North Central Regional Aquaculture Center

Annual Progress Report 2018-19

January 2020

29th Annual Progress Report

For the Period
September 1, 2018 to August 31, 2019

North Central Regional Aquaculture Center

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Introduction

The U.S. aquaculture industry generated nearly $1.4 billion for over 3,000 producers in 2013 (USDA 2014). Though minor in a global context, accounting for 0.73% of total world value in 2015 (FAO 2017), the domestic impact of U.S. aquaculture is substantial, accounting for approximately almost 20% of the total U.S. seafood production (NOAA 2018). Yet, anticipated growth in the industry, both in magnitude and in species diversity, continues to fall short of expectations in many regions of the U.S.

Much of what is known about aquaculture science is a result of institutional attention given to our traditional capture of wild fisheries with the goal of releasing cultured fishes into public waters for enhancement of declining public stocks. Despite extensive efforts to manage wild populations for a sustained yield, as a nation we consume substantially greater amounts than we produce. Much of the United States' demand for seafood continues to be met by imports. The U.S. imports a majority of its fish and shellfish and is currently the world's largest importer of edible seafood (valued at $21.5 billion in 2017; FAO 2017, NOAA 2018). Fish and shellfish imports are the second largest contributor to the U.S. trade deficit among agricultural products (USDA 2016). In 2017, the trade deficit was nearly $14.1 billion for edible fishery products.

Landings for most U.S. commercial capture fisheries species and recreational fisheries have been relatively stable during the last decade, with many fish stocks being overexploited. In this situation, aquaculture provides an opportunity to reduce the trade deficit and meet the rising U.S. demand for fish products. This can be achieved by a partnership of the Federal government, State and local public institutions, and the private sector with expertise in aquaculture development.

The U.S. Congress has stressed the importance of a strong domestic aquaculture industry to: (1) increase American production of fish and shellfish, (2) reduce dependence on foreign suppliers, and (3) benefit rural America by the development of alternative agricultural crops and creation of new jobs. Recognizing that the aquaculture industry cannot achieve full potential without strong national leadership and direction, the U.S. Congress created an opportunity for making significant progress in aquaculture development in 1980 by passage of the National Aquaculture Act -362). This act addressed the importance of a strong domestic aquaculture industry and established the Joint Subcommittee on Aquaculture (JSA). The JSA is an interagency body that is chaired by the Secretary of Agriculture. It has numerous responsibilities and is to provide coordination and recommendations for Federal aquaculture policy. The Congress also amended the National Agricultural Research, Extension, and Teaching Policy Act of 1977 in Title XIV of the Agriculture and Food Act of 1980 (P.L. 97-98) by granting authority to USDA to establish aquaculture research, development, and demonstration centers in the United States in association with colleges and universities, State Departments of Agriculture, Federal facilities, and non-profit private research institutions. Five such centers have been established: one in each of the northeastern, north central, southern, and western regions, and one in Hawaii. As used here, a Center refers to an administrative center currently funded through USDA National Institute of Food and Agriculture (NIFA). Centers do not provide monies for brick-and-mortar development.

Centers encourage cooperative and collaborative aquaculture research and extension educational programs that have regional or national application. Center programs complement and strengthen other existing research and extension educational programs provided by USDA and other public institutions. As a matter of policy, centers implement their programs by using institutional mechanisms and linkages that are in place in the public and private sector.

The mission of the RACs is to support aquaculture research, development, demonstration, and extension education to enhance viable and profitable U.S. aquaculture, which will benefit consumers, producers, service industries, and the American economy. The North Central Regional Aquaculture Center (NCRAC) serves as a focal point to assess needs, establish priorities, and implement research and extension educational programs in the 12-state agricultural heartland of the United States. NCRAC also provides for coordination of interregional and national programs through USDA's National Coordinating Council for Aquaculture (NCCA). The council is composed of the RAC directors and USDA personnel.

Organization Structure

In the period of 1988 through 2011, Michigan State University (MSU) and Iowa State University (ISU) worked together to develop and administer programs of NCRAC through a memorandum of understanding. MSU was the prime contractor for the Center and had administrative responsibilities for its operation; ISU administered the extension/outreach activities for the Center. In 2012 NCRAC became solely administered by Iowa State University where the Office of the Director is now located.

Funds to operate NCRAC are granted by the USDA-NIFA USDA-National Institute of Food and Agriculture (NIFA) to ISU. ISU disperses funds and serves as legal and fiscal agent in the receipt and disbursement of funds. The Center at ISU also coordinates implementation and operation of individual projects as agreed upon by the Board of Directors as well as fiscal and technical reporting to the USDA-NIFA.

The staff of NCRAC at ISU included Joseph E. Morris, Director, Denise Birney, Administrative Specialist II, and Stephen Grausgruber, Graduate Extension Assistant for regional programming in 2018/19. In 2018 the NCRAC Director's NCRAC appointment decreased to 70% with the additional institution duties serving as Iowa State University Extension Specialist. Also, Denise Birney resigned in July 2019 and Quinn Zuercher was appointed as Administrative Specialist I in August 2019.

The Center Director has the following responsibilities (0.40 FTE [current grant], 30% of salary is from previous grants [FY16-FY18] for 70% NCRAC appointment):

- Develop and submit proposals to USDA-NIFA which, upon approval, becomes a grant to the Center;
- Coordination the development of research and extension projects including Work Group formation, review of project outlines for technical and scientific merit, feasibility, and applicability to priority problems and then submission to the Board of Directors for their approval after which, Board-approved project outlines are submitted to USDA-NIFA for approval in a Plan of Work or an Amendment to a Plan of Work;
- Oversee the development of appropriate agreements (sub-contracts) by the Administrative Assistant for purposes of transferring funds for implementation of all projects approved under the grants;
- Serve as executive secretary to the Board of Directors, responsible for preparing agenda and minutes of Board meetings;
- Serve as an ex-officio (non-voting) member of the TC and IAC;
- Coordinate and facilitate interactions among the Administrative Center, Board of Directors, IAC, and TC;
- Monitor research and extension activities;
- Recruit other Administrative Center staff as authorized by the Board of Directors;
- Serve as an additional source of technical information for the regional aquaculture community;
- Maintain liaison with other RACs; and
- Serve on USDA's National Coordinating Council for Aquaculture.

The Administrative Specialist II (0.70 FTE [current grant], 30% of salary is from previous grants [FY16-FY18] for 100% NCRAC appointment) has the following responsibilities:

- Schedule meetings, make travel arrangements, attend meetings and take minutes;
- Maintain the administrative calendar;
- General office management, prepare correspondence;
- Answer or direct inquiries appropriately relating to aquaculture in general and the Center in particular;
- Compile information for periodic reports to the Center's Board of Directors and maintain records of Board business;
- Assist in preparation of Center reports to USDA-NIFA, including annual reports and plans of work;
- Maintain database of persons interested, involved with, or who should be kept informed of the Center's activities;
- Monitor Web site and keep Director and Program Specialist updated on changes/additions;
- Assist with grant application (pre-award);
- Maintain and monitor all budgetary matters for both the Center and sponsored projects including developing and monitoring sub-contracts with other parties for purposes of transferring funds for implementing all approved projects (post-award); and
- Manage procurement and travel for NCRAC.

The Graduate Extension student (0.5 FTE) has the following responsibilities:

- Interaction with associated information technology staff at Iowa State University regarding the NCRAC Web site;
- Regional Extension meetings;
- Regional presentations;
- Representation on NCRAC TC as Iowa's representative on extension;
- Preparation of impact statements resulting from NCRAC-funded extension projects;
- Maintain the NCRAC video collection and distribution;
- Initial editing of "final" draft of new NCRAC publications;
- Review and prepare responses to e-mail requests sent to NCRAC@iastate.edu; and
- Help with technical and logistical support for the NCRAC Annual Program Planning Meetings.

The Board of Directors (BOD) is the primary policy-making body of the NCRAC. The BOD has established an Industry Advisory Council (IAC) and Technical Committee (TC). Membership of the BOD consists of four persons from the IAC, a representative each from the North Central Regional Association of State Agricultural Experiment Station Directors and the North Central Cooperative Extension Association, a member from a non-land grant university, representative from the university (Iowa State University) responsible for the Center, a member from a 1890 institution, and chairs of the two subcommittees of the Center's Technical Committee. The IAC is composed of representatives from each state's aquaculture association and six at-large members appointed by the BOD who represent various sectors of the aquaculture industry and the region as a whole. The TC is composed of a sub-committee for Extension (TC/E) and a sub-committee for Research (TC/R). Directors of the Cooperative Extension Service and Experiment Station Directors within the North Central Region appoint representatives to the TC/E and TC/R, respectively. The TC/R has broad regional make-up and is composed of scientists from universities and state agencies with varied aquacultural expertise who are appointed by the BOD. Each sub-committee of the TC has a chairperson who serves as a member of the BOD.

NCRAC functions in accordance with its *Operations Manual* located on the NCRAC web site https://www.ncrac.org/ which is periodically amended and updated with BOD approval. It is an evolving document that has changed as the Center's history lengthens. It is used for the development of the cooperative regional aquaculture and extension projects that NCRAC funds.

Administrative Operations

Since the inception of NCRAC on February 1, 1988, the role of the Administrative Center has been to provide all necessary support services to the BOD, IAC, TC, and project work groups for the North Central Region as well as representing the region on the NCC. As the scope of the NCRAC programs expand, this has entailed a greater work load and continued need for effective communication among all components of the Center and the aquaculture community.

The Center functions in the following manner.

- After BOD approval of Administrative Center costs, the Center submits a grant to USDA/NIFA/Grants Management Branch for approval. To date the Center has received 31 grants from USDA for FY88 (Grant #88-38500-3885), FY89 (Grant #89-38500-4319), FY90 (Grant #90-38500-5008), FY91 (Grant #91-38500-5900), FY92 (Grant #92-38500- 6916), FY93 (Grant #93-38500-8392), FY94 (Grant #94-38500-0048), FY95 (Grant #95-38500-1410), FY96 (Grant #96-38500-2631), FY97 (#97-38500-3957), FY98(#98-38500-5863), FY99 (#99-38500-7376), FY00 (#00-38500- 8984), FY2001 (#2001-38500-10369), FY2002 (#2002-38500-11752), FY2003 (#2003-38500-12995), FY2004 (#2004-38500-14269), FY2005(#2005-38500- 15847), FY2006 (#2006-38500-16900), FY2007 (#2007-38500-18569), FY2008 (#2008-38500-19157), FY2009 (#2008- 38500-19157 extension) FY2010 (#2010-38500-20929), FY2011 (#2010-38500-20929 Amendment), FY2012 (2012-38500-19550), FY2013 (#2012- 38500-19550 Amendment), FY2014 (2014-38500-22138), FY2015 (2014-38500-19550 Amendment), FY2016 (2016-38500-25753), FY2017 (2016-38500-25753 Amendment), and FY18 (2018-38500-28887) with monies totaling $23,139,051. Currently, two 2-year grants are active (FY16 and18); the first 27 grants (FY88-14) have terminated and final reports provided to USDA-NIFA. The Center annually coordinates a biannual program planning meeting which typically sets priorities for the next 2-year funding cycle and calls for development of project outlines to address priority problem areas.

- Work Groups are formed which submit project outlines to the Center. The projects are peer reviewed by experts from both within and outside the region and a Project Review Committee.
- In 2016, the Center developed a new grant development process that includes RFP for Pre-Proposal, Instructions for Submission of the full proposals, and Rapid Response Proposals for short-term projects.
- All pre-proposal outlines are initially reviewed by the Executive Committees of the IAC and TC/R, and TC/E (10 members). Reviews are provided to the NCRAC Board to select which proposals to accept for submission as full proposals. Full Proposals are then peer reviewed by individuals who are well qualified for a particular project because of their expertise and interests. Project outlines are mailed to three-four five reviewers within and outside the twelve state North Central Region. Final selection of projects to be submitted to USDA-NIFA for funding is done by the NCRAC Board with one final review done by the NCRAC community during the annual NCRAC meeting.
- The Out-of-Cycle Proposals are reviewed by the Executive Committees of the IAC and TC/R and TC/E (10 members); outside reviewers can be done if directed by the Executive Committee. Those that are approved for funding are asked to submit revised project outlines incorporating BOD, Project Review Committee, and reviewers' comments (if any).
- The Center then submits the revised project outlines as a Plan of Work (POW) to USDA for approval.
- Once a POW is approved by USDA, the Center then prepares subcontracts for each participating institution. The Center receives all invoices for sub contractual agreements and prepares payment vouchers for reimbursement. Thus, Center staff serve as fiscal agents for both receiving and disbursing funds in accordance with all terms and provisions of the grants.

Through January 1, 2020, the Center has funded or is funding 137 projects through the first 28 grants received. Funding for these Center- supported projects is summarized in Table 1 below (pages 9-13). Information about funded projects is also available at the Center's Web site (http://www.ncrac.org). During this reporting period, the Publications Office at ISU produced and distributed a number of publications including fact sheets, technical bulletins, and videos. A complete list of all publications from this office is included in the on-line Appendix under Extension.

Other areas of support by the Administrative Office during this reporting period included: monitoring research and extension activities and developing progress reports; developing liaisons with appropriate institutions, agencies and clientele groups; soliciting, in coordination with the other RACs, written testimony for the U.S. House Appropriations Subcommittee on Agriculture, Rural Development, Food and Drug Administration, and Related Agencies and the U.S. Senate Appropriations Subcommittee on Agriculture, Rural Development, and Related Agencies; participating in the NCA; numerous oral and written presentations to both professional and lay audiences; working with other fisheries and aquaculture programs throughout the North Central Region; and maintaining the NCRAC Web site.

Project Reporting

As indicated in Table 1, NCRAC has funded a number of projects for many of the project areas it has selected for research and extension activities. For example, there have been 31 separately funded projects in regard to Extension/education and 12 on Yellow Perch. Project outlines have been written for each separate project within an area, or the project area itself if only one project. These project outlines have been submitted in POWs or amendments to POWs for the grants as indicated in Table 1. Many times, the projects within a particular area are continuations of previously funded activities while at other times they are addressing new objectives. Presented below are Progress Reports for projects that were underway or completed during the period September 1, 2018 to August 31, 2019. Projects, or Project components, that terminated prior to September 1, 2017 have been reported on in earlier documents (e.g., 1989-1996 Compendium Report and other Annual Progress Reports). The following reports are placed in order of selected key word(s): Aquaculture Drugs, Aquaponics, Baitfish, Conferences/Workshops, Crayfish, Economics/Marketing, Extension, Hybrid Striped Bass, Largemouth Bass, National Coordinator for Aquaculture, Nutrition/Diets, Other, Salmonids, Sunfish, Tilapia, Viral Hemorrhagic Septicemia, Walleye, Wastes/Effluents, and White Papers. In addition, the format style of these reports differs from previous years, e.g., inclusion of Project Summary and Impacts Summary.

A cumulative list of all publications, manuscripts, papers presented, or other outputs for all funded NCRAC project areas is located at https://www.ncrac.org/.

Table 1. North Central Regional Aquaculture Center-Funded Projects.

