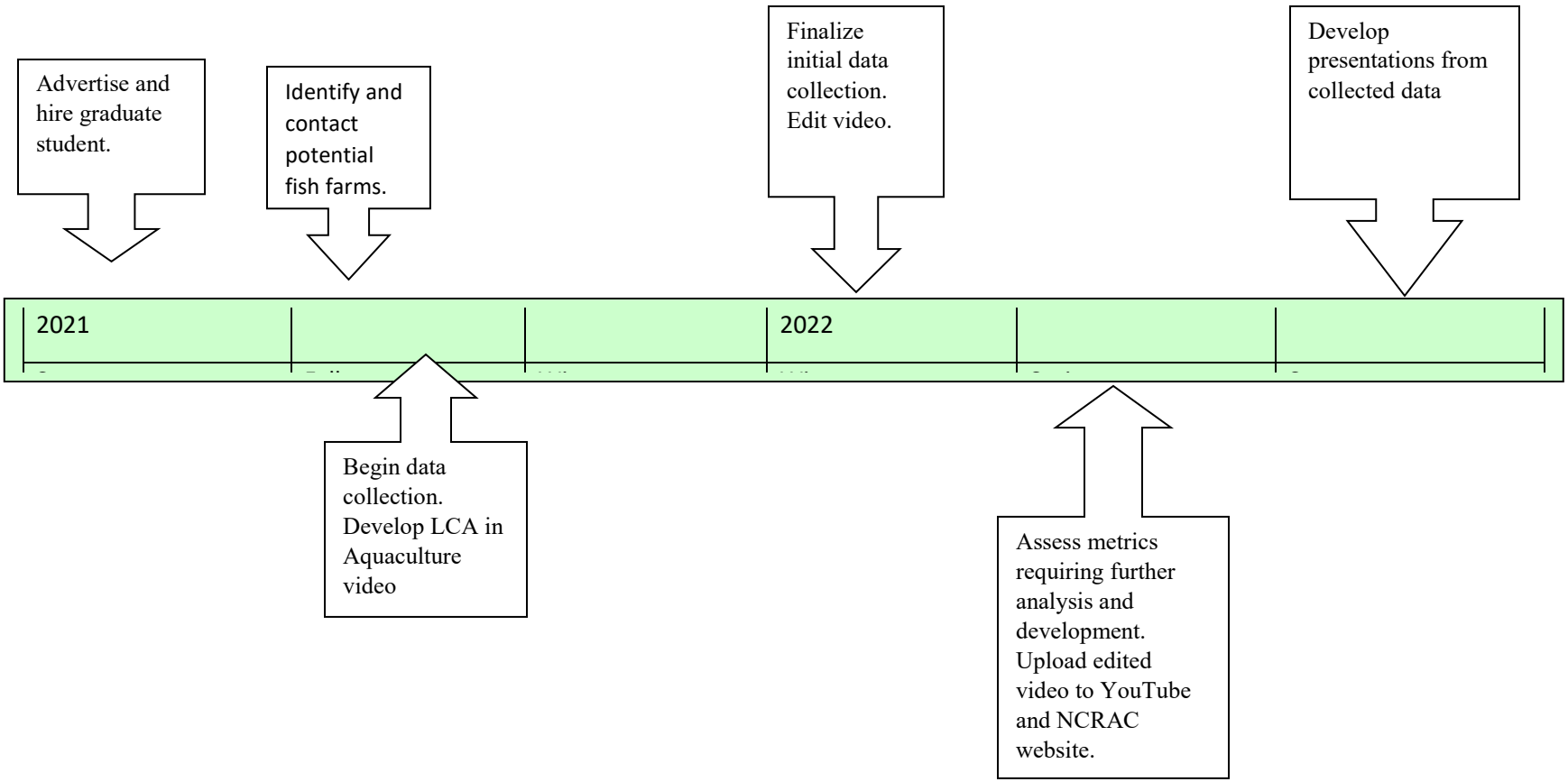
Objective 1, Years 1 and 2

	Purdue (Brown, Huang and MacGowan)	**UW (Anex)**	**TOTAL**
Salaries, Wages, and Fringe Benefits	$76,456	$11,230	$87,686
Equipment	--	--	--
Materials and Supplies	$6,000	--	$6,000
Travel	$6,000	--	$6,000
All Other Direct Costs	--	--	--
TOTAL	$88,456	$11,230	$99,686

Schedule for Objective Completion

Timeline

Sustainable aquaculture: development of new quantitative metrics for use in marketing aquaculture products