Project Area	Project Number	Funding Level	Proposed Duration	Grant Number	
Aqua Drugs	1	$27,000	7/1/96-6/30/97	95-38500-1410	
	2	$950	12/1/96-11/30/97	95-38500-1410	
	3	$8,415	10/1/99-9/30/00	97-38500-3957	
	4	$223,677	6/1/04-11/30/05	2003-38500-12995	
	5	$60,000	7/15/04-7/14/05	2003-38500-12995	
	6	$50,000	11/1/04-10/31/06	2002-38500-11752	
	7	$129,936	1/1/06-12/31/06	2005-38500-15847	
	8	$150,000	9/1/08-8/31/10	2008-38500-19157	
	9	$27,880	9/1/09-8/31/10	2008-38500-19157	
	10	$100,000	9/1/11-8/31/31	2010-38500-20929	
	11	$240,000	9/1/12-8/31/14	2012-38500-19550	
Total		**$1,017,858**			7.40%
Aquaponics	1	$24,596	7/1/16-6/30/17	2014-38500-22138	
Total		**$24,596**			0.18%
Baitfish	1	$61,973	9/1/92-8/31/94	92-38500-6916	
	2	$111,997	9/1/06-8/31/08	2006-38500-16900	
	2	$88,003	9/1/06-8/31/08	2005-38500-18547	
Total		**$261,973**			1.90%
Conf./Wrkshp					
Env. Strategies Symp.	1	$5,000	9/1/00-5/31/01	96-38500-2631	
Nat. Aqua. Ext. Conf.	1	$3,005	10/1/91-9/30/92	89-38500-4319	
	2	$3,700	12/1/96-11/30/97	95-38500-1410	
	3	$4,500	11/1/02-10/31/03	00-38500-8984	
	4	$5,000	1/1/06-12/31/06	2005-38500-18547	
	5	$5,000	9/1/10-8/31/11	2008-38500-19157	
NCR Aqua. Conf.	1	$7,000	6/1/90-3/31/91	90-38500-5008	
	2	$3,000	12/9/98-6/30/99	96-38500-2631	
Percis III	1	$4,000	11/1/02-10/31/03	00-38500-8984	
Total		**$40,205**			0.29%
Crayfish	1	$49,677	9/1/92-8/31/94	92-38500-6916	
Total		**$49,677**			0.36%
Economics/Mkt	1	$127,338	5/1/89-12/31/91	88-38500-3885	
	1	$34,350	5/1/89-12/31/91	89-38500-4319	
	2	$53,300	9/1/91-8/31/92	91-38500-5900	
	3	$40,000	9/1/93-8/31/95	93-38500-8392	
	4	$47,916	9/1/99-8/31/01	97-38500-3957	
	5	$50,000	9/1/03-8/31/04	2002-38500-11752	

Project Area	Project Number	Funding Level	Proposed Duration	Grant Number	
	6	$23,565	9/1/10-8/31/11	2010-38500-20929	
	7	$75,276	9/1/12-8/31/14	2012-38500-19550	
	8	$198,608	7/1/2019-6/30/2021	2016-38500-25753	
Total		**$650,353**			4.73%
Base Ext	1	$39,221	5/1/89-4/30/91	88-38500-3885	
	1	$37,089	5/1/89-4/30/91	89-38500-4319	
	2	$31,300	3/17/90-8/31/91	89-38500-4319	
	3	$94,109	9/1/91-8/31/93	91-38500-5900	
	4	$110,129	9/1/93-8/31/95	91-38500-5900	
	5	$10,813	9/1/95-8/31/97	92-38500-6916	
	5	$20,391	9/1/95-8/31/97	95-38500-1410	
	6	$38,000	9/1/97-8/31/99	97-38500-3957	
	7	$94,000	9/1/99-8/31/01	99-38500-7376	
	8	$28,500	9/1/01-8/31/03	99-38500-7376	
	8	$18,154	9/1/01-8/31/03	2001-38500-10369	
	9	$28,000	9/1/03-8/31/05	2002-38500-11752	
	10	$211,545	9/1/05-8/31/07	2003-38500-12995	
	10	$7,735	9/1/05-8/31/07	2005-38500-15847	
	11	$21,850	9/1/07-8/31/09	2006-38500-16900	
	11	$92,469	9/1/07-8/31/09	2007-38500-18469	
	12	$37,966	9/1/08-8/31/10	2007-38500-18469	
	12	$22,539	9/1/08-8/31/10	2008-38500-19157	
	13	$29,000	9/1/09-8/31/11	2008-38500-19157	
	14	$35,700	9/1/11-8/31/13	2010-35800-20929	
	15	$45,000	9/1/13-8/31/15	2012-38500-19550	
	16	$23,175	9-1-15-8-31-16	2012-38500-19550	
	17	$50,000	9/1/16-8/31/18	2014-38500-22138	
Total		**$1,126,685**			8.19%
AREF	18	$100,000	9/1/03-8/31/05	2002-38500-11752	
Total		**$100,000**			0.73%
RAES	19	$199,624	9/1/05-5/31/09	2004-38500-14269	
	20	$150,000	9/1/09-8/31/11	2008-38500-19157	
	21	$196,612	9/1/11-8/31/13	2010-38500-20929	
	22	$101,820	9/1/13-8/31/14	2012-38500-19550	
	23	$103,347	9/1/14-8/31/16	2014-38500-22138	
	24	$124,993	9/1/16-8/31/18	2014-38500-22138	
Total		**$876,396**			6.37%
Other Ext.	25	$34,950	7/1/16-6/30/17	2014-38500-22138	
	26	$34,977	7/1/16-6/30/17	2014-38500-22138	
	27	$70,000	9/1/16-8/31/18	2014-38500-22138	
	28	$188,036	7/1/17-6/30/19	2016-38500-25753	

Project Area	Project Number	Funding Level	Proposed Duration	Grant Number	
	29	$151,739	7/1/17-6/30-19	2016-38500-25753	
	30	$150,000	10/1/2018-9/0/2020	2016-38500-2573	
	31	$132,368	10/1/2018-9/0/2020	2016-38500-2573	
Total		**$762,070**			5.54%
Total Ext.		**$2,865,151**			20.83%
Hybrid Striped Bass	1	$68,296	5/1/89-8/31/91	88-38500-3885	
	1	$68,114	5/1/89-8/31/91	89-38500-4319	
	2	$101,000	6/1/90-8/31/92	90-38500-5008	
	3	$96,550	9/1/91-8/31/93	91-38500-5900	
	4	$168,000	9/1/93-8/31/95	93-38500-8392	
	5	$150,000	9/1/95-8/31/97	95-38500-1410	
	6	$15,000	6/1/99-5/31/00	96-38500-2631	
	7	$98,043	9/1/01-5/31/04	98-38500-5863	
		$211,957	9/1/01-5/31/04	2001-38500-10369	
Total		**$976,960**			7.10%
Largemouth Bass	1	$170,000	9/1/05-5/31/07	2004-38500-14269	
	2	$155,000	9/1/14-8/31/16	2014-38500-22138	
Total		**$325,000**			2.36%
INADs/NADs	1	$55,241	9/1/93-5/14/00	89-38500-4319	
	2	$89,000	7/15/04-5/14/09	2003-38500-12995	
Total		**$144,241**			1.05%
Nutrition/Diets	1	$200,000	9/1/04-8/31/06	2002-38500-11752	
	2	$80,000	9/1/07-8/31/09	2006-38500-16900	
	3	$80,000	9/1/09-8/31/11	2008-38500-19157	
	4	$124,400	9/1/10-8/31/12	2008-38500-19157	
	5	$75,000	9/1/12-8/31/13	2010-28500-20929	
	6	$35,000	3/1/18-2/28/19	2016-38500-25753	
	7	$45,156	7/1/2019-6/30/2021	2016-38500-25753	
	7	$78,629	7/1/2019-6/30/2021	2018-38500-28887	
	8	$89,481	7/1/2019-6/30/2021	2016-38500-25753	
	8	$79,986	7/1/2019-6/30/2021	2018-38500-28887	
Total		**$887,652**			6.45%
Other					
Feed Training	1	$165,446	9/1/06-8/31/08	2005-38500-15847	
	1	$134,554	9/1/06-8/31/08	2006-38500-16900	

Project Area	Project Number	Funding Level	Proposed Duration	Grant Number	
Snail/Grub Mgmt	2	$225,000	9/1/07-8/31/09	2007-38500-18469	
RAS Microbial	3	$65,000	9/1/09-8/31/10	2008-38500-19157	
Winter Kill	4	$175,000	9/1/11-8/31/13	2008-38500-19157	
Field Assess.	5	$34,998	7/1/16-6/30/17	2014-38500-22138	
Total		**$799,998**			5.82%
Salmonids	1	$9,000	6/1/90-8/31/92	89-38500-4319	
	1	$120,799	6/1/90-8/31/92	90-38500-5008	
	2	$149,997	9/1/92-8/31/94	92-38500-6916	
	3	$199,290	9/1/94-8/31/96	94-38500-0048	
	4	$158,656	9/1/97-8/31/99	97-38500-3957	
Total		**$637,742**			4.64%
Sunfish	1	$130,758	6/1/90-8/31/92	90-38500-5008	
	2	$149,799	9/1/92-8/31/94	92-38500-6916	
	3	$173,562	9/1/94-8/31/96	94-38500-0048	
	4	$199,921	9/1/96-9/31/98	96-38500-2631	
	5	$199,748	9/1/99-8/31/01	99-38500-7376	
	6	$160,000	9/1/13-8/31/15	2012-38500-19550	
Total		**$1,013,788**			7.37%
Tilapia	1	$118,791	9/1/96-8/31/98	96-38500-2631	
	2	$150,000	9/1/98-8/31/00	98-38500-5863	
Total		**$268,791**			1.95%
VHS	1	$197,960	9/1/08-8/31/10	2008-38500-19157	
Total		**$197,960**			1.44%
Walleye	1	$177,517	5/1/89-8/31/91	89-38500-4319	
	2	$111,657	6/1/90-8/31/92	90-38500-5008	
	3	$109,223	9/1/91-8/31/92	91-38500-5900	
	4	$75,000	9/1/92-8/31/93	89-38500-4319	
	5	$150,000	9/1/93-8/31/95	93-38500-8392	
	6	$117,395	9/1/95-8/31/97	94-38500-0048	
	6	$59,835	9/1/95-8/31/97	95-38500-1410	
	7	$127,000	9/1/99-6/30/02	98-38500-5863	
	8	$97,775	7/1/2019-6/30/2020	216-38500-25753	
	8	$127,646	7/1/2019-6/30/2021	2018-38500-28887	
Total		**$1,153,048**			8.38%
Wastes/Eff.	1	$153,300	9/1/92-8/31/94	92-38500-6916	
	2	$100,000	9/1/96-8/31/98	96-38500-2631	
	3	$106,186	9/1/01-8/31/04	00-38500-8984	
	3	$88,814	9/1/01-8/31/04	2001-38500-10369	

Project Area	Project Number	Funding Level	Proposed Duration	Grant Number	
Total		**$448,300**			3.26%
White Papers	1	$4,999	7/1/98-12/31/98	96-38500-2631	
	2	$17,495	9/1/99-12/31/99	97-38500-3957	
Total		**$22,494**			0.16%
Yellow Perch	1	$76,957	5/1/89-8/31/91	88-38500-3885	
	1	$85,723	5/1/89-8/31/91	89-38500-4319	
	2	$92,108	6/1/90-8/31/92	90-38500-5008	
	3	$99,997	9/1/91-8/31/93	91-38500-5900	
	4	$150,000	9/1/93-8/31/95	93-38500-8392	
	5	$199,507	9/1/95-8/31/97	95-38500-1410	
	6	$185,458	9/1/97-8/31/99	97-38500-3957	
	7	$92,370	9/1/98-8/31/00	98-38500-5863	
	8	$326,730	9/1/01-5/31/04	00-38500-8984	
	8	$125,016	9/1/01-5/31/04	2001-38500-10369	
	9	$150,000	9/1/10-8/31/13	2010-38500-20929	
	10	$190,000	9/1/13-8/31/15	2012-38500-19550	
	11	$162,261	7/1/17-6/30/19	2014-38500-22138	
	12	$30,838	3/1/18-2/28/19	2016-38500-25753	
Total		**$1,966,965**			14.30%
137 Projects		**$13,752,752**			

Regular Project Reports

Project Title: Extension [Progress Report]
Total Funds Committed: $1,126,885
Initial Project Schedule: May 1, 1989 to August 31, 2019
Current Project Year: September 1, 2017 to August 31, 2018
Participants: D. E. Bauer, University of Nebraska-Lincoln; M. E. Clark, North Dakota State University; J. A. Held, University of Wisconsin-Stevens Point, Wisconsin; C. E. Hicks, Lincoln University; P. Hitchens, Southern IL University – Carbondale, Illinois; R. E. Kinnunen, Michigan State University; C. D. Lee, Kansas State University; J. E. Morris, Iowa State University; A. Pattillo, Iowa State University; A. Garcia, South Dakota State University, South Dakota; N. Phelps, University of Minnesota; K. K. Quagrainie, Purdue University, Illinois/Indiana Sea Grant; M. Smith, The Ohio State University; C. Weeks, Michigan State University.
Industry Liaison: Dan Vogler, Harrietta Hills Trout Farm, Michigan

Project Objectives

1. Strengthen linkages between North Central Regional Aquaculture Center (NCRAC) Research and Extension Work Groups.
2. Enhance the NCRAC extension network for aquaculture information transfer.
3. Develop and implement aquaculture educational programs for the North Central Region)

Project Summary

The existing aquaculture industry members need relevant information on new techniques and technologies in aquaculture, as well as updated information related to changing state and federal regulations. Increasingly, a large number of individuals are interested in aquaculture as a means of agriculture diversification or urban development. The NCRAC Extension Work Group meets these diverse client needs through on-site advice, publications, and specialized workshops. As the industry matures, the advisory service needs will shift toward more specialized and advanced knowledge than is currently provided at general introductory conferences and events. Entrepreneurs and prospective aquaculturists often require an enormous amount of time to educate and can benefit from the availability of the electronic media.

Anticipated Benefits

The NCRAC Extension Work Group will continue and expand its efforts to promote and advance commercial aquaculture in a responsible fashion through its organized education/training outreach programs and through educating the public on the health benefits of commercially raised fish. The primary benefits are: increased public awareness through publications, short courses, and conferences regarding the potential of aquaculture as a viable agricultural enterprise in the NCR; technology transfer; improved lines of communication between interstate aquaculture extension specialists and associated industry contacts; and an enhanced legal and socioeconomic atmosphere for aquaculture in the NCR. The development of aquaculture education programs for the NCR has provided "hands- on "opportunities for prospective and experienced producers.

Approximately 6,000 individuals have attended workshops or conferences organized and delivered by the NCRAC Extension Work Group. Clientele attending regional workshops have gained information related to aquaculture development strategies in other areas of the country and acquired information which was of direct use to their own enterprises. Education programs also created situations where problems encountered by producers were expressed to extension personnel who later relayed them to researchers at NCRAC work group meetings for possible solutions through the research effort.

Project Progress

Objective 1. — Aquaculture Extension Work

Group members have:

- Served as an extension liaison, if not an active researcher, for every NCRAC-funded project;
- Assisted in developing, writing, and editing several culture manuals as well as fact sheets, book chapters, and videos based on NCRAC-funded research;
- Assisted with the planning, promotion, and implementation of taxa-specific workshops held throughout the region;
- Participated as Steering Committee members for public forums related to revision of the National Aquaculture Development Plan and the four past National Aquaculture Extension Workshops/Conferences;
- Served as a non-funded collaborator on the Regional Aquaculture Extension Specialist; and
- Met with industry representatives and university researchers involved with aquaculture to discuss how the aquaculture industry could grow in the NCR.

Objective 2. — Networking of specialists and Cooperative Extension Service (CES) - designated contacts has maximized the efficiency of education programs and minimized duplication. Individual state extension contacts often respond to 120+ annual calls from outside their respective state as well as interacting with colleagues with mutual concerns related to developing aquaculture activities. This extension network is critical to being able to match specific aquaculture questions with the best source of information.

Lee has continued to assist the Kansas Aquaculture Association by developing, printing and distributing the Kansas Aquaculture Association Directory. Bauer distributed NCRAC information to the Nebraska aquaculture industry. Clark developed an updated list of state producers for submission to the NCRAC Publications Office as well as worked with state public agency personnel concerning state/federal regulations for North Dakota producers. Pierce assumed Hicks' role in developing factsheets on pond aquaculture and sportfish management.

Pattillo developed two NCR-centered fact sheets covering aquaculture and hydroponic components of aquaponic systems and led the development of an aquaculture webinar series in 2016 and 2017 in partnership with the National Aquaculture Association and U.S. Chapter of the World Aquaculture Society. This webinar series was a partnership between NCRAC, the National Aquaculture Association and the United States Aquaculture Society and covered a range of important and timely topics. Videos are available at https://www.ncrac.org/video.

Objective 3. — A number of workshops, conferences, symposia, videos, field-site visits, hands-on training sessions, and other educational programs have been developed and implemented (see the Appendix for a listing of many of these activities). Through these workshops, critical issues in the private aquaculture industry have been identified, e.g., market availability, economic returns, and regulatory concerns.

Recent workshops include the 2017 Iowa Aquaculture Conference (videos of presentations located at https://www.ncrac.org/video) and the 2018 North Central Aquaculture Conference in Kansas City, Missouri (hosted by Missouri Aquaculture Association and NCRAC; presentations at https://www.ncrac.org/presentation/2018-north-central-aquaculture-conference).

NCRAC Extension contacts have served as editors for regional aquaculture newsletters as well as in-state aquaculture association newsletters; served on state aquaculture advisory councils and state aquaculture task forces; and assisted in the planning and implementation of state aquaculture association meetings.

In addition to the previously mentioned areas, NCRAC Extension contacts have been instrumental in fostering the continued growth of the aquaculture industry in the region through a variety of activities and many have worked with industry and governmental representatives to produce state aquaculture plans and improved governmental regulations. One such an example is the Aquatic Invasive Species-Hazard Analysis Critical Control Point (AIS-HACCP) plan developed by Kinnunen and Phelps to address biosecurity, particularly in regard to diseases such as viral hemorrhagic septicemia (VHS). Kinnunen and Phelps have also taught other members of the NCR aquaculture extension community about their AIS-HACCP program, in essence, they've "trained the trainers" and all AIS-HACCP materials are available at www.seagrant.umn.edu/ais/haccp.

In 2017 Pattillo coordinated a 2-day meeting of the NCRAC Publications Review Team in Des Moines, Iowa. This team of Extension, TC/E and TC/R members reviewed current NCRAC publications for content and whether or not they were still relevant to current aquaculture practices. Authors of past publications were contacted for identified updates in 2018. The departure of Pattillo in October 2017 resulted in Morris being appointed to ISU Extension in January 2018; Morris has since directed the new identified publications to be completed. ISU Extension staff have been doing the final edits and layout with the first publications have been distributed to the aquaculture community in 2019 with all publications to be completed in 2020.

Outreach Overview

Enhancing state-wide and regional communication and training among those in the aquaculture industry is imperative for continued growth of aquaculture in the Midwest. Aquaculture Extension Specialists are important to the distribution of aquaculture extension related materials, providing research-based information to the farmers who will use it. Additionally, promoting networking between public institutions and private aquaculturists helps enhance the transfer of aquaculture information and technology.

The workshops were mainly hands-on, which enabled participants to acquire knowledge and skills in indoor recirculating aquaculture systems. Some workshop participants have started aquaculture operations after attending the workshops. Additional services include on-line educational materials, workshops, business planning assistance, facility tours and production training.

Target Audiences

Current and prospective fish farmers.

Deliverables (Outputs)

Pattillo completed two NCR-centered fact sheets covering aquaculture and hydroponic component s of aquaponics systems in 2017. Pattillo also led the development of an aquaculture webinar series that was a partnership among NCRAC, the National Aquaculture Association and the United States Aquaculture Society and has covered a range of important and timely topics. Pattillo, Kinnunen, and Phelps all contributed talks to the webinar series. Topics included aquaponics, biosecurity, economic cost of regulations, seafood facts for retailers, seafood benefits for dieticians, use of social media in aquaculture, branding opportunities for aquaculture producers, new Food Safety Inspection Service information, veterinary feed directive updates, recreational pond management, AIS-HACCP issues, fish health, and indoor marine shrimp production techniques. Archived webinars can be accessed at http://www.ncrac.org/video or https://vimeo.com/channels/958980 , as well as through www.thenaa.net and www.usaquaculture.org.

Outcomes/Impacts

The 2016-17 Aquaculture Webinar Series fostered a partnership among NCRAC, the National Aquaculture Association, and the United States Aquaculture Society. This partnership broadened the scope and participation in these webinars nationwide. This 18-part series covered timely and relevant aquaculture topics for the NCR and the overall US aquaculture industry.

Impacts Summary

Relevance. — Fish farmers require some basic extension services including responding to various questions relating to fish production. Extension activities would include providing resources relating to addressing issues such as poor water quality, diseases, low oxygen levels, water temperature, and feeding strategies. Fish farmers need basic and advanced aquaculture information in an easy to understand format that is readily accessible to them to improve their operations. Web-based training opportunities fit this need.
Response. — Pattillo led the development of an aquaculture webinar series that is currently underway. Topics included aquaponics, biosecurity, economic cost of regulations, seafood facts for retailers, seafood benefits for dieticians, use of social media in aquaculture, branding opportunities for aquaculture producers, new Food Safety Inspection Service information, veterinary feed directive updates, recreational pond management, AIS-HACCP issues, fish health, and indoor marine shrimp production techniques.
Results. — Current viewership of these webinars is ca. 17,000 views. Recording can be accessed at https://vimeo.com/channels/958980 .

Recap. — In response to industry concerns, webinars, workshops, publications, videos, and other web-based resources have been developed throughout the region to address industry needs.

Publications, Manuscripts, Workshops, and Conferences

See the Appendix for a cumulative output for all NCRAC-funded Extension activities.

Project Title: Regional Aquaculture Extension Specialist (RAES) [Termination Report]
Total Funds Committed: $124,993
Initial Project Schedule: September 1, 2016 to August 31, 2018
Current Project Year: September 1, 2016 to June 30, 2019
Participant(s): C. Weeks, Michigan State University, *replaced by M. Smith, Ohio State* University
Extension Liaison: K. Quagrainie, Purdue University
Industry Liaison: William Lynch, Mill Creek Perch Farms, Marysville, Ohio
Reason for Termination: Completion of project objectives.

Project Objectives

1. Continue RAES support to the NCRAC Aquaculture Community through ongoing activities in areas of liaison services, leadership, assessing and addressing industry needs and information transfer.
2. Develop and strengthen partnerships from within the NCR and outside the region among regulatory agencies, industry, academia, and other relevant entities to foster open, meaningful dialog on critical issues and build support for the NCR aquaculture industry.
3. Coordinate efforts for seeking non-NCRAC support for NCR aquaculture development.

Deliverables

1. Open door liaison services to the NCR aquaculture community
2. Serve on 3 or more committees and panels as an industry representative
3. Support for, and interaction with, all NCR state aquaculture associations; attendance at 3 or more state association meetings, regional and/or national conferences per year
4. Direct information exchange to over 500 individuals per year through personal communications and site visits
5. Continue information outlet and topical news on the NCR fish culture list -serve and Xtension Ask-an-Expert
6. Annual updates to the NCRAC regulation website
7. Dialogue and information exchange on policy issues (e.g. Federal Register posts, legislation and regulation)
8. Regional aquaculture needs survey (once every 3 years)
9. Establish partnerships for NCR aquaculture industry development, submitting at least one grant proposal per year as a team member for NCR industry support.
10. Assist the Directors office in strategic planning and project selection protocol effectiveness.

Project Summary

The Regional Aquaculture Extension Specialist (RAES) project was initiated in 2008 under an overarching goal of advancing commercial aquaculture in the region. The initial RAES objectives were to provide leadership and enhance information transfer to the aquaculture industry in the North Central Region (NCR). This work plan builds upon outcomes and achievements of RAES activities to date under expanded objectives. Specifically, the RAES has continued to strive to identify industry needs, work with others to develop and implement strategies to address those needs, provide liaison services to industry sectors, disseminate information to industry, public trust agencies and the general public, and develop and strengthen partnerships for sustainable aquaculture development in the NCR.

Technical Summary and Analysis

Chris Weeks resigned from this Michigan State University and the project in January 2018. In the interim, remaining project funds were re-allocated to University of Ohio in 2019; Matt Smith assumed leadership towards the end of the project's schedule duration. This project was taken over by Matt Smith. PI Smith provided support for the NCRAC community, was involved on the National Aquaculture Association's Aquatic Nuisance Species (ANS) committee, and sought external non-NCRAC funding to support aquaculture advancement in the region.

Prior activities undertaken by Chris Weeks are listed by objective.
Objective 1.— RAES activities over the 2017-18 project period include: NCRAC regulation website update by ISU staff, a region wide survey on concerns regarding risk of aquatic invasive species (AIS), phone and direct personal contact with stakeholders, attendance and presentations at state association and aquaculture development meetings, interviews, and postings to the NCR Fish culture List Serve. Additionally, the RAES obtained funding and was PI on a team to develop a model AIS HACCP verification program for aquaculture and baitfish sectors. The RAES also took lead coordinating roles on steering committees of the 2016 and 2018 North Central Aquaculture Conferences.

Objective 2. — Chris Weeks continued memberships with the National Aquaculture Association, Michigan Farm Bureau, and Coalition for Sustainable Seafood Production (CUSP); served on the Michigan Farm Bureau Aquaculture Advisory Committee, Great Lakes Panel for Aquatic Nuisance Species, NSFI Food Division Advisory Council, and various funding review panels; worked with MN and MI DNR agencies, and the Nature Conservancy on AIS HACCP verification programs; and provided interaction with, and presentations to, the National Soybean Council, 4H, and Michigan Environmental Health Association.

The RAES also served as co-PI on NCRAC projects including leadership training for NCR state aquaculture associations, NCRAC Base Extension, and as extension liaison for the NCRAC Comprehensive Outreach and Training project. Additionally, the RAES has provided support to regional programs such as Aquaculture Boot Camp (Ohio), the Minnesota Aquaculture Workshop, and Coalition to Support Iowa's Farmers (CSIF).

Objective 3. — The RAES, over the course of the project, has been awarded $347,000 from non-NCRAC sources to support regional aquaculture growth as PI and an additional $456,840 as co-PI.

Principal Accomplishments

Objective 1. — Participated in regional/national work as applicable and assisted the NCRAC community by presenting and networking to enhance the nation's knowledge of aquaculture production in the Midwest.
Objective 2. — Committee member of the National Aquaculture Association ANS committee. Participation in NOAA Sea Grant panels to express the necessity of further aquaculture support in the NCR.
Objective 3. —Submitted proposals, unsuccessfully, for non-NCRAC support for regional development.

Impacts

The RAES has gained a reputation as a go to information source, and as an industry liaison on regulatory and AIS matters. The RAES is often asked to help clarify legal, biological, environmental, business development and facility design questions, and asked repeatedly to present on these types of issues at meetings and conferences. Through this funding, water quality supplies were obtained that have already been utilized during other workshops which helps transfer the technology of water science to the community.

Recommended Follow-up Activities

NCRAC should summarize the Extension programs and the deliverables from the RAES projects in manner that illustrates on the importance of regional aquaculture work.to North Central universities.

Publications, Manuscripts, Workshops, and Conferences

See the Appendix for a cumulative output for all NCRAC-funded Extension activities.

Project Title: Comprehensive Outreach and Training Program to Expand Development of NCR Aquaculture [Termination Report]

Extension Liaison: Chris Weeks (replaced by Matt Smith)

Total Funds Committed: $151,739

Initial Project Schedule: 9/1/17-8/31/19

Current Project Year: 9/1/17 – 7/31/18

Participants: Smith, M.A., The Ohio State University Primus, A.E., University of Minnesota; Phelps, N.B.D., University of Minnesota

Industry Liaison: William Lynch, Millcreek Perch Farm, LLC, Marysville, Ohio

Reason for Termination: Completion of project objectives.

Project Objectives:

1. Develop a comprehensive training program that addresses subject priorities critical to the advancement of NCR aquaculture.
2. Identify a core team of subject experts who can develop and deliver high quality presentations and demonstrations throughout the NCR.
3. In cooperation with NCR states, deliver workshops and training region-wide.
4. Develop a comprehensive evaluation plan to assess the adoption/integration of information to the target audience.

Project Summary

The PIs reached out to producers and/or university research and Extension personnel to learn which topics they would like training on in their respective states. Identified topics were water quality, fish health, aquaponics, aquaculture economics, and aquaculture marketing. States were identified by their location within the region as well as participation by university personnel or producers who were willing to assist with the logistics of planning a workshop. Support from the state aquaculture associations was vital to the success of the trainings. Once location, workshop training topics, and dates were set, we identified a team of experts both from within and outside of the North Central Region. Workshops were delivered and successful with all workshops published in video form online. Surveys were provided at four of the six workshops with strong support and technology transfer. In addition to the workshop videos, PI Primus and the Center for Animal Health and Food Safety produced two online educational modules, each consisting of short multimedia videos (final edits currently underway) related to water quality and fish health for those who need introductory assistance. If interested or established producers are interested in learning more about water quality, fish health, or aquaculture economics and marketing, then these workshop videos will now be the cornerstone for transferring knowledge to those who were not able to be at the workshops in person. Topics of concern originally identified by the states proved important when analyzing the survey results.

Technical Summary and Analysis

In Missouri, Workshop #1 partnered with the North Central Aquaculture Conference (sponsored by the North Central Regional Aquaculture Center, Missouri Aquaculture Association, and Kansas Aquaculture Association) to present a workshop on Aquaponics and Recirculation Aquaculture Systems (RAS). Although a workshop on RAS and aquaponics was a not originally a specified track at the conference, Dr. Wetzel's (Lincoln University) recent research and statements on numerous small spring wells in southern Missouri possibly being utilizing for semi-recirculating indoor production systems with species such as rainbow trout was the impetus for this workshop.

In Minnesota, the University of Minnesota has led two previously successful aquaponic symposiums with grant support that were developed out of a stated need from the industry. This project supported the symposium, speaker travel, and all hands-on activities which would not have been possible otherwise. Although producers will likely encourage follow-up symposiums for years to come, recording all content for publishing online is highly valuable as this symposium cannot happen without financial support.

In Ohio, the Ohio State University (OSU) Aquaculture Extension program partnered with the Ohio Aquaculture Association (OAA) after meetings to discuss workshop ideas. The OAA stated their producers wanted to bring back another workshop on Fish Health as it has been designated a high priority for their members. The OSU South Centers had a grant-funded project from USDA NIFA called "Aquaculture Boot Camp 2" in which new and beginner farmers meet up once a month to educate on a different financial or biological topic. It only made sense to combine resources for a NCRAC (this project), OAA, and OSU ABC-2 workshop to enhance the experience than would otherwise be possible as OSU ABC-2 did not have the financial resources to bring in outside assistance for their attendees. This project led to a successful workshop of both the beginner/interested producers (ABC-2) and current producers (OAA members).

The support allowed travel for PI Smith, Dr. Flint (professor, OSU), Dr. Hartman (USDA APHIS, Florida), and Dr. Reichley (Certified Aquatic Veterinarian and Director of Fish Health Clear Springs Foods, Idaho), as well as meal and printed educational materials. Dr. Reichley led the hands-on fish necropsy and each participant dissected their own fish.

In Wisconsin, the Wisconsin Aquaculture Association (WAA) and the University of Wisconsin-Stevens Point (UWSP) were the contacts. The WAA and UWSP led the Friday conference and WAA assisted this project on Saturday by obtaining and managing registration and contacts with the hotel conference center. This project supported all PI travel, meals, hands-on materials, printed educational materials, and video/audio recordings. PI Primus led the walleye necropsies (donated by UWSP) and PI Smith led the discussions of key water quality parameters and various methods of testing multiple parameters.

In Indiana, the Indiana Aquaculture Association Inc. (IAAI) and Purdue University were the contacts. The one-day conference was moderated by IAAI and they led registration and assisted in acquiring local fish health contacts. This project supported PI travel, all meals, printed educational materials, hands-on materials, and video/audio recordings. PI Primus led the fish necropsies (multiple species donated by Purdue University) and PI Smith led the discussions of key water quality parameters and various methods of testing multiple parameters.

In Iowa, the Coalition to Support Iowa's Farmers and the Director of NCRAC were the contacts. The 2-day conference consisted of a Friday conference on a myriad of pertinent topics (Iowa regulations, business planning, Iowa marketing, history of Iowa aquaculture, question and answer panel discussion). Saturday was moderated by PI Smith with assistance from Dr. Morris from NCRAC. Saturday presentations were by a private consultant, Dr. Engle from Engle-Stone Aquatic$ in Virginia. Presentations were given with group discussions in between to engage the audience in a "round-table" fashion. This project supported all meals, PI travel, printed materials, honorarium, and travel for visiting presenters.

Principal Accomplishments

The PIs reached out to producers and/or university research and Extension personnel to learn which topics they would like training on in their respective states. Identified topics were water quality, fish health, aquaponics, aquaculture economics, and aquaculture marketing. Support from the state aquaculture associations was vital to the success of the trainings. Once location, workshop training topics, and dates were set, we identified a team of experts both from within and outside of the North Central Region. Workshops were delivered and successful with all workshops published in video form online. Surveys were provided at four of the six workshops with strong support and technology transfer. In addition to the workshop videos, PI Primus and the Center for Animal Health and Food Safety produced two online educational modules, each consisting of short multimedia videos (final edits currently underway) related to water quality and fish health for those who need introductory assistance. If interested or established producers are interested in learning more about water quality, fish health, or aquaculture economics and marketing, then these workshop videos will now be the cornerstone for transferring knowledge to those who were not able to be at the workshops in person.

Online Educational Modules: URL published soon
Description/Justification: Each module contains five multimedia videos at approximately 5-7 minutes in length. Recent educational data indicates that videos of this length maximize viewership and content dissemination (when compared to longer online videos).

Fish Health Module Presentations

1. Introduction to Fish Health
2. Infectious Disease
3. Disease Prevention
4. Biosecurity
5. Diagnostic Techniques

Water Quality Module Presentations

1. Introduction to Water Quality in Aquaculture
2. Basic Water Quality Parameters 1
3. Basic Water Quality Parameters 2
4. Basic Water Quality Parameters 3
5. Considerations for Different Types of Aquaculture Systems

Details for each workshop and resource links are identified below:

Workshop #1:
Partner: North Central Aquaculture Conference
Location: Kansas City, Embassy Suites KCI Airport
Date: February 10, 2018
Attendance: >30
Participating experts: David Brune (UM), Greg Fischer (UWSP NADF), Greg Trusso (Global Aquaculture Supply), Chris Hartleb (UWSP), Matt Rogge (UWSP)
Presentation topics: Advanced aquaponics and RAS production systems, shrimp production, hatchery design, economics of system design, trends in aquaponics, microbes in aquaponics.

Survey summary: No survey results
URL: https://www.ncrac.org/presentation/2018-north-central-aquaculture-conference

Workshop #2:
Partner: Minnesota Aquaponics Symposium
Location: University of Minnesota, St. Paul, MN
Date: April 28, 2018
Attendance: >45
Participating experts: Matt Smith (OSU), Alex Primus (UMN), Marie Abbey (UMN), Lee Scogins (Urban Organics)

Presentation topics: Water quality in aquaponics, fish health and disease control, plant production in aquaponics, large scale aquaponic production example.
Hands-on activities: Water quality testing equipment and procedures, fish health assessment procedures, plant health, production, and pest management.

Survey summary: No survey results
URL: https://youtu.be/JFv15wjrgh0

Workshop #3:
Partners: Ohio Aquaculture Association and OSU ABC
Location: Ohio Department of Agriculture, Reynoldsburg, OH
Date: November 10, 2018
Attendance: > 45
Participating experts: Stephen Reichley (Clear Springs Foods), Matt Smith (OSU), Mark Flint (OSU), Kathleen Hartman (USDA-APHIS)

Presentation topics: Antibiotics and veterinary feed directives, common diseases, farm biosecurity, stress management
Hand-on activities: Fish necropsy by attendees and expert panel discussion.

Survey summary: No survey results
URL: https://southcenters.osu.edu/abc2_intensive_november2018

Workshop #4: URL published soon
Partner: Wisconsin Aquaculture Association Annual Conference
Location: Holiday Inn South I-94, Eau Claire, WI
Date: February 16, 2019
Attendance: >63
Participating experts: Nick Phelps (UMN), Alex Primus (UMN), Matt Rogge (UWSP), Matt Smith (OSU), Myron Kebus (WI DATCP), Sue Marquenski (WI DNR, retired)

Presentation topics: fish health, microbiome, infectious disease treatment, water quality, response to fish health issues
Hands-on activities: Fish necropsy by all attendees and water quality testing and discussion of various methods of testing pertinent parameters.

Survey summary (n=38): 63% of participants were current aquaculture or aquaponic producers and considered fish health and water quality to be a major concern for their business (4.6/5). Participants learned useful information about fish health (4.4/5) and water quality (4.1/5), and the many stated they were very likely to use what they learned on their farm (4.2/5) and thought it would improve production efficiency/profitability (4.1/5).