List of Principal Investigators

Purdue University
- Paul Brown
- Jen-Yi Huang
- Brian MacGowan

University of Wisconsin
- Rob Anex

VITA

Paul B. Brown
Purdue University
715 West State Street
West Lafayette, IN 47907-2061

Phone: (765) 494-4968
Fax: (765) 496-2422
E-mail: pb@purdue.edu

Education

B.S.	University of Tennessee, 1980, Wildlife and Fisheries Sciences
M.S.	University of Tennessee, 1983, Aquatic Animal Nutrition
Ph.D.	Texas A&M University, 1987, Aquatic Animal Nutrition

Positions

Professor (1997-), Associate Professor (1993-1997), Assistant Professor (1989-1993), Aquaculture Nutrition, Purdue University, Department of Forestry and Natural Resources

Scientific and Professional Organizations

American Society of Nutritional Sciences
World Aquaculture Society

Selected Publications

Chen, P., G. Zhu, Hye-Ji Kim, Paul B. Brown, Jen-Yi Huang. 2020. Comparative life cycle assessment of aquaponics and hydroponics in the midwestern United States. Journal of Cleaner Production 275:122888.

Estruch, G., S. Martinez-Llorens, A. Tomas-Vidal, R. Monge-Oetiz, M. Jover-Cerda, P.B. Brown, and D. S. Penaranda. 2020. Impact of high dietary plant protein with or without marine ingredients in gut mucosa proteome of gilthead seabream (*Sparus aurata*, L.). Journal of Proteomics 216:103672.

Minh, Hoang Le and P.B. Brown. 2016. Effects of time after hormonal stimulation on milt properties in Waigieu seaperch *Psammoperca waigiensis*. Israeli Journal of Aquaculture-Bamidegeh 68:1326-1335.

Liu, B., Z. Zhou, P.B. Brown, H. Cui, J. Xie, H.M Tsion, and X. Ge. 2016. Effects of graded levels of dietary vitamin A on the growth performance, blood composition and disease resistance in juvenile Wuchang bream (*Megalobrama amblycephala*). Aquaculture 450:23-30.

Hart, S.D., A.S. Bharadwaj and P.B. Brown. 2010. Soybean lectins and trypsin inhibitors, but not oligosaccharides or the interactions of factors, impact weight gain of rainbow trout (*Oncorhynchus mykiss*). Aquaculture 306:310-314.

Bharadwaj, A.S., S.D. Hart, B.J. Brown, Y. Li, B.A. Watkins and P.B. Brown. 2010. Dietary source of stearidonic acid promotes increased muscle DHA concentrations in hybrid striped bass. Lipids 45:21-27. doi 10.1007/s11745-009-3372-9.

Hart, S.D., B.J. Brown, N.L. Gould, M.L. Robar, E.M. Witt and P.B. Brown. 2010. Predicting optimal dietary essential amino acid profile for growth of juvenile yellow perch with whole body amino acid concentrations. Aquaculture Nutrition 16:248-253.

Gonzales, J.G. and P.B. Brown. 2007. Nutrient retention capabilities of Nile tilapia (*Oreochromis niloticus*) fed bio-regenerative life support system (BLSS) waste residue. Advances in Space Research 40:1725-1734.

Kasper, C.S., B.A. Watkins and P.B. Brown. 2007. Evaluation of two soybean meals fed to yellow perch (*Perca flavescens*). Aquaculture Nutrition 13:431-438.

VITA

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Education

B.S.	National Taiwan University, 2005, Bio-Industrial Mechatronics Engineering
M.S.	National Taiwan University, 2007, Food Science and Technology
Ph.D.	University of Cambridge, 2013, Chemical Engineering and Biotechnology

Positions
Assistant Professor (2016-), Department of Food Science, Purdue University
Assistant Professor by Courtesy (2019-), Environmental and Ecological Engineering, Purdue University Research Fellow (2013-2015), Food Science and Technology Program, National University of Singapore

Scientific and Professional Organizations
Society of Food Engineering
Institute of Food Technologist

Selected Publications

Chen, P., G. Zhu, Hye-Ji Kim, Paul B. Brown, Jen-Yi Huang. 2020. Comparative life cycle assessment of aquaponics and hydroponics in the midwestern United States. Journal of Cleaner Production 275:122888.

Chapa, J., Farkas, B., Bailey, R.L., Huang, J.-Y. 2020. Evaluation of environmental performance of dietary patterns in the United States considering food nutrition and satiety. Science of the Total Environment, 722:137672.