Lastly, participants highly rated the overall workshop (4.1/5) and were highly likely to recommend it to others (4.6/5).
URL: published soon
Workshop #5:
Partner: Indiana Aquaculture Association Conference
Location: Lions Club, Russiaville, IN
Date: March 15, 2019
Attendance: >33
Participating experts: Bob Rode (PU), Paul Brown (PU), Eric Fischer (IN DNR), Jennifer Strasser (IN BOAH), Daniel Gascho (Four Star Veterinary Services), Paul Zajicek (NAA), Matt Smith (OSU), Amy Stone (Aquatic Equipment and Design), Alex Primus (UMN).

Presentation topics: Nutrition, regulations, fish health, water quality, system design
Hands-on Activities: Fish necropsy by all attendees and water quality testing and discussions about the different ways of testing water quality parameters.

Survey results (n=21): 48% of participants were current aquaculture or aquaponic producers and considered fish health and water quality to be a major concern for their business (4.2/5). Participants learned useful information about fish health (4.7/5) and water quality (4.4/5), and many stated they were very likely to use what they learned on their farm (4.7/5) and thought it would improve production efficiency/profitability (4.6/5). Lastly, participants highly rated the overall workshop (4.6/5) and were highly likely to recommend it to others (4.7/5).
URL: published soon

Workshop #6:
Partners: Iowa Aquaculture Conference and the Coalition to Support Iowa's Farmers
Location: Quality Inn and Suites Starlite Village Conference Center, Ames, IA
Date: March 22-23, 2019
Attendance: >125
Participating experts: Joe Morris (ISU), Matt Smith (OSU), Brian Waddingham (Coalition to Support Iowa's Farmers), Scott Platt (IA DIA), Brian Tapp (ISU), Carole Engle (Engle-Stone Aquatic$, LLC)

Presentation topics: Intensive pond production, best management practices, rules and regulations for aquaculture and food markets, role of markets, business and financial planning.
Hands-on activities: March 23, Financial planning and budgeting worksheets led by Dr. Engle with assistance from Smith and Dr. Morris.

Survey summary (n=32 for Friday and n=23 for Saturday): Friday Miscellaneous agenda: 61% of the respondents stated that the speakers' presentations were very valuable to them and 96% stated the variety of speakers and topics were valuable or vary valuable. Overall value of the Friday conference was recorded as 46% very valuable. Saturday Business Planning/Marketing agenda: 70% (16/23) noted they were currently producing in the aquaculture/aquaponics sectors and participants noted they neither agreed nor disagreed (3.7/5) that business planning and marketing were a major concern for their business. Participants learned useful information about business planning (4.6/5) and marketing aquaculture products (4.3/5). They thought it would improve the production efficiency on their farm (4.4/5) and they intended to use their new knowledge on their farm (4.3/5). Lastly, participants thought the overall workshop was valuable (4.5/5) and would recommend the workshop to others (4.4/5).
URL: https://www.supportfarmers.com/iowa-aquaculture-conference/

Impacts

- A significant number of people (at least 330) participated in the workshops
- Twenty-four different experts presented to producers for a total of 40 presentations with many experts at multiple workshops
- Experts were from 10 different states and included in and out-of-region experts as well as public and private experts for high-caliber trainings to increase knowledge transfer
- In addition to presentations, most workshops included hands-on activities for participants to practice what they learned, which improved learning outcomes
- Over 14.5 hours of developed educational content has been published for producers and interested producers to learn and reference freely online. An estimated 6 hours of content are in the final stages of editing and will be available online soon
- In-person and online content facilitates technology transfer which allows for current and potential producers to learn from academic and industry presenters. Based on the surveys, we expect this will improve profitability, assist industry development/expansion, and troubleshoot production issues

- Due to limited researchers and Extension FTEs in the North Central Region these resources will serve as “quick reference” for existing producers and interested producers

Recommended Follow-up Activities

This project was asked for by industry in 2015-2016 and is being touted as a successful transfer of technology to the industry. As there will be over 16 hours of content published online (with specified topics time-stamped as to not overwhelm viewers), this should assist the limited aquaculture FTEs by allowing them to become more streamlined with their technology transfer. It is clear there is ample appreciation and desire for more Extension FTEs and while this has been a valuable educational stream, hands-on education needs to continue and that requires additional FTEs. As baby boomers in aquaculture Extension reach retirement age, it is vital that universities maintain commitment to aquaculture by filling positions so that these hands-on trainings committee.

Publications, Manuscripts, Workshops, and Conferences

See the Appendix for a cumulative output for all NCRAC-funded Extension activities.

Project Title: Educating a Workforce for the Aquaculture Industry: Matching Skill Needs of the Aquaculture Industry with US Career and Technical Education (CTE) **[** Termination Report]
Total Funds Committed: $188,036
Initial Project Schedule: July 1, 2017 to June 30, 2019
Current Project Year: July 1, 2017 to June 30, 2019
Participants: Evans, B.I., Lake Superior State University; Helal, H., Lake Superior State University; Hartleb, C., University of Wisconsin Steven's Point; Slemmons, K., University of Wisconsin Steven's Point; Pattillo, D. A. Iowa State University (replaced by Lambert, M., Iowa State University)
Extension Liaison: D. Allen Pattillo (replaced by Joseph E. Morris)
Industry Liaison: William B. West, Iris Fish Farm LLC, Black Creek, Wisconsin
Reason for Termination: Completion of project objectives.

Project Objectives

1. Assess the workforce needs for the aquaculture industry throughout the 12 states of the North Central Region (NCR). Identify which skills are needed in the workforce to promote industry growth.
2. Assess the level of youth focused aquaculture curricula/programs in the NCR. Identify schools with a Career and Technical Education (CTE) certification in the Agriculture, Food and Natural Resources career cluster that includes aquaculture. Identify other youth aquaculture related activities.
3. Integrate industry and high school/youth career center information through a web-based platform that:
   a) creates awareness of the aquaculture industry skill needs
   b) allows assessment of the level and distribution of aquaculture curricula
   c) utilizes the web-based platform (ncrac-yea.org) to co-develop curricula to address industry needs
   d) creates incentives for youth to pursue aquaculture skills training
4. Create and promote aquaculture workshops for educators and Extension professionals and provide access funding for them to attend existing workshops.
5. Identify community colleges or universities with aquaculture courses/programs, and create opportunities for interested students to be dual enrolled in existing college classes, or "less than class size" internship opportunities at fish farms and hatcheries.….

Project Summary

Advancement of the aquaculture industry requires recruitment of a workforce experienced with the many facets of aquatic farming. Although globally aquaculture is growing rapidly, the projected workforce in the US is insufficient to meet future demands for aquaculture. Our goal is to identify where the industry sees a need for skill development and then create career pathways to the aquaculture industry. Identifying the level of youth aquaculture engagement that currently exists throughout the North Central Region (NCR) will allow coordination of these efforts through an online aquaculture forum we have developed. Identification of what resources are needed to support current programs, and where aquaculture could be initiated, will allow academic institutions and private industry to co-develop the needed workforce. Aquaculture development is in the national interest, and providing training in aquaculture for the next generation, is essential to fostering the skills needed for this industry. Another key component of education is providing continuing education for the educators and extension professionals. We developed aquaculture and aquaponic workshops focusing on the needs of the schools and extension educators, as well as providing access funding for them to attend these workshops. A basic education in aquaculture opens the door for students to attend universities with potential careers in business, engineering and the life sciences, all vital skills required by the aquaculture industry. We engaged youth in aquaculture throughout the NCR and identified career pathways to the aquaculture and aquaponic industries with appropriate skill training opportunities.

Technical Summary and Analysis

Objective 1. — A survey was given to state and industry hatchery managers, and aquaculture extension in Michigan, who provided a list of skill needs/expectations for new aquaculture hires. We have summarized our expectations in Figure 1. For successful aquaculture, a basic understanding/expectation of "normal" fish behavior and compromised health (live) was identified as essential. Knowledge of major parasites, bacterial and viral diseases in the region, and a summary of how bacterial and viral disease are diagnosed, is needed for future culturists. They should understand cause-and-effect of stress, procedures and policies to control pathogens, invasive species, and non-target organisms (following HACCP procedure). Being able to perform basic necropsy and Gram-stain gill and skin smears for microscopic examination and being able to perform calculations for therapeutic chemicals used in a flow-through and static bath treatment should be required as part of aquaculture education. Understanding mortality and water quality monitoring, record keeping of tolerances (DO, pH, NH_3, NO_2, CO_2) as well as an understanding of mechanical systems commonly used in hatcheries, such as the basics of well field development, pumps, small engines, fish feeders, degassing theory and application is needed. Methods should also be identified for understanding effluent management.

Funding from this program was leveraged with funding from Wisconsin Sea Grant to conduct surveys of Wisconsin seafood consumers and fish farmers to better understand workforce needs and barriers to industry growth. The WI Sea Grant project was, "Supporting Wisconsin aquaculture by assessing the marketing needs of producers and perceptions of consumers about eating locally farmed fish." Reports are available at: https://www.uwsp.edu/cols-ap/nadf/Pages/Supporting-WI-Aquaculture-by-Assessing-the-Marketing-Needs-of-Producers-and-Consumer-Perceptions-.aspx

Objective 2. — A pilot project, "Youth Education In Aquaculture" funded through NCRAC, was completed with the development of the web platform www.ncrac-yea.org, with a five-year hosting contract. We compiled a list of all high schools throughout Michigan (@1100) and Wisconsin (@500) and identified the state of aquaculture education at each school. We created a newsletter and online survey that was sent to each school and we asked local intermediate school districts to provide information from their regions. The web platform was beta tested and survey results were obtained by April 1, 2017 using 8 schools involved with the Aquaculture Challenge competition. Increased exposure to aquaculture engages students and increases their interest in math and science (Wingenbach et al., 1999), as well as developing generic and occupation specific life skills (Pita et al., 2014). Our preliminary work in the K-12 system showed strong interest in aquaculture by young students, but their options for follow-up were limited.

During this project, we identified the schools in each of the following states that incorporated some form of aquaculture education at the secondary level: Michigan, Wisconsin, Ohio and Illinois. We also have some data on activity in Iowa and Kansas. The website domain is funded through 4/5/2022, so we will continue to go through each of the remaining 6 states in the NCR to complete our list. Once schools are identified and GIS coordinates determined, we are using a variety of methods (surveys, newsletters, social media) to ascertain the level of aquaculture engagement of youth in these regions. This information is available on the website we have developed www.ncrac-yea.org (Figure 2).

Objective 3. —

a) creates awareness of the aquaculture industry skill needs

The Home page of the website (ncrac-yea.org), introduces Youth Education in Aquaculture (YEA), and makes the case for the need for aquaculture education. The skill set needed is also identified on the home page. The domain name, ncrac-yea.org has been purchased through 4/5/2022.

b) allows assessment of the level and distribution of aquaculture curricula, and

c) utilizes the web-based platform (ncrac-yea.org) to co-develop curricula to address industry needs

The ncrac-yea.org Outreach page provides the visualization of the location of aquaculture businesses and surrounding high schools. This shows if there are local high schools with curricula that would provide the preliminary skills necessary to fuel their workforce needs. By providing this online resource, it allows schools to visualize the surrounding points of interest, whether it be a nearby aquaculture business or school with an active aquaculture curriculum, and presents them the opportunity to reach out and potentially collaborate with the surrounding aquaculture organizations. The website also contains a resource page which provides numerous links to assist with the understanding of aquaculture, including resources provided for the Aquaculture challenge, that could very well be utilized by schools not participating. Additionally, the site contains a secure forum for teachers and business owners to collaborate with each other, encouraging problem solving and school to business connections.

By providing this website, it creates opportunities for schools to access resources to utilize themselves, find local businesses and schools with aquaculture to connect with, converse with participating businesses and schools via the forum, and presented the opportunity for schools to register and participate in the aquaculture challenge. Teachers and businesses can use these resources to create opportunities for students to acquire the skills necessary for the industry, and create interest in their students to drive them to pursue further aquaculture education and training.

d) creates incentives for youth to pursue aquaculture skills training

Beginning in 2016, as part of the MiSTEM grant project, we started a competition for our local high schools, called the "Aquaculture Automation Challenge". Students were given materials to design an aquaculture system and programmed micro-controllers with sensors to monitor the environmental parameters of their system. We were amazed at how motivated and engaged the students were with their projects for the competition. http://www.sooeveningnews.com/news/20160520/sault-team-wins-aquaponics-challenge.

The Youth Education in Aquaculture (YEA) website was used to host the competition online, and is now called the Aquaculture Challenge. Student teams were given materials and guidance to construct an aquaponics system, program a microcontroller for system monitoring, and develop an entrepreneurial business plan. The past 3 years have had a final showcase on 5/5/2017, 4/6/2018 and 4/25/2019.

Objective 4. − Create and promote aquaculture workshops for educators and Extension professionals and provide access funding for them to attend existing workshops.

Throughout the design and build phase of the Aquaculture Challenge competition, the educators mentoring the teams indicated they needed more aquaculture training for themselves. This appears to be a common occurrence (Duncan et al., 2006), and was also observed in a survey of high school aquaculture programs in the mid 1990's in the northeastern U.S. (Wingenbach et al., 2000).

We are seeing progress in aquaculture education with successes in programs such as the UWSP-Northern Aquaculture Demonstration Facility and Aquaponics Innovation Center. In addition to offering aquaculture workshops to industry personnel to help educate, train and provide updated knowledge, UWSP has also introduced an Aquaponics Certificate Program that allows students to use coursework from other institutions and does not hold them back with institutional residency requirements. UWSP's aquaculture educational programs have educated over 400 students from 12 states and 4 countries since 2011. The programs have also placed more than 25 interns with private industry partners (http://www.uwsp.edu/cols-ap/nadf/Pages/Past-Interns.aspx) and that has led to a 90% success rate in student job placement in the aquaculture industry. In Michigan, Michigan Sea Grant is also working to establish an aquaculture technician program; however, to facilitate these efforts, we need to make our youth aware of the potential for careers in aquaculture.

While popularity in aquaponics continues to grow, most educators are ill prepared and lack the formal training required to properly integrate aquaponics into their curriculum. The UW-Stevens Point Aquaponics Innovation Center (UWSP-AIC) was built to assist both educators and businesses in learning science-based aquaponics and for integrating this culture method into school programs and new businesses. UWSP and Nelson & Pade staff developed an aquaponics curriculum component that was used to educate and train twenty educators/extension professionals at the UWSP-AIC on August 13-15, 2018. In 2019, thirty-five educators/extension professionals attended the workshop July 11-13. During the 3-day Aquaponic Master Class for Teachers, participants were trained in the science of aquaponics, with particular reference to STEM components, as well as ways that school aquaponic programs can provide safe, sustainable seafood and vegetables to the schools while preparing students for careers in aquaculture. Educators and extension professionals were provided access funding for attending the workshop to help defray costs. Fully hands-on training was provided with example exercises (available at: https://www.uwsp.edu/cols-ap/nadf/Pages/Current-Projects-At-The-Facility.aspx).

Curricula for a similar 3-day workshop were held in Muskegon MI (August 6-8, 2019) at the Annis Water Resources Institute.

Objective 5. − Identify community colleges or universities with aquaculture courses/programs, and create opportunities for interested students to be dual enrolled in existing college classes, or "less than class size" internship opportunities at fish farms and hatcheries.

A list of community colleges and universities with aquaculture courses/programs was obtained from the U.S. Aquaculture Society and was cross checked for accuracy and updated (given it was ten years old). Twenty-four programs were identified in the U.S. (Table 2). UWSP offers two college-level courses in aquaponics, one is online and the other is offered as a 3-day short course so that students at any university can enroll in the courses. UWSP also offered NINE summer internship opportunities to students at aquaculture/aquaponic facilities (https://www.uwsp.edu/cols-ap/nadf/Pages/Past-Interns.aspx and https://www.uwsp.edu/cols-ap/aquaponics/Pages/AIC-Staff.aspx).

LSSU has added an aquaculture minor beginning in Fall 2019. They have also introduced an Introduction to Aquaponics course Fall 2019 as a pilot towards adding an aquaponics minor.

West Shores Community College (WSCC) was proposed as a model for developing the Aquaculture CTE program, however the faculty member at WSCC has now retired, and the college has hired a botanist to replace them. There is no longer an aquaculture program at West Shores Community College.

Principal Accomplishments

Our results were disseminated through our websites www.ncrac-yea.org; and the University of Wisconsin Steven's Point sites for aquaponics education https://www.uwsp.edu/cols-ap/aquaponics/Pages/default.aspx, and their Northern Aquaculture Demonstration Facility (NADF) website https://aquaculture.uwsp.edu. We also created a website page for this project that has photos, links and handouts we can share from the workshops. It is located at: https://www.uwsp.edu/cols-ap/aquaponics/Pages/AIC-Projects-.aspx. We also share information through the Superior AquaSystems Facebook page https://www.facebook.com/superioraquasystems/?ref=bookmarks.

An extensive curriculum was developed for the Aquaponic Master Class for Teachers (Table 1). A total of 55 educators and extension professionals attended the Master Class for Teachers held at the UW-Stevens Point Aquaponics Innovation Center in 2018 and 2019. Nearly half of those who attended (27) already had classroom aquaponic systems but were not properly trained on their operation or how they may incorporate the systems into classroom curricula. The other educators/extension personnel did not have aquaponic systems and were interested in purchasing/constructing a system and incorporating it into their curriculum. All 55 educators/extension personnel will have aquaponic systems in their classroom by 2022 and will use the curriculum created/provided by this project to enhance the Science, Technology, Engineering and Mathematics (STEM) curriculum in their school. One of the industry partners, Nelson & Pade, plan to continue offering the Master Class for Teachers for years to come, further reaching educators throughout the U.S.

Objective 1. — We have surveyed agency, academic and extension personnel for gaps in the knowledge base of the existing workforce.

Objectives 2 & 3. — We continue to refine our website (www.ncrac-yea.org) and are well underway to fully populating the databases for aquaculture outreach. We have held three rounds of the Aquaculture Challenge are in the process of hosting another competition beginning January 2020.

Objective 4. — To date we have held two aquaponic 3-day workshops, one in 2018 for 20 educators, and in 2019 held another aquaponic 3-day workshop for 35 educators. A third 3-day workshop is planned for August 6-8, 2019 for 10 educators.

Objective 5. — We have identified 24 aquaculture focused programs in the US and are encouraging universities and colleges to do more to make these skills more available.

Impacts

Increasing awareness of the level of youth engagement in aquaculture allows targeted responses for making resources and expertise available. We have been encouraged to find more aquaculture activity in the schools than we expected. We also found the educators to be extremely receptive to our workshops and asked how more of this type of learning can be obtained. A total of 55 educators and extension professionals attended the Master Class for Teachers held at the UW-Stevens Point Aquaponics Innovation Center in 2018 and 2019. Nearly half of those who attended (27) already had classroom aquaponic systems but were not properly trained on their operation or how they may incorporate the systems into classroom curricula. The other educators/extension personnel did not have aquaponic systems and were interested in purchasing/constructing a system and incorporating it into their curriculum. All 55 educators/extension personnel will have aquaponic systems in their classroom by 2022 and will use the curriculum created/provided by this project to enhance the Science, Technology, Engineering and Mathematics (STEM) curriculum in their school. One of the industry partners, Nelson & Pade, plan to continue offering the Master Class for Teachers for years to come, further reaching educators throughout the U.S.

By adding our findings to the www.ncrac-yea.org website, we are revealing the landscape of aquaculture engagement. Our immediate knowledge of the resource needs has increased, and we are confident this will accelerate as we continue with the project. In particular, the enthusiasm of the educators in the workshops was infectious and will no doubt be passed on to their students and colleagues.

The 2016-17 Aquaculture Webinar Series fostered a partnership among NCRAC, the National Aquaculture Association, and the United States Aquaculture Society. This partnership broadened the scope and participation in these webinars nationwide. This 18-part series covered timely and relevant aquaculture topics for the NCR and the overall US aquaculture industry.

We anticipate, as we near the end of this project, the aquaculture industry will benefit from detailed interactive maps of aquaculture education throughout the NCR. These maps will identify regions where future skilled workers can likely be found. The maps utilize updateable fusion tables that give detailed information on a variety of metrics including extent of curricula and what may be lacking for the schools to move their program forward. The web platform is also accessible by the schools listed on the map. Cost of travel is a major barrier for schools to interact. Using ncrac-yea.org, they will now be able to locate other programs in their geographic area, as well as link to schools across the state and region. By sharing their struggles and successes, they will be able to advance their education more quickly than by working alone. We also envision this web platform continuing to host competitions such as the “Aquaculture Challenge”, with minimal cost. Each year, teams could be challenged to address a problem facing aquaculture. Teams could pitch their solutions using a video meeting, and judges would evaluate how well they solved the problem. Winning teams could be invited to present at the biennial NCRAC conference, and other aquaculture venues.

We created aquaculture/aquaponic content for workshops to train educators and extension personnel in STEM (Science, Technology, Engineering and Math) related fields and other industry-related concepts such as business operation, marketing, and financial management. Now that development is complete, these workshop materials could be used in the NCR and throughout other RAC’s. With undergraduate enrollment declining at most universities, the addition of more applied courses/programs such as aquaculture and aquaponics could help reverse this trend by identifying a clear career pathway that shows how college education coupled with internship programs can lead to career opportunities in aquaculture. Ultimately, the aquaculture industry will benefit from an educated, skilled, young workforce that will help the U.S. aquaculture industry prosper and be ready to “carry the torch” for the industry as a generational change takes place. This can be best accomplished by the co-development of the aquaculture workforce.

Recommended Follow-Up Activities

The benefits of online and in-person workshops and learning activities are the immediate response and feedback you receive from participants. Like many of these programs, follow-up activities include continued feedback from participants as they continue to use the knowledge gained and resources used in their own programs. Also, continued funding is necessary to keep online information available and to continue offering the workshops to additional new educators and extension professionals.

Publications, Manuscripts, Workshops, and Conferences

See the Appendix for a cumulative output for all NCRAC-funded Education activities.

Table 1. Aquaponic curriculum developed and provided to educators as part of Aquaponic Master Class for Teachers.

Source	Chapter	Topic
Nelson & Pade	1	Introduction & History of Aquaponics
	2	Establishing & Maintaining the Fish Tank
	3	Seed Germination & Planting
	4	Plant Selection & Care
	5	Plant Nutrient Requirements
	6	Photosynthesis, Transpiration and Light
	7	Fish Anatomy
	8	Fish Nutrition & Health
UWSP	9	Plant Physiology & Light
	10	Fish Physiology
	11	Water Quality & Chemistry
	Appendix A	Additional Information Sources & Pertinent Websites
	Appendix B	Project & Experimental Ideas
	Appendix C	Other Products & Multimedia
	Appendix D	Argument Driven Approach Rubric

Table 2. List of higher education institutions where aquaculture or a related field is offered as part of curriculum (list provided by the US Aquaculture Association).

Auburn University
Brunswick Community College
Carteret Community College
College of Southern Idaho
Florida Institute of Technology
Gadsden State Community College
Hillsborough Community College
Hocking College
Kentucky State University
Lake Superior State University
Mansfield University
Roger Williams University
Southern Illinois University
State University of New York, Cobleskill
Texas A&M
Trinidad State Junior College
University of Arkansas at Pine Bluff
University of California Davis
University of Hawaii
University of Idaho
University of Maine
University of New England
University of Rhode Island
University of Wisconsin-Stevens Point

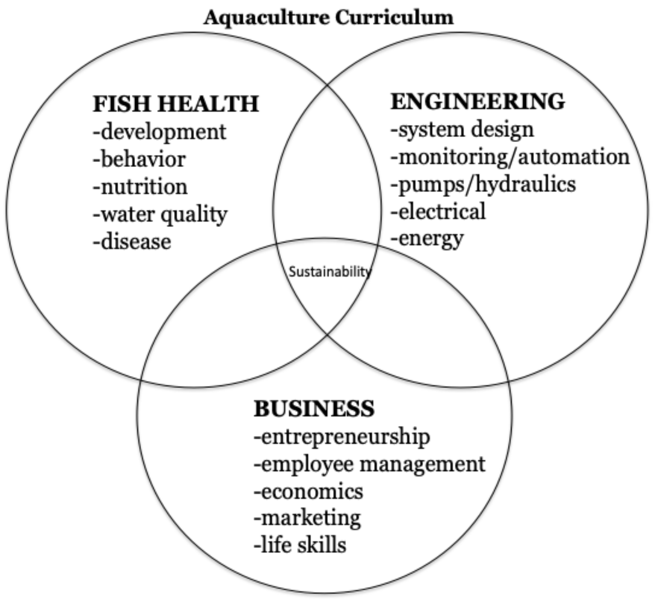

Figure 1: Workforce Skill Needs for the Aquaculture Industry

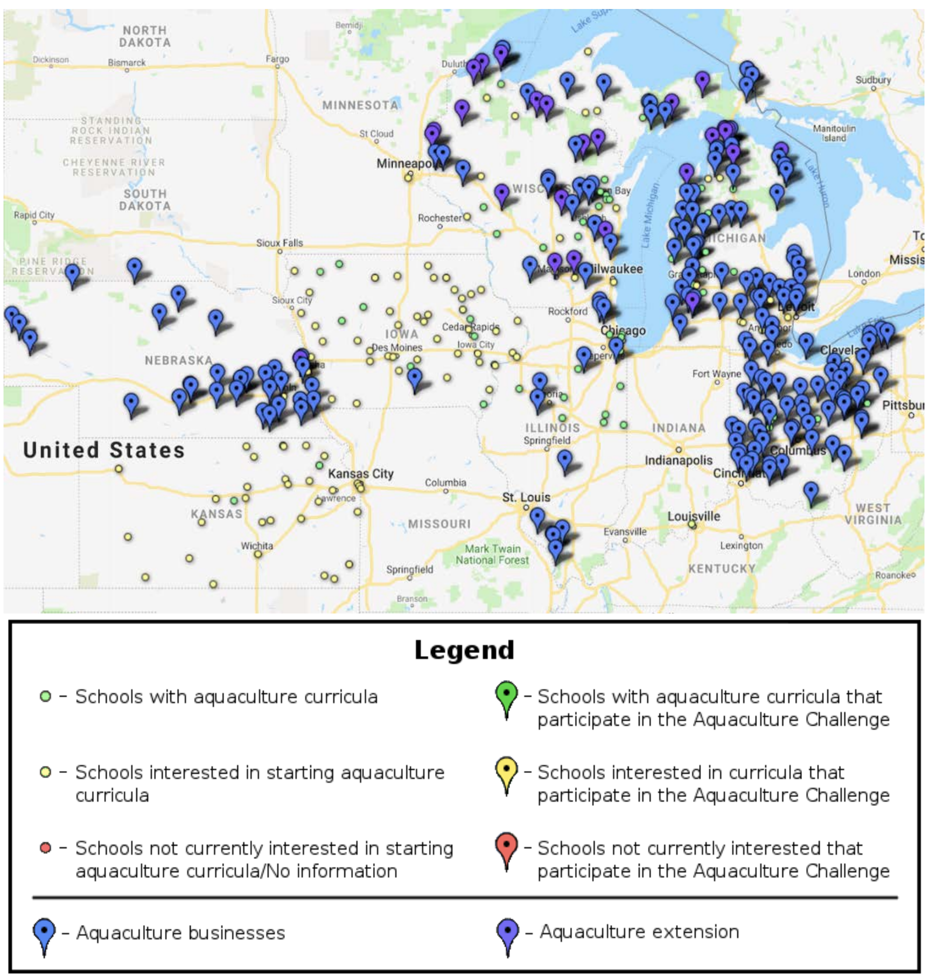

Figure 2: Aquaculture Activity in the NCR www.ncrac-yea.org

Project Title: Development of an All-Female Yellow Perch Population: A Strategic Approach Using Thermal Manipulation, Sperm Selection, and Genomic Data Analysis [Termination Report]

Total Funds Committed: $162,261

Initial Project Schedule: July 1, 2017 to June 30, 2019

Current Project Year: July 1, 2-2017 to June 30, 2018

Participants: Sepulveda Villet, O.J., University of Wisconsin-Milwaukee; Dabrowski, K.E., The Ohio State University

Extension Liaison: Jim Held, *replaced by J. E. Morris, Iowa State University*

Industry Liaison: Stinton, A., RDM Shrimp, Fowler, Indiana

Reason for Termination: Completion of project objectives.

Project Objectives

1. To determine the influence of temperature on gonadal differentiation in Yellow Perch of Ohio origin raised at low 14°C (57°F) or high 24°C (75°F) water temperature from fertilization until completion of sex differentiation.
2. Examine the sex ratio and growth rate of progenies sired by potentially sex reversed males (obtained from objective 1) reared in parallel groups (OSU) and separately in a "common garden" design by factorial crossing (UW-Milwaukee). Additionally, outcross performance (fertilization, survival, growth rates at 30 and 90 days, feed efficiency) will be evaluated among crosses of Ohio strain and hybrids between UW-MILWAUKEE genetically improved yellow perch x Ohio perch sperm.
3. To determine if the use of a flow-cytometry-based cell sorting method will correctly identify and segregate "Y"- and "X"-sperm, using a fluorescent nuclear tag and differential fluorescence as separation criteria (UW-Milwaukee).
4. To characterize DNA from "X"-sperm and utilize a novel yellow perch genome to identify putative sex-linked markers that can be used to increase efficiency of cell-sorting or other molecular-based sperm selection methods (UW-Milwaukee).
5. To optimize high-throughput cryopreservation methods for yellow perch sperm and develop a pilot cryo-bank of sex-reversed ("XX") male yellow perch sperm, which will be immediately available for use by fish farmers in the North-Central region to produce all-female progenies for grow-out (OSU).

Deliverables

1. The development of standardized methods for collection, extension, cryopreservation and distribution of yellow perch semen.
2. A technique of thermal manipulation that will result in sex-reversed male yellow perch, which produce all-female progenies when crossed to female yellow perch.
3. The identification of putative sex-determining gene(s) for yellow perch.
4. A method to screen and select sperm, as a strategy to produce monosex lines.
5. Primary, peer-reviewed literature highlighting our research products.
6. Technical white paper(s) on collection techniques and use of cryopreserved semen in commercial fish farms.
7. A web-based outreach and training program for the use of cryopreserved semen in commercial farms.

Project Summary

The problem addressed by this research project is the lack of analytical and research tools needed for development of a sustainable method to produce all-female fingerlings, and to reliably preserve semen from genetically improved and sex-reversed yellow perch. The technologies and resources gained from these efforts will benefit the aquaculture industry by increasing hatchery efficiency and enabling the production of all-female populations for grow out. This research proposal directly addresses USDA/ NCRAC targeted research area (TRA) A-1: "Reproduction/ Early life history", with activities for "Broodstock quality/ management" and "Monosex production", as well as TRA A-5: "Enhanced Growth Technology" through activities for "Improved strains". This project will increase the number of aquaculture facilities dedicated to yellow perch aquaculture by increasing the year-round availability of yellow perch gametes, and will reduce the scope and size of broodstock operations by reducing the number of male breeder fish required to supplement out of cycle-spawning in commercial facilities. The increased availability of yellow perch gametes will also develop a commodity product, similar to that found in porcine, cattle and poultry industries, with the sale of high quality, pedigreed and validated gametes for commercial hatchery use. The development of molecular sex markers will allow further development of mono-sex yellow perch strains, which will reduce operational variation in fish size ranges, and reduce operation costs through the abatement of labor-intensive processes, such as size grading and sorting.

Finally, this project will secure the availability of yellow perch fingerlings by facilitating the storage and availability of locally-adapted genetic resources found in the Great Lakes region and beyond.

Technical Summary and Analysis

Objective 1. – To determine the effect of temperature on gonad differentiation in Yellow Perch, 11 full-sibling progenies were produced at OSU in April 2018. Each sibling group was divided to two individual tanks in two separate recirculation systems and reared at low (14°C; 57°F) and high (27°C; 81°F) water temperature. Fish were exposed to these two different temperatures from the start of exogenous feeding until presumed sex differentiation was completed (mean total length of individuals reached approximately 30mm; 1.2in). Growth and survival were monitored throughout (56 days at high temperature, 144 days at low temperature) and samples were taken once fish reached target body size for histological analysis of gonad formation. Temperatures were then adjusted to follow seasonal variation for continued grow-out.

We attempted to determine sex ratio externally in May 2019. However, due to average small size of fish from high ([22.9±10g; 13.4±1.7cm] [0.8±0.4oz; 5.2±0.7in]) and low ([6±2g; 8.3±1.1cm] [0.2±0.1oz; 3.3±0.4in]) temperature groups, not all fish had reached externally identifiable sexual maturity, such as release of sperm. We observed male-biased sex ratios in several high temperature groups (Table 1). Spermiating males from low and high temperature groups were chosen randomly to fertilize eggs and identify possible neomales (Objective 2.) Due to the potential presence of neomales without open sperm ducts, these fish continued to be grown-out for final determination of sex ratio externally, January 2020.

Objective 2.− Extended samples of OSU Yellow Perch semen were received by UW-Milwaukee in 2018, to establish a common protocol of cross-strain fertilization. Semen was collected from OSU normal males. OSU staff macerated testes from putative neomales, and UW-Milwaukee Choptank strain males were also used. Semen samples were distributed to small sections of freshly spawned eggs (UW-Milwaukee Choptank strain) to allow for fertilization. Data on the number of non-viable eggs, eggs per 2.5cm (1in) grid, and fertilized eggs after 2 hours were collected. Fertilization was low for both the OSU normal males, and OSU putative neomale semen samples, ranging from 0-10.35% fertilization. Use of fresh semen, stripped from control males, resulted in high fertilization (81.86-93.08%, n = 25), underscoring a need to improve methods and protocols for the transportation of cryopreserved and extended semen samples.

In spring 2019, spermiating males from high and low temperature groups at OSU were randomly chosen for fertilization trials in order to produce progenies and at later staged to identify potential neomales produced by methods previously described in Objective 1. The number of spermiating males across high and low temperature groups at OSU in April 2019 was low, and males only gave small volumes of sperm. In addition, egg quality of OSU perch females was low due to unsuitable spring water temperatures (accelerated temperature increased from 10 to 18°C [50 to 64°F]), resulting in low hatching success across all progenies produced. Fifteen progenies from thirteen different 2018 males (from five high temperature and one low temperature 2018 groups) were divided and stocked to individual aquaria in three recirculation systems. Progenies are currently being reared in high (27°C; 81°F), mid-range (23°C, 73°F), and low (14°C; 57°F) temperatures.