Lu, J., Corvalan, C.M., Huang, J.-Y. 2020. Deformation and removal of viscous thin film by submerged jet impingement. AIChE Journal, 66: e16745.

Zhang, B.Y., Tong, Y., Singh, S., Cai, H., Huang, J.-Y. 2019. Assessment of carbon footprint of nano-packaging considering potential food waste reduction due to shelf life extension. Resources, Conservation & Recycling, 149:322-331.

Salazar, M.B., Cai, H., Bailey, R., Huang, J.-Y. 2019. Defining nutritionally and environmentally healthy dietary choices of omega-3 fatty acids. Journal of Cleaner Production, 228:1025-1033.

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Suwal, S., Coronel-Aguilera, C.P., Auer, J., Applegate, B., Garner, A.L, Huang, J.-Y. 2019. Mechanism characterization of bacterial inactivation of atmospheric air plasma gas and activated water using bioluminescence technology. Innovative Food Science & Emerging Technologies, 53:18-25.

Suwal, S., Li, J., Engelberth, A.S., Huang, J.-Y. 2018. Application of electro-membrane separation for recovery of acetic acid in lignocellulosic bioethanol production. Food and Bioproducts Processing, 109:41-51.

Robert P. Anex
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Madison, WI 53726 E-mail: anex@wisc.edu

Education

B.S.	University of California, Davis, 1981, Mechanical Engineering
M.S.	University of California, Davis, 1983, Mechanical Engineering
Ph.D.	University of California, Davis, 1995, Environmental Engineering

Positions

Professor (2010-), University of Wisconsin-Madison, Department of Biological Systems Engineering
Professor (2010), Associate Professor (2003-2009), Iowa State University, Department of Agricultural and Biosystems Engineering
Associate Professor (2002-2003), Assistant Professor (1996-2002), University of Oklahoma, School of Aerospace & Mechanical Engineering, and Science & Public Policy Program
Section Head (1989-1991), Senior Engineer (1987-1989), Engineer (1983-1987), Systems Control Technology, Palo Alto, CA

Scientific and Professional Organizations

International Society for Industrial Ecology
American Society of Agricultural and Biological Engineers

Selected Publications

Ortiz-Reyes, E., and R. P. Anex. 2019. Life cycle environmental impacts of non-cellulosic fermentable carbohydrates for the production of biofuels and chemicals. International Journal of Life Cycle Assesssment 25:548-563.

Ortiz-Reyes, E., and R. P. Anex. 2018. A life cycle impact assessment method for freshwater eutrophication due to the transport of phosphorus from agricultural production. Journal of Cleaner Production 177: 474-482.

Gunukula, S. and R. Anex. 2017. Evaluating and guiding the development of sustainable biorenewable chemicals with feasible space analysis. Biochemical Engineering Journal 119:74-83.

Gunukula, S. and R. Anex. 2016. Risk advantages of platform technologies for biorenewable chemical production. Chemical Engineering Research and Design 107:24-33.

Anex, R.P. and R. Lifset. 2014. Life Cycle Assessment: different models for different purposes. Journal of Industrial Ecology 18: 321-323.

Christiansen, K. L., D. R. Raman, and R. P. Anex. 2012. Predicting growth and performance of first-generation algal production systems. Energy Policy 51:382-391.

VITA

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Education

B.S. Ohio State University, 1995, Natural Resources
M.S. Purdue University 1998, Wildlife Science

Positions

Extension Coordinator (2015-), Extension Co-Coordinator (2007-2015), Extension Wildlife Specialist (1999-), Graduate Teaching Assistant (1996-1998), Purdue University, Department of Forestry and Natural Resources

Scientific and Professional Organizations

The Wildlife Society
International Association for Society and Natural Resources
Purdue University Cooperative Extension Specialists Association

Selected Publications

MacGowan, B. J., A. S. Singh, B. Overstreet, M. O'Donnell, H. Klotz, and L. S. Prokopy. 2018. Designing Demonstration Events – Producer's Opinions and Preferences. Journal of Extension, 16269RIB.

Singh, A. S., B. J. MacGowan, J. D. Ulrich-Schad, M. Dunn, M. O'Donnell, H. Klotz, B. Overstreet, and L. S. Prokopy. 2018. The influence of demonstration sites and field days on adoption of conservation practices. Journal of Soil and Water Conservation, 73(3):276-283.