In June 2019, average weight of fish in high temperature (19.3±14.2mg; 0.3±0.2gr) was significantly ($p<0.001$) greater than mid-range (14.7±11.3mg; 0.2±0.2gr) and low (11.7±3.7mg; 0.2±0.05gr) temperature groups after 14 days of rearing at target temperatures. Average length of fish in high (13.2±2.3mm; 0.5±0.1in) and low (12.9±2.9mm; 0.5±0.1in) temperature groups were significantly ($p<0.0001$) greater than in low temperature groups (12±1.1mm; 0.5±0.04in) after 14 days of rearing at target temperatures. After 42 days of rearing at target temperatures, in July 2019, average weight of fish in high (69.4±34mg; 1.1±0.5gr) and mid-range (66.5±30.9mg; 1±0.5gr) temperature groups were significantly ($p=0.0057$) greater than in low (54.8±21.3mg; 0.8±0.3gr) temperature groups, but not significantly different from each other. Average length of the high temperature group (19.7±2.5mm; 0.8±0.1in) was significantly ($p=0.0448$) greater than the low temperature group (18.8±2.1mm; 0.7±0.08in), but not the mid-range group (19.5±2.4mm; 0.8±0.09in) at 42 days. Average survival of the low temperature group (67.6%) to 14 days of rearing at target temperature was higher than average survival in the mid-range (62.3%) and high (56.2%) temperature groups. Average survival at 42 days of rearing was highest in the high temperature group (63.8%), followed by the mid-range (57.3%) and then low (46.1%) temperature groups. This suggests that rearing at the high and mid-range temperatures accelerated growth of fish and did not have a significant impact on survival. These temperatures may not only produce XX-neomales, but ensure that neomales reach sexual maturity before fish reared in lower temperatures. This may lead to participation in spawning as 1- and 2-year olds, respectively.

Progenies will continue to be reared in target temperatures until the end of August 2019. Fish will then be reared in seasonal temperatures for grow-out until reaching sexual maturity in Spring 2020. Fish will be dissected at this time to determine sex ratio of each group. It will allow us to conclude which sires, produced in 2018 (Objective 1), are XX-neomales.

Objective 3. — Two fluorescent nuclear dyes were identified as compatible with freshly collected yellow sperm cells, and compatible with two flow-cytometry platforms, Thermo Fisher Scientific's Attune NxT flow cytometer, and BD Facsaria III Fusion flow cytometer with cell sorter. While initial trials were unable to distinguish distinct populations of preserved sperm cells, we will continue trials to determine appropriate methods to sort sperm cell populations based on nuclear density and volume, following methods used in cattle to separate male- from female-bearing sperm cells.

Objective 4. — A high resolution nuclear genome of the yellow perch has been completed, using a number of resources, including existing transcriptome data from USDA-ARS, as well as new data generated in Illumina Hi-Seq and Pacific Biosciences RSII analyzers. Total read coverage of the new genome exceeds 87x coverage, with a putative size of 1.1Gbp. Additionally, a histone-based spatial scaffold has been constructed using Dovetail Genomics' HiC method. This resulted in an annotated scaffold containing 24 likely chromosomes, matching already known karyotypes for yellow perch. Predicted protein transcripts identified at least 7 likely sex-determination genes also observed in other teleost fishes. Further analyses will determine if these genes are concentrated in a specific putative chromosome. To fulfill this effort, a research consortium was developed among researchers from UW-M, USDA- ARS, Mississippi State University, and with contract work from Dovetail Genomics. This high-resolution genome comprises annotated gene sequences, predicted protein transcripts, as well as spatial and putative chromosome-level information (derived from Dovetail Genomics' HiC method).

Objective 5. — UW-Milwaukee staff have collected sperm from March-spawning male broodstock, and have processed it as described in Miller et al. (2018). A portion of these samples for long term storage (beginning the cryobank at UWM, 25 individuals collected from two strains, (50 individuals total), and another portion will be used for the fertilization trials in March. OSU staff are currently conducting a literature review on cryopreservation of percid sperm. This literature review is part of the funded PhD student's dissertation and is expected to be completed by December 2019. During 2018 spawning season the amount of sperm from "XX-neomales" was not sufficient due to their body size and volume of sperm produced, to establish the depository. Potential neomales are expected to be identified once progenies have been grown-out to 5g individual mass and can be dissected to determine sex ratio. Sperm from identified neomales will then be collected in early Spring 2020 and cryopreserved following the methods of Miller et al. (2018) in order to establish the depository. These resources will be made available to the North Central Region aquaculture community. Additionally, UWM will transfer 30 fish (15 female, 15 male, F4 Choptank strain) adult brooders, as an initial broodstock exchange between the two institutions. This will allow the development of outcrosses, additional collection of germplasm, and initiate a redundant or contingency stock, to reduce risk of accidental loss of improved strains at UWM.

Principal Accomplishments

Objective 1. – Temperature manipulation was used as a possible technique to produce sex-reversed Yellow perch. External sex determination of high temperature reared experimental groups showed presence of male-biased sex ratios. Low temperature reared groups did not reach externally identifiable sexual maturation in the first year. Fish are continuing grow-out for evaluation of sex ratio when fish reach age-2 in 2020.

Objective 2. – Males from low and high temperature reared groups were used to sire progenies in Spring 2019 to evaluate progeny sex ratios and identify XX-neomales produced in Objective 1. Progenies are being reared in high, mid-range, and low temperature. Growth and survival monitoring of progenies showed that high temperature fish grew largest after 14 days of rearing at high temperature, compared to mid-range and low temperature groups. However, there was no significant difference in average fish weight of high and mid-range temperature from 14 to 42 days of rearing. Average survival in the high temperature groups was lowest at 14 days of rearing (56.2%), but highest from 14 to 42 days of rearing (63.8%) compared to the other groups. Results suggest warmer rearing temperatures benefit fish growth without significantly decreasing survival. Progenies will be grown-out and dissected to determine sex ratios in Spring 2020.

Objective 3. − The initial identification of compatible dyes and flow cytometry platforms will allow to develop common, standardized, and replicable methods to separate male- from female- bearing populations of yellow perch sperm cells, thus providing an additional method to obtain all-female cohorts of yellow perch.

Objective 4. − The completion of a high resolution, annotated genome marks a watershed point for development of improved strains of yellow perch, as marker assisted selection can now take place at an accelerated rate. By having this genomic resource, gene families associated with desirable traits, such as growth rate, disease resistance, sex-determination, etc., can now be more easily identified. This type of effort and product has resulted in improved strain development in other species, such as catfish, tilapia, and rainbow trout.

Objective 5. − The start of a yellow perch sperm cryobank at UWM and OSU establishes the beginning of a framework that will eventually allow fish farmers to reduce their broodstock sizes by obtaining cryopreserved semen from these institutions, and any future partners. This will allow more farmers to produce their own stocks, as vertically integrated broodstock production is currently not common, due to the high costs of feeding large numbers of adult breeders. By reducing those broodstocks to only females, this expense can be reduced.

Impacts

- First data investigating the effect of thermal manipulation on Yellow perch sexual determination
- XX-neomale sperm will be cryopreserved and made available to the North Central Region farmers and researchers through a cryobank located at OSU once fish reach sexual maturation in Spring 2020
- Completed fully annotated and chromosome-mapped nuclear genome of yellow perch, with corresponding RAD panels develop to screen for sex-differential gene activity.
- Compatible dyes identified for flow-cytometry based sorting of yellow perch sperm cells in two flow-cytometry platforms.
- Development of a practical method for collection and processing of yellow perch semen, including the design and testing of a collection funnel to minimize cross contamination during specimen retrieval.
- Three graduate students supported by this grant (1 PhD student at OSU, 2 MS students at UWM), with a fourth UWM MS student participating as a collaborator in objectives 2 and 4.

Publications, Manuscripts, Workshops, and Conferences

See the Appendix for a cumulative output for all NCRAC-funded Yellow Perch activities.

Project Title: A NCRAC-Sea Grant Partnership for Regional Aquaculture Extension Focused on Marketing and Consumer Demand **[** Progress Report]
Total Funds Committed: $150,000
Initial Project Schedule: November 1. 2018-October 30, 2020
Current Project Year: November 1, 2018-August 30, 2019
Participants: J. S. Carlton (Purdue University)
Extension Liaison: R. Kinnunen (Michigan State University), replaced by K. Quagrainie (Purdue University)
Industry Liaison: M. Emerson, Crystal Lake Fisheries, Missouri

Project Objectives

1. Hire a regional aquaculture extension specialist housed at Purdue University and jointly appointed in the North Central Region Sea Grant Programs and serving all 12 states of the North-Central Region.
2. Conduct a regional needs assessment to better understand what consumer- and marketing-oriented aquaculture programming is being done and how to best use extension to address needs and impediments.
3. Work with existing personnel throughout the North Central Region to develop and deliver extension programming to address consumer needs and impediments aimed at all of the states in the North Central Region.
4. Coordinate development of regional aquaculture extension networks by serving as a liaison among the Sea Grant programs, partnering universities, NCRAC stakeholders, and other stakeholders throughout the North Central Region.
5. Use quantitative and qualitative evaluation to assess the effectiveness of the specialist's program and to help plan subsequent years of the program.
6. Partner with stakeholders to develop funding extending beyond the initial two-year period.

Project Summary

Aquaculture is an important source of healthy protein for ever-expanding domestic and global populations. However, the US edible seafood trade deficit was over $14 billion in 2016. Aquaculture production in the North Central Region (NCR) could grow if producers have improved access to knowledge, skills, and technology and consumers demand this healthy, sustainable, locally produced food. This project is a partnership between the North-Central Regional Aquaculture Center (NCRAC) and Sea Grant, co-funded by NCRAC and Sea Grant, housed at Purdue University, and host a regional aquaculture specialist jointly appointed to the five NCR Sea Grant programs: Illinois-Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The initial focus of the program will be aquaculture marketing and consumers. In the first two years of the project, the pro- gram will assess industry extension needs and impediments, deliver responsive, consumer-oriented programming and marketing, serve as a liaison among project partners and regional stakeholders, and seek future funding. The over- all goal of the project is increased consumer awareness of and demand for the locally grown, healthy farmed-fish protein, resulting in a more resilient aquaculture industry.

Anticipated Benefits

Short-term knowledge gains (timeframe: 1–2 years):

- Consumers will increase knowledge of the health, environmental, and eco- nomic benefits of locally produced seafood
- Consumer awareness of locally produced farmed seafood will increase
- Consumers will increase knowledge of how to clean and cook seafood
- Producers will have increased knowledge of consumer preferences and marketing techniques and understanding of relevant food supply chain regulations
- Program staff, NCRAC, USDA, and Sea Grantwill increase their understand- ing of how to effectively partner on synergistic resource issues

Medium-term behavior changes (timeframe: 2–5 years)

- Consumers will increase their consumption of locally produced seafood
- Seafood producers, distributors, and sellers will adapt their practices based on consumer preferences
- The aquaculture industry will receive increased investment from existing and potential producers
- NCRAC, USDA, and Sea Grant will invest in continued partnerships on re- source issues.

Long-term condition changes (timeframe: 5+ years)

- Consumers will be aware of and demand locally produced aquaculture as a healthy, sustainable source of protein.
- The aquaculture industry in the NCR will be more resilient through in- creased sales, a better- understood market position, and increased consumer demand
- Enhanced quality of life for NCR residents thanks to increased production and consumption of locally grown seafood and a vibrant aquaculture industry
- A culture of collaboration and partnership between NCRAC, USDA, and Sea Grant

We will be creating aquaculture content for workshops to train educators and Extension personnel in STEM (Science, Technology, Engineering and Math) related fields and other industry-related concepts such as business operation, marketing, and financial management. Once development is completed, these workshop materials could be used in the NCR and throughout other RACs. With undergraduate enrollment declining at most universities, the addition of more applied courses/programs such as aquaculture could help reverse this trend. Few students are aware of the career opportunity available in aquaculture, so there is a need for identifying a clear career pathway that shows how education coupled with internship programs can lead to career opportunities in aquaculture. Ultimately, the aquaculture industry will benefit from an educated, skilled, young workforce that will help the U.S. aquaculture industry prosper and be ready to "carry the torch" for the industry as a generational change takes place. This can be best accomplished by the co-development of the aquaculture workforce.

Project Progress

Objective 1. —After a failed initial search due to a lack of acceptable candidates, we are pleased to have hired Amy Shambach, who started around July 30, 2019. Amy has an extensive background in aquaculture and her knowledge and work ethic are a boon to the program. Due to the failed search, Amy started about 7 months after we hoped to have the position filled, so we are playing catch-up.

Objective 2. —We are making progress on this objective. We have created an initial contacts database that we are now working with partners to verify and expand. Additionally, we have drafted questions for a needs assessment and are testing them internally and with key stakeholders.

Objective 3. —Although the extension programming will begin in earnest after we analyze and evaluate the needs assessment, we have already begun working with existing personnel on a regional level by engaging with aquaculture stakeholders throughout the region and taking part in the Great Lakes Aquaculture Collaborative, a new Sea Grant regional project designed to facilitate aquaculture extension throughout the region. In addition, Amy has made dozens of contacts with aquaculture producers, distributors, and other stakeholders throughout the region to inform the needs assessment and introduce the project to relevant stakeholders.

Objective 4. —Amy Stinton has begun to do this, in collaboration with other project personnel, by participating in an in-person regional Sea Grant Aquaculture meeting and by helping to form the Great Lakes.

Objective 5. —No progress on this objective to date.

Objective 6. — No progress on this objective to date.

Outreach Overview

To date there are not results to distribute. Once we have information to share, we will do it via the various networks and advisory committees that we are developing as part of this project.

Target Audiences

The target audience of the extension work will be aquaculture producers as we take our findings and use them to inform marketing-related extension work. Additional audiences include land and Sea Grant personnel who might be working on aquaculture-related issues, and any other relevant stakeholders.

Deliverables (Outputs)

None to date as we await the needs assessment.

Outcomes/Impacts

The project is just ramping up, so we do not have any measurable impacts on stakeholders, but we have already significantly increased our knowledge of the potential aquaculture market to date by developing a database that consists names and contact information for many of the known food-fish producers and potential aquaculture distributors (e.g., seafood distributors, major restaurant groups, grocers, etc.) throughout the region.

Impacts Summary

Relevance. — Aquaculture is a diffuse industry in the North Central Region and there is no central database of food-fish producers across the region. In addition, there is no central database of actual or potential aquaculture distributors across the region, either. As a result, it can be difficult and inefficient to work on aquaculture extension on a regional basis.
*Respons*e. — With funds from the NCRAC-Sea Grant Partnership for Regional Aquaculture Ex- tension, Illinois-Indiana Sea Grant personnel developed a database consisting of:

1. All known food-fish producers in the region, complete with names, species and, if possible, contact information, and
2. Potential or actual members of the aquaculture distribution chain, including fish haulers, seafood dealers, restauranteurs, grocers, farmers' markets, etc.

Results. — By completing this work, project personnel are able to have a broader under- standing of the market and are more efficient in planning aquaculture marketing needs assessments and extension work.
Recap. — Personnel in the NCRAC-Sea Grant Partnership for Regional Aquaculture Extension developed a database of food-fish producers and potential or actual supply-chain members to inform extension work on the project.

Project Title: Supporting and Expanding Aquaculture in the Midwest Through Extension and Outreach **[**Progress report]

Total Funds Committed: $131,432
Initial Project Schedule: November 1, 2018-October 30, 2020
Current Project Year: November 1, 2018-August 30, 2019
Participants: M. Smith (Ohio State University)
Extension Liaison: A. Primus (University of Minnesota)
Industry Liaison: J. Blackburn, Fresh Harvest Farms, Ohio

Project Objectives

1. Build upon previously successful Extension and outreach programs to enhance the established North Central Region (NCR) industry by assisting farmers, educating educators, and assessing and prioritizing the needs of the NCR industry in ways that will not be probable at this time without NCRAC support.
2. Act in a liaison capacity on a variety of collegiate, state, regional, and national committees to ensure the NCR is well-represented when issues or opportunities that can or will affect the NCR aquaculture/aquaponic industry arises.
3. Develop and strengthen partnerships from within the NCR and outside the region among regulatory agencies, industry, academia, and other relevant entities to foster open, meaningful dialog on critical issues and build support for the NCR aquaculture/aquaponic industry.
4. Work closely with the liaisons of every NCRAC funded project to assist in developing and achieving strong deliverables to the industry.
5. Coordinate efforts for seeking non-NCRAC support for NCR aquaculture development; including consumer perception of aquaculture/aquaponics and technology transfer.

Project Summary

There are limited FTEs in Extension with aquaculture expertise in the Midwest. This project proposed and is accomplishing developing Extension programs that are definable and achievable to support the industry. This includes farm visits to learn of farmers problems and proposing potentials solutions or connecting the research(s) to the farmer, workshop development, liaison with other agencies/regions/support systems, and seek outside funding to enhance Midwest aquaculture.

Anticipated Benefits

One of the key components to this work is the development of a survey to assess how the industry feels about NCRAC and the work that is currently being developed. We believe that the research will help set the tone for an all-day discussion in early 2020 which will revolve around the researchers, extension, and the industry getting to learn more about each other so that the researchers can feel confident that the work they are seeking funding for is directly applicable to the researchers. Additionally, we are attempting to achieve some sort of consensus or agreement from the farmers about how to proceed with grant writing since there are more than 35 species cultured in the Midwest in at least six different production systems. Additional benefits to the industry include stated deliverables in the funded project.

Project Progress

Objective 1.− Extension support to any producer, researcher, or extension person in the Midwest who needs extension assistance. This is not something that happens overnight but questions are coming in from other states looking for assistance.

- Designed and led a hands-on water quality workshop in north central Indiana (conveniently located for other states to participate in) with the assistance of the IAAI. and Purdue Extension.

Objective 2. − Liaison support for the researchers as applicable.

- Survey developed with OSU IRB approval to survey producers in the Midwest (on going with results to be presented at NCAC 2020).
- Scheduled NCRAC liaison in the Atlantic Salmon workshop in Northern Wisconsin in Dec 2020.

Objective 3. − Available to all researchers as the Extension Liaison for their research projects to be submitted to NCRAC.

Objective 4. − Working with Purdue Ext and IN/IL Sea Grant to assist their Specialist with their consumer perception work (on their Regional Aquaculture Website Development Team)

- Obtained alteration of my own OSU FTE to include 50% FTE regional duties (formal approval lasting longer than this grant period, if applicable).

Outreach Overview

Personal farm visits with hands-on water quality workshop in north Central Indiana (conveniently located for several surrounding states), phone calls/emails with producers and the groundwork being laid for future communication.

Target Audiences

The target audience of the extension work will be aquaculture producers.

Deliverables (Outputs)

Hands-on water quality workshops, social media posts as applicable, assist the OAA and NCRAC Director with development of the 2020 North Central Aquaculture Conference, and sought aquaculture funding for Midwest support

Outcomes/Impacts

The survey that was developed will not have data produced until early 2020 but I expect producers and researchers to obtain new knowledge and likely change their actions (how they review proposals or how they write proposals) as the entire goal is to get everyone on the same page so that the work that NCRAC funds is highly applicable to the producers in the regions. Additionally, water quality workshops, especially ones that are hands-on, commonly support a change in behavior. I believe this to be the case as their water production water brought in by farmers and we tested various parameters with several different types of meters and test kits and educated about why we test what we test and how we test what we test. The producers who brought in their own water were very surprised to see some of the results they thought they had, not to mention the learning curve of utilizing different equipment was drastically shortened as I was there to educate on the various methods of testing. Producers mentioned investing and testing water quality parameters more often following this workshop.

Impacts Summary

Relevance. — Although there continues to be interest in all facets of aquaculture in the NCR, there are limited FTEs in Extension with aquaculture expertise.
Response. — Using funds from this project, the PI is working to develop a consensus or agreement from the farmers about how to proceed with grant writing since there are more than 35 species cultured in the Midwest in at least six different production systems. Funds garnered from this grant as well as future grants will be used to develop training activities and materials to support the aquaculture industry in this region.
Results. — At the completion of this project, improved training materials will be available to address the needs of the NCR aquaculture industry.
Recap. — To address the limited FTEs of extension staff with aquaculture expertise, a strategy for developing a strategy for obtaining funding for future extension program is being developed.

Rapid Response Projects

Project Title: Formulation and Assessment of a New Generation of Starter Diets for Largemouth Bass (*Micropterus salmoides*) and Yellow Perch (*Perca flavescens*) larvae [Annual Report]

Project Period: March 1, 2017-February 28, 2019; extension to August 30, 2020.

NCRAC Funding Level: $35,000

Participants: K. Dabrowski, The Ohio State University, Ohio; T. Barry, University of Wisconsin- Madison.

Extension Liaison: Alex Primus, University of Minnesota

Industry Liaison: Adam Hater, Jones Fish Farm, Ohio

Project Objectives:

1. To raise larval LMB and YP on live rotifer/brine shrimp nauplii diets as a control and transition to commercial formulated feed (Otohime) or laboratory prepared microparticulate diets.
2. To prepare a *Pichia pastoris* (yeast) culture in order to obtain sufficient biomass of the product proven to be successful in diets for marine and freshwater fish larvae. In addition, we will express salmon trypsinogen in *Pichia* to increase the protein digestion capacity of larval fish fed with this ingredient.
3. To compare growth rate, survival, and swim bladder inflation of LMB and YP in side-by-side laboratory (OSU and UW-Madison) and practical, on-farm (Coral Reef, New Albany, OH) experiments during the larval-juvenile transition period.

Project Summary

There has been no success in rearing of both largemouth bass and yellow perch larvae on formulated diets from the beginning of food intake in order to replace live feeds (rotifers or brine shrimp nauplii) to date. Therefore, we proposed analyzing dry diets that include the yeast species that was used successfully in other fish larvae initial feeding and modifying this yeast so it expresses proteolytic enzyme in order to facilitate digestion process. Pichia pastoris yeast was cultured in standard condition using methanol as carbon source, then tested live and autoclaved for maintaining GFP-protein complex intact. The most recently developed protocol for rearing larvae in optimal environmental conditions, temperature, light regime, turbidity, and salinity were used. Survival and growth were recorded throughout and we studied differences in feed acceptance, intestinal transition time and performance. Results indicated enrichment of live food with Pichia to have a positive effect on fish performance. The model species, Zebrafish (Danio rerio) was used.

Project Progress

Objective 1.— Experiments carried out in OSU lab in 2019 concentrated on zebrafish as the surrogate, model species only due to the delay of the award in the first year of the project. In 2019 spawning season of both yellow perch (May) and largemouth bass (June) were already completed before the first culture batch of *Pichia* was produced. The first feeding experiment addressed the effect of live food (*Artemia naupli*) enrichment with *Pichia* yeast along other commercial enrichments on zebrafish performance during juvenile stage and follow-up to the phase of maturation. Zebrafish larvae were stocked at the density of 110-114 larvae in six 6-L (1.6-gal) cylindrical containers and conditions followed the procedure described earlier, 3 ppt saline, constant light and 28–29 ºC (82-84 ºF) (Dabrowski and Miller (2018).

During the first 7 days (5-11 days post fertilization; dpf), larvae in all containers were fed marine rotifers *Brachionus plicatilis*. At 12 dpf, larvae were divided into three groups (two replicates) and transitioned to feeding with enriched *Artemia*, with one of 3 prepared diets; *Nannochloropsis* algae (NA) (Nanno 3600 Instant Algae®), baker's yeast (*Saccharomyces cerivisiae*) (SC), or live, concentrated Pichia yeast (PY). This phase lasted 3 weeks. At 34 dpf, fish from each group was divided into three replicates and were transferred to a recirculating Zebrafish rack system (2-L [0.53-gal] containers) and fish were transitioned to feeding dry food (Otohime B2® diet). Fish were fed 4-5 times/day based on fish biomass at 26.5-27 °C (80-81 ºF) and photoperiod at 12:12 (L:D). The mean body weight for fish was 60.7, 79.7mg and 78.7 mg (0.002, 0.003 and 0.003 oz), and survival 87, 82.7 and 85.9%, for NA, SC and PY, respectively. Differences between treatments were not significant at this point. Following transition to dry feed differences in performance widened, and zebrafish at 91 dpf showed differences in the mean weight, 296.6, 316.3 and 307.7 mg (0.010, 0.011, and 0.0011 oz). We concluded that enrichment of live food with Pichia during larval-juvenile transition have positive effect on fish performance in comparison to algae enrichment alone.

The second experiment in 2019 addressed the estimation of live feed (enriched rotifers and/or *Artemia* nauplii) (labelled with Fluorescent GFP-Pichia; Green Fluorescent Protein expressed) in comparison to dry formulated feed acceptance, intestinal transition time and performance (growth and survival in the similar rearing unite set- up). Larvae used in this experiment (Casper (transparent) strain, 7 dpf and wild type pigmented fish, 5 dpf, were divided randomly into six groups with two replicates (40 larvae /replicate). Larvae were subjected to six feeding treatments (T) as follows:

1. Treatment 1(Rotifer): larvae were fed on rotifers during the 2 phases of experiment (Rotifers were fasted for 16 h). 2. Treatment 2 (Rotifer-P): larvae were fed on Pichia enriched rotifers during the 2 phases of experiment (Rotifers were enriched with Pichia for 16 h). 3. Treatment 3 (Dry diet-P): larvae were fed on Pichia containing dry diet (size 106-212 µm) during the two phases of experiment. 4. Treatment 4 (Rotifer-*Artemia*): larvae were fed on rotifers during the first phase, 7 days (rotifers were fasted for 16 h) then shifted to *Artemia* during the second phase, 7 days (*Artemia* were starved for 17-18 h). 5. Treatment 5 (Rotifer-*Artemia*-P): larvae were fed on rotifers during the first phase (rotifers were fasted for 16 h) then shifted to Pichia enriched *Artemia* during the second phase (*Artemia* were enriched for 17-18 h). 6. Treatment 6 (Rotifer-Dry diet-P): larvae were fed on rotifers (rotifers were fasted for 16 h) during the first phase then shifted to Pichia containing dry diet (size 106-212 µm).

Fish were fed manually 4-5 times /day. Fish for observations under the fluorescent microscope (Nikon 80i Epifluorescent microscope) collected after 1 h of feeding (Figure 1). Green light images demonstrate intake of fluorescent marker in rotifers (A and B) and *Artemia* nauplii (Fig. 1C and D). The anesthetized fish from the first 3 groups were taken at 8dpf and at 13th dpf (1st day of phase 1 and 2, respectively). In the second phase, samples were taken from the other 3 groups (4-6) at 15 dpf (1st day of phase 2) and at 20 dpf (5 days after feeding of the designed food in this phase). After 21 dpf, juveniles were counted in all the tanks for survival and samples (n = 12) were taken for measuring weight (g) and length (mm) of juveniles (Table 1). These samples were kept in -80 ºC (-112 ºF) to be used for the gene expression (trypsin enzyme) analysis.

At the completion of this experiment significant differences were recorded in mean weight of zebrafish that indicate highly inferior performance of fish fed formulated dry feed (Table1). Dr. Rappley's laboratory carried out studies aimed at transforming linear DNA sequence of fish trypsinogen into Pichia cells. To address this objective, previously characterized trypsin-II (ST-II) mRNA sequence of salmon trypsin (CAA49678.1 trypsin II) was used to extract the full sequence of salmon trypsinogen. >XM_014155449.1, predicated Salmo salar trypsinogen II, mRNA sequence, was then used. A synthetic gene was made that lacked the secretion signal so that the trypsin would be maintained within the yeast cells rather than secreted into the medium. This gene was then inserted into a cloning vector (pCR600), and transformed into E.coli cells following the direction of (Invitrogen kit manufacturer). After that, the plasmid DNA of the recombinant clones was purified, digested SalI to produce linear DNA, and transformed into Pichia GS115. Four transformants of each construct were tested for salmon trypsinogen expression by immunoblotting using the FLAG or 6xHIS epitope tags. For constitutive expression vectors (i.e. glyceraldehyde-3-phosphate dehydrogenase (GAPDH) promoter, and translation elongation factor (TEF1), the cells were grown in 2 ml of minimum glucose medium overnight at 30oC. For constructs that use the methanol-regulated AOX1 promoter, cells were first gown up overnight in 2 ml of minimum glycerol (1%) medium at 30oC (86 F). After that, cells were harvested by centrifugation and cultured in minimum Pichia base with added methanol to final concentration of 0.5, 1 and 2 % and incubated at 30 ºC (86 ºF) with shaking. Cloning of Salmon trypsinogen II (ST-II) gene and its transformation into Pichia pastoris were successfully achieved and confirmed by sequencing. For constructs using the TEF1 promoter, none of the transformants showed expression of the trypsinogen protein.

However, expression of a GFP transgene under control of the same promoter was successfully detected. The same results were obtained when trypsinogen genes were expressed from the methanol-induced promoter AOX1. These results directly linked the failure in expression of trypsinogen to the Salmon trypsinogen transgene and not a problem in the yeasts themselves or the expression system employed. Consequently, future work will attempt to use alternate fish trypsinogens such as cod trypsinogen and cunner fish (Tautogolabrus adsperus) (Macouzet et al.2005; Spilliaert and Gudmundsdottir 1999). We have requested synthesis of primers.

Experiment carried out in OSU lab concentrated on yellow perch only due to the spawning season of Largemouth Bass (June) being already finished. Live feed group was fed rotifers for 3 days and then transitioned to live *Artemia* nauplii for the following 7 days. These juveniles were then stocked into twelve 30- L (7.9-gal) aquaria at a density of 190 individuals per aquarium. Four diets were tested in triplicate, live *Artemia* nauplii, and three formulated feeds on the basis of (1) freeze dried whole fish, (2) cultured and freeze-dried Pichia, and (3) commercial yeast (Instant Yeast, Lesaffre, Milwaukee, WI).

After 14 days of feeding, juveniles were preserved in formalin for determining survival, size and swim bladder inflation (Table 1). Survival and the mean size were significantly greater in live *Artemia* group than in any of the formulated feeds. Acceptance of food and survival was the second best in the group fed "whole fish" as major ingredient.

Mr. Melman constructed a floating cage system in his farm raceway (Figure 1) and carried out an experiment with two formulated commercial feeds, Otohime B1 and starter feed from Omega Sea LLC (Painsville, OH). Yellow perch juveniles initially cultured for 23 day on live feeds (mean weight 21 + 3 mg [) in our laboratory aquaria were transferred to the farm. Fish were stocked to six cages of 56 L (15 gal) working volume, at density 89- 130 fish per nylon (500-um mesh size). Each diet was tested in triplicate. Following 14 days of feeding, fish were preserved in formalin to determine size and survival. Survival was on average 27.5 + 7.1% and mean weight of fish fed Otohime (107 mg) was higher than with Omega diet (66.1 mg). Several improvements need to be introduced, such as extended thermal acclimation, frequency of feeding or water degassing, in order to increase survival and growth of juveniles in these floating cages. University of Wisconsin-Madison (UW-Madison) co-investigator raised yellow perch larvae using live rotifers (*Brachionu*s sp.) in stagnant water system (with aeration) until 23 days post-hatching. Those fish (survival 25-40%) were then offered two commercial formulated feeds (Otohime B1 was one of those diets). After 16 days of feeding survival was 40-44% and fish body length 11-12 mm in both diet groups. The stagnant water system with 50% water change every 3 days was used and it will be replaced in the next studies with a flow-through system.

Objective 2. — Experiments carried out in OSU lab in 2019 concentrated on zebrafish as the surrogate fish, model species, only due to the delay of the award in the first year of the project. In 2019 spawning season of both yellow perch (May) and largemouth bass (June) were already completed before the first culture batch of *Pichia* was produced. Culturing of *Pichia* is still on going in Dr. Rappleye's lab and we use yellow perch broodstock to be spawn in January 2020 from Dr. Sepulveda, UW Madison.

Objective 3. — As LMB and yellow perch larvae were not available at the time of harvest of the first batches of *Pichia*, we continued experiments with zebrafish as a surrogate species and examined effects of nutritional programming of the larvae and juveniles on their performance as broodstock, that is when they attained reproductive age/size. At 34 dpf, fish were transferred to a recirculating system. Fish from each group were divided into 3 replicates with the density of 20 fish / replicate. Fish were transitioned to the feeding on dry food (Otohime B2® starter diet, Reed Mariculture, Campbell, CA) which was offered manually 4-5 times / day according to the tank total biomass. During this phase, juveniles were kept at temperature of 26.5-27 °C and photoperiod was set at 12:12 (light: darkness). After sampling the fish at 104 dpf, the sex of the adult fish in the different groups was assessed by the visual observation of the fish body shape and anal fin coloration. Three spawning pairs from each "feeding" group were randomly chosen for testing fertility (n = 9 pairs total for all groups). Spawning was done as mentioned above for broodstock fish with an average temperature 26.3°C. Fertilization rate; the number of fertilized eggs / total number of eggs produced per spawning (2 h) * 100 and Average fecundity, the total number of eggs produced / female were calculated. Hatching rate was also determined after 5 days of egg incubation, number of live larvae / total No of eggs* 100 (Table 2). Significant difference was found in absolute fecundity (egg per 3 females), twice as high, between fish fed at larval stage with *Pichia* enrichment and two other treatments (Baker's yeast and algae).

Targeted Audiences

Yellow Perch operations in the North Central Region (NCR) have all experienced difficulties in out of season reproduction and raising perch larvae in captivity, in recirculated systems. The industry has long recognized that expanding Yellow Perch culture from ponds to indoor systems would require replacement of live feeds with nutrient complete diets from larval stage to broodstock. Cost-effective starter diets or minimizing duration of live feed (rotifer and brine shrimp) use is a prerequisite of the economic viability of perch culture within NCR.

Outreach Overview

Oral presentations to the visitors of Aquaculture laboratory at Ohio State included description of the experiments carried out with juvenile perch fed formulated feeds. Undergraduate students taking aquaculture class were familiarized with a new technology in diet formulation that includes modified yeast. The visitors of the Melman's farm representing community of ornamental fish breeders in Columbus area were introduced to the project carried out in his facility.

Deliverables

Hands-on instructions were given to participating farmer, Mr. Melman, regarding the methods of raising yellow perch larvae/juveniles. During visits to the farm we also helped Mr. Melman with koi carp reproduction following hormonal induction and larval rearing of carp.

Outcomes/Impacts

This work has made a significant contribution to the development of formulated diets for first feeding in commercial species in order to replace live feeds.

The results produced in this project provide valuable and necessary preliminary knowledge and methods for formulating dry diets containing transgenic yeast to enhance fish performance. Availability of these diets in the future, after further research and development, will make culture of Largemouth bass and yellow perch feasible year-round. Industry would be able to avoid the limitations of unpredictable weather effects on pond zooplankton and the short growing season in the NCR.

Impacts Summary

Problem. — We received approval of the project for funding from the NCRAC on March 3 and fully executed agreement in July 11, 2018. It was extremely difficult to plan and organize the project bearing in mind the fact that yellow perch spawning in NCR takes place in April-May. Therefore, in this season we concentrated on establishing procedures related to formulated (dry) diets utilization and testing facilities available to collaborators.

Response. — We have obtained significant experience in respect to timing and infrastructure required for performing experiments with yellow perch larvae/juveniles. Data was collected on fish performance following early transition from live feeds to formulated diets.

Results. — Through the first experiment, we concluded that enrichment of live food with Pichia during larval-juvenile transition have positive effect on fish performance in comparison to algae enrichment alone. We developed a protocol for enriching live food with Pichia yeast, and utilized an optimal rearing system. In experiment two, we developed a protocol for producing Pichia containing dry diet for first feeding and compared that to live food. At the completion of this experiment, we recorded significant differences in mean weight of zebrafish, indicating highly inferior performance of fish fed formulated dry feed (Table1).