V. Hale, B. J. MacGowan, L. Corriveau, D. Huse, A.F.T. Currylow, and S. Thompson. 2017. Radio Transmitter Application in the Wild Timber Rattlesnake, *Crotalus horridus*. Journal of Wildlife Diseases 53(3):591-595.

MacGowan, B.J., Currylow, A.F.T., and MacNeil, J.E. 2017. Short-term responses of Timber Rattlesnakes (*Crotalus horridus*) to even-aged timber harvests in Indiana. Forest Ecology and Management 387(1):30-36. https://doi.org/10.1016/j.foreco.2016.05.026

Olson, Z.H., B.J. MacGowan, M.T. Hamilton, A.F.T. Currylow, and R.N. Williams. 2015. Survival of timber rattlesnakes: Investigating individual, environmental, and ecological effects. Herpetologica 71:274-279.

Carlton, J.S., Angel, J.R., Fei, S., Huber, M., Koontz, T., MacGowan, B.J., Mullendore, N.D., Babin, N., and L.S. Prokopy. 2014. State service foresters' attitudes toward using climate and weather information when advising forest landowners. Journal of Forestry 112(1):9-14.

LaGrange, S., Kimble, S.J, MacGowan, B.J. and Williams, R.N. 2014. Seasonal variance in hematology and blood plasma chemistry values of the timber rattlesnake (*Crotalus horridus*). Journal of Wildlife Diseases 50(4):990-993.

Currylow, A.F., B.J. MacGowan, and R.N. Williams. 2012. Hibernal thermal ecology of eastern box turtles within a managed forest landscape. Journal of Wildlife Management 77(2):326-335.

Currylow, A.F., B.J. MacGowan, and R.N. Williams. 2012. Short-term forest management effects on a long-lived ectotherm. PLoS ONE 7(7):e40473.

Liaison Letter of Intent

In accordance with the Guidelines for Extension Involvement in the North Central Regional Aquaculture Center (adopted in 1994), directives of the NCRAC Board of Directors and USDA-NIFA guidance, all NCRAC-funded projects must include an Extension Liaison that is funded to do extension and outreach activities associated with that project. NCRAC projects must also include an Industry Liaison who will serve as a contact between project PI(s) and the industry.

Name (Appointed Liaison): Matthew A. Smith

Title of Project: Sustainable aquaculture: development of new quantitative metrics for use in marketing aquaculture products

Project Duration: September 1, 2021 – August 31, 2023

The conditions and terms of the offer being made to you are outlined below:

Position (Extension or Industry): Extension

Primary Duties/Activities of Liaison: Work with research, industry liaison, and Purdue's wildlife specialist to develop educational videos and additional outreach tools producers can use to educate their consumers.

Appointment offered by: Dr. Paul Brown

Project Chair **Date**

Offer approved by:

NCRAC

Director
Date

I have read and I understand the offer and its terms and conditions, and I agree to these terms and accept this offer. The terms of this offer may be modified only by subsequent written agreement signed by both parties.

Liaison Signature: Matthew Smith

October 5, 2020

Date

October 5, 2020

IOWA STATE UNIVERSITY
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Liaison Letter of Intent

In accordance with the Guidelines for Extension Involvementin the North Central Regional Aquaculture Center (adopted in 1994), directives of the NCRAC Board of Directors and USDA-NIFA guidance, all NCRAC -fonded projects must include an Extension Liaison that is funded to do extension and outreach activities associated with that project. NCRAC projects must also include an Industry Liaison who will serve as a contact between project Pl(s) and the industry.

Name (Appointed Liaison): Dan Mosier -

Title of Project: Sustainable aquaculture: development of new quantitative metrics for use in marketing aquaculture products

Project Duration: September 1, - August 31 2023

The conditions and terms of the offer being made to you are outlined below:

Position (Extension or Industry)-: Industry_____ _

Primary Duties/Activities of Liaison: Work with the researchers and extension to ensure proposed work is meaningful and relatable to the industry; along with assisting them with gathering any necessary farm-baseddata. Work with extension to ensure deliverables are meaningful, accurate, and geared towards the correct audiences.

Appointment offered by: Dr. Paul Brown — October 5, 2020

Project Chair — Date

Offer approved by.___ _

NCRAC Director — Date

I have read and I understand the offer and its terms and conditions, and I agree to these terms and accept this offer. The terms of this offer maY, e m6'dified only by subsequent written agreement signed by both parties.

Liaison Signature: _ ---'/- _____ October 5, 2020 - - - - - - - -

Date

Please return this letter by: October 19[1], 2020 to the Project Chair.

TIPPCO FISH, INC PO Box 201

Romney, IN 47981

Dr. Paul Brown

Professor of Fisheries and Aquatic Sciences Department of Forestry and Natural Resources

195 Marsteller St.

West Lafayette, IN 47907

Dear Dr. Brown,

As an owner of a RAS tilapia production farm in Indiana, I would like to voice my support of the proposed research project, *Sustainable aquaculture: development of new quantitative metrics for use in marketing aquaculture products*. TIPPCO FISH has been in operation for 8 years in Romney, Indiana.

The domestic aquaculture industry has many challenges when competing with imported products. Learning more about the sustainability of various aquaculture methods may help give local produced products an advantage over imported products. Having research data available can also help farmers make informed decisions on the operation of their business.

This project will hopefully give local farmers data to substantiate the claim that our products are locally produced and sustainable. Any information that adds value to our products is a great help in competing against cheaper imported products.

Sincerely,

Phillip Shambach TIPPCO FISH, CEO

1681 South 7 ½ Road, Harrietta, MI 49638

Phone: (231) 389-2514 / Fax: (231) 389-2513

dan@harriettahills.com

Dr. Paul Brown

Purdue University, Department of Forestry and Natural Resources 195 Marsteller St.

West Lafayette, IN 47907

July 1, 2020

Dr. Brown,

This letter is in support of your proposed NCRAC project "Sustainable Aquaculture: development of new quantitative metrics for use in marketing aquaculture products".

As a trout producer that has been involved in marketing aquaculture products as food for consumers for over 23 years, the question of "Sustainability" of aquaculture in the United States has had profound impacts on our business throughout my career. Developing the necessary social license for aquaculture to thrive in the NCR and the United States requires efforts to quantify and define "sustainability" so that this information can be used to not only guide production practices, but also to communicate with consumers, regulators and other interested parties.

This project looks like a step in the right direction, although additional work in this area will need to be done. We support this effort and hope that this project will be successful in receiving NCRAC funding.

Sincerely,

Dan Vogler

President

To Whom it may concern:

I am writng this letter in support of the USDA NCRAC proposal

Sustainable aquaculture: development of new quan7ta7ve metrics for use in marke7ng aquaculture products

developed by Paul Brown, Jen-Yi Huang, & Rob Anex.

I am a shrimp farmer in Fowler, IN and have been raising marine shrimp for 10 years. I have also set up marine shrimp farms in 10 countries and 10 states in the US. Sustainability is an important term with our customers and we do not see much research in this area. This proposal seems headed in the right direc2on for us, our customers and for new shrimp farmers considering entrance into this industry. We hope you will give this proposal serious considera2on.

Thank you

Karlanea Brown

Co/Owner - VP of Opera2ons

RDM Aquaculture LLC

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Checklist for Submission of Pre-Proposals for Standard Proposals

___X_ Follow guidelines with the exception of the budget sheets

___X___ Format manuscripts for 22 x 28 cm (8½ x 11 inch).

___X___ Number *all* pages sequentially.

___X___ Use 10-12 font; Times New Roman. Do not justify right margins.

___X___ Format headings appropriately

___X___ Leave at least a 2.5-cm (1-inch) margin on all sides.

__X__ Use metric units of measurement with English units in parenthesis, e.g., 2.54 cm (1 inch).

__X__ Define all abbreviations the first time they are used.

__X__ Express ratios by using a slant line (e.g., mg/L).

__X___ Scientific names should accompany common names in the title and when they are first mentioned in the abstract and in the text. Authority for scientific names need not accompany the genus and species unless needed for clarity.

__X__ Spell out one to ten unless followed by a unit of measurement (e.g., four fish, 4 kg, 14 fish). Do not begin a sentence with a numeral. Use 1,000 instead of 1000; 0.13 instead of .13; and % instead of percent.

__X__ Use the 24-hour clock for dial time: 0830, not 8:30 a.m. Calendar date should be day month year (7 August 1990).

__X__ Assemble the manuscript in this order: Title Page, Project Summary, Objective(s), Approach, Facilities, Budget, and Curriculum Vitae for Principal Investigators (PIs).

_X__ Three *Letters of Support* (not directly associated with the project) from commercial industry members or associations are required to provide additional evidence of the benefits to the aquaculture industry of the proposed project.

__X__ All identified co- PIs have been provided a final draft of the pre-proposal.

__X__ Submit in Word and PDF formats.

If the NCRAC Administrative Office cannot verify inclusion of any element, the Pre-Proposal will not be accepted.

10/30/20

Principal Investigator Signature Date