Recap. — These results during the feeding trials are directly linked to the failure in the yeast's expression of the Salmon trypsinogen transgene and not a problem in the yeasts themselves or the expression system employed. We anticipate that use of alternate fish trypsinogens will result in expression of this protein, increasing performance of fish fed Pichia containing dry diet. We have thus developed a protocol for preparing this yeast with a trypsinogen transgene, though alternate sources need to be investigated, and subsequently preparing diets containing this transgenic yeast for first feeding.

Table 1. Growth and survival of Zebrafish larvae at 21 dpf (initial mean weight of zebrafish larva is 0.22 mg).

Treatments	Body weight (mg)	Body length (mm)	Survival (%)
Rotifer	61.2± 5.0 [a]	19.7 ± 0.5 [a]	80.6 ± 9.1
Rotifer-P	69.1± 2.1[a]	20.4 ± 0.2 [a]	78.4 ± 3.1
Dry diet- P	8.1 ±2.6 [b]	6.8 ± 1.0 [d]	62.4 ± 2.2
Rotifer-*Artemia*	60.5 ±3.7[a]	17.3 ± 0.1 [b]	85.9 ± 6.6

Table 2. Size and fertility of the adult fish at 107-114 dpf (n= 9 breeding pairs)

	Nannochloropsis algae	*Pichia* Yeast	*Saccharomyces* Yeast
Female weight (mg)	363.8 ± 43.16	353.6 ± 24.17	382.3 ± 24.28
Male weight (mg)	250.0 ±10.1 [b]	269.3 ± 6.4 [b]	304.1 ± 10.6 [a]
Female Length (mm)	32.35 ± 1.3	32.38 ± 0.76	31.84 ± 1.3
Male Length (mm)	30.81 ± 0.39	32.04 ± 0.52	31.80 ± 1.1
Average fecundity [1]	251 ± 71.5 [b]	497 ± 26.6 [a]	269 ± 134.5 [b]
Fertilization Rate (%) [2]	74.41 ± 2.2	75.03 ± 8.3	71.21 ± 5.4
Hatching rate (%) [3]	56.04 ± 14.7	55.57 ±3.9	61.33 ± 10.5
Average spawning efficiency	0.67 ± 0.16	0.77 ± 0.25	0.55 ± 0.25

[1]Average fecundity: Number of eggs produced per 3 female/ day up to 2 h post fertilization.
[2]Fertilization rate (%): Number of fertilized eggs/ total number of eggs produced *100.
[3] Hatching rate (%): Number of live larvae / total number of eggs produced *100.

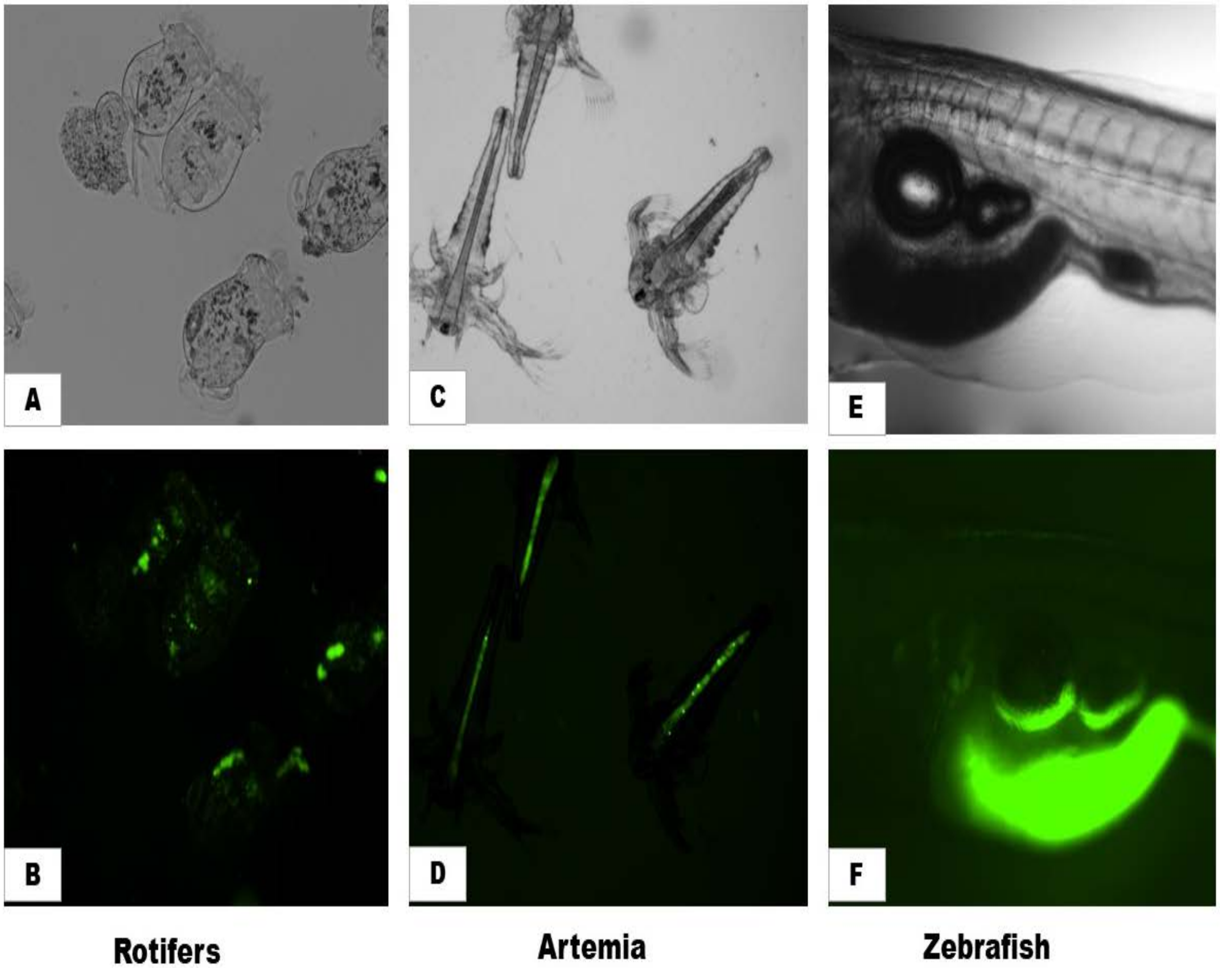

Figure 1. Enriched rotifers (A and B) which were enriched with Pichia for 16 h; Enriched *Artemia* (C and D) which were enriched with *Pichia* for 17-18 h; zebrafish larvae (E and F) as larvae was fed on rotifers during the first phase then shifted to Pichia containing dry diet during the second phase. First row of pictures is under natural light while the second row is using fluorescence. All pictures were captured using the Nikon 80i fluorescent microscope, 4x.

Publications, Manuscripts, Workshops, and Conferences

See the Appendix for a cumulative output for all NCRAC-Funded Yellow Perch activities.

Project Title: Evaluation of Alternative Management Techniques and Systems to Improve Production of Pond-Reared Yellow Perch (*Perca flavescens*): Modeling the U.S. Catfish Market [Termination Report]
Project Period: March 1, 2017-February 28, 2019
NCRAC Funding Level: $30,838
Participants: M. Smith, The Ohio State University
Extension Liaison: K. Quagrainie, Purdue University
Industry Liaison: William B. West, Blue Iris Fish Farm, LLC, Black Creek, Wisconsin
Reason for Termination: Project objectives completed.

Project Objectives

1. Evaluate water quality parameters, fish growth, condition, feed conversion, final length frequencies, survival, specific growth rates, and feeding rates of first-year yellow perch fingerlings (stocked at twice normal rate) provided with either intensive aeration or using an aerated split pond design.
2. Collect the economic data of producing first year yellow perch in either an intensively aerated or an aerated split pond design.
3. Compare these data to long-term historical pond data (stocked at the normal rate) available from both Millcreek Perch Farm and Brehm Perch Farm.
4. To immediately disseminate results to industry via final termination report, fact sheet, presentations, and other information technology transfer strategies.

Deliverables

1. Education at an on-farm workshop in conjunction with the OAA for those interested in learning about the positives and negatives of intensification on their farms.
2. Cost of production data available for yellow perch in the two proposed systems
3. "Proof-of-concept" results disseminated to all of the Midwest and beyond via electronic methods, formal presentations, informal meetings, and any other practical means.

Project Summary

Intensifying pond production systems have been proven to be imperative in assisting U.S. aquaculture farmers with staying competitive in an increasing world economy. For U.S. catfish production (primarily ♀ *Ictalurus punctatus* X ♂ *Ictalurus furcatus*) that has meant the development and research of intensively aerated (≥9.2 kW/ha) ponds and split ponds. While these systems increase the costs (greater electricity, labor, fingerlings, feed, aeration, capital investment to convert systems, risk, among others) the outputs (greater kg/ha of catfish pond surface water) are worth it for some farmers if they follow the recommendations by economists.

Two on-farm Extension demonstration projects were conducted in 2018 at Millcreek Perch Farm LLC (farmer William E. Lynch, Jr.) in Marysville, Ohio and Brehm's Perch Farm LLC (farmer Matt Brehm) in West Liberty, Ohio in order to investigate the feasibility of intensifying yellow perch (*Perca flavescens*) ponds in the Midwest. We attempted to double production (normally 98,842 perch/ha [40,000 perch/ac]) by utilizing these systems. This could assist the farmers in 1) meeting the reinvigorated demand for farm-raised yellow perch as a food and 2) allowing the farmers to be more resource conservative by limiting their need to build additional ponds to meet the demand due to their increased production (kg/ha). Production data was collected and aggregated. Basic cost of production for 2018 and historical data of Millcreek Perch Farm was compared and contrasted. While the systems were not in replicate, and as such there is no statistics involved, the farmers involved were satisfied with the initial project.

Due to the success of this project, Millcreek and Brehm's are following the same protocol for the 2019 growing season, and PI Smith will collect most of the same data that was collected in 2018 for a multi-year comparison and disseminate the results to the public.

Recommended Follow-Up Activities

1. Encourage a further, more robust, study investigating the two systems in replicate with additional on-farm complimentary work.
2. Encourage a further investigation into the economics of the two systems.
3. Investigate other species that are important to the Midwest in these systems.

Technical Summary and Analysis

First year yellow perch (3.6 cm [1.4 in] and 0.51 g [0.02 oz]) were stocked after a 21-d feed habituation period in the split pond at Brehm's Perch Farm on June 1, 2018. Brehm's split pond consisted of three ponds joining for total of 0.40 ha (1.00 ac) (Figure 1), with yellow perch retained in 25% of the total pond surface area and the remaining 75% a waste treatment area. Stocking occurred at a rate of 197,684 perch/ha (80,000 perch/ac; estimated 79,954 perch/ac actual) with a gross weight of 41.73 kgs (91.9 lbs). The split pond contained one 1.5 kw (2 hp) paddlewheel aerator that was moved from the fish culture pond to the secondary waste treatment pond 38 d into the project. Aeration was only added when needed.

The Millcreek Extension demonstration project consisted of one 0.20 ha (0.50 ac) intensively aerated pond and one 0.40 ha (1.00 ac) intensively aerated pond (3.7 kw/ha [2 hp/ac] which ran 24/7 for the duration of the project. The 0.2 ha (0.50 ac) pond was stocked on June 3, 2018 with first year yellow perch (4.0 cm [1.6 in] and 0.6 g [0.2 oz]) after a 21 d feed habituation period. The 0.40 ha (1.00 ac) pond was stocked the same day with yellow perch (3.6 cm [1.4 in] and 0.5 grams [0.02 oz]). Stocking occurred at a rate of 197,684 perch/ha (80,000 perch/ac; estimated 79,398 perch/ac actual) in the 0.20 ha (0.50 ac) pond and 197,684 perch/ha (80,000 perch/ac; estimated 80,039 perch/ac actual) in the 0.4 ha (1.00 ac) pond with a gross weight of 23.1 kgs (51 lbs) and 36.7 kgs (81 lbs), respectively.

At stocking, 300 yellow perch were randomly sampled for individual length and weight for each pond. At least three subsamples of >200 fish per sample were counted and weighed to obtain average individual weight at stocking. Fish were sampled approximately monthly with 100 lengths and weights recorded.

Upon stocking, both farms launched floating automatic feeds where they were refilled daily and remained for 21 d (Figure 2). After removal of the automatic feeders, feed was fed twice daily (morning and just prior to sunset) at both locations to apparent satiation; however, Brehm's added a 31.75 kgs (70 lbs) automatic feeder (Texas Hunter Products, San Antonio, Texas) approximately half way into the project. This allowed Brehm's to have three feedings per day; whereas Millcreek fed twice per day. Feed rate was adjusted according each farm's experience, consultation with yellow perch experts, water quality, and yellow perch consumption with total kgs fed recorded daily. Amount of feed fed was recorded daily. Feed protein, lipid, and diameter size used was adjusted based on growth. Millcreek began the study with Zeigler Feeds (East Berlin, Pennsylvania) through a 1.5 mm (0.06 in) fingerling feed then Zeigler's 2 mm (0.08 in) fingerling feed was blended with Purina Aquamax 200 Fry Starter and 300 Grower 400 until termination of the study. Brehm followed a similar regime although they started to include Aquamax a little later in the study as their yellow perch did not receive the quantity of feed early on in the study like Millcreek. Feeds began to be mixed as the producers were running out of the Zeigler feeds because the yellow perch were consuming significantly more feed than anticipated, and the local elevator provides Purina feed with very little lead time required.

Millcreek ponds did not require modification; only the addition of more paddlewheel aerators (Figure 3). Brehm's split pond required moderate modification. Neither farm location added pond dye to limit algal growth; however, Brehm's used both well water and neighboring pond water to fill the split pond. The neighboring water had recently had blue pond dye added to it, leading to some pond dye being transferred to the split pond. Visually there was little impact on the system after a few days as the dye was quickly diluted. Prior to construction Brehm's ponds were not connected. Two 15.24 cm (6 in) polyvinyl chloride (PVC) pipes were professionally laid in the levees to connect two of the ponds (Figure 4 and Figure 5). The last connection was made by attaching flexible PVC pipes to the submersible pumps located in the second waste treatment pond. A siphon from PVC was started at the end of the primary waste treatment pond at approximately two weeks into the project to assist in water circulation between the three ponds. The larger submersible pump (Xylem, Goulds Water Technology, WS_D3 Series, Model 3888D3, Seneca Falls, New York) moved water at approximately 1,249 lpm (330 gpm) and the smaller submersible pump (Xylem, Goulds Water Technology, WS_BHF Series, Model 3887BHF) moved water at approximately 984 lpm (260 gpm) for 113% turnover rate every day. Both submersible pumps were located on a metal cart at the bottom of waste treatment pond 2 (Figure 6) to limit waste treatment pond sediment from being pulled into the fish culture pond. Differences in water surface height between the second waste treatment pond (where the submersible pumps were located) and the fish culture pond was approximately 1.4 m (4.5 ft). The small submersible pump was started on d 13 and the large pump was started on d 14. Both pumps ran 24/7 for the remainder of the study. Electricity was updated to handle the pumps and additional aeration.

Temperature was recorded daily along with dissolved oxygen (DO) at Brehm's with a YSI 550a DO Meter (YSI Company, Yellow Springs, Ohio) and a YSI Pro20 (YSI Company) at Millcreek. Alkalinity and hardness were measured by digital titration with a Hach Test Kit Model FF-1A (Hach Company, Loveland, Colorado) at the beginning of the study at Brehm's and monthly at Millcreek. pH was measured daily in the evening with a YSI EcoSense® pH10A pH and temperature pen (YSI Company) at both locations. Total ammonia-nitrogen (NH^{4+} + NH_3) and nitrite-nitrogen (NO_2-N) were measured with a SMART 3 colorimeter (LaMotte Company, Chestertown, Maryland) at both farm locations every three days. Un-ionized ammonia was calculated every three days as a function of pH, temperature, and total ammonia-nitrogen at both locations. Water quality testing was increased or repeated if results were high or uncharacteristic.

Feed fed over the last 15 years was acquired from Millcreek records for comparison to this project. Millcreek produced their cost of production data for 2017 which was considered a typical production cycle and the costs were compared to this project for a base comparison. Any additional profit, if there was any, from this production system was not attempted to be calculated due to unknowns to the PI, variables between farms, limited data, and protection of the farmer's records.

Principal Accomplishments

Brehm's Perch Farm LLC

The split pond (0.4 ha; 1.00 ac) had a net production of 4,323.13 kgs/ha (3,849 lbs/ac) (Table 1). Mean (±SD) individual length was 11.9±3.2 cm (4.7±1.3 in) and individual weight was 25.1±21.2 g (0.9±0.7 oz) (Table 1) for an estimated 40 fish/kg (18.2 fish/lb). Feed conversion ratio (FCR = kgs feed fed during the season/ kgs fish at harvest) was 0.99 and total kg feed fed was 1,728 kgs (3,802 lbs). Survival is estimated at 90% and average Fulton's condition factor (K = 100 x (body weight, g)/body length, cm)^3 was 1.11. K offers an idea of a fishes "condition" with numbers > one typically consistent with healthy fish. Yellow perch in the split pond had a size distribution of 4 cm – 20 cm (1.5 in – 7.9 in) (Figure 7) with the peak of the bell curve between 11 cm – 14 cm (4.3 in – 5.5 in).

Millcreek Perch Farm LLC

0.20 ha (0.50 ac) intensively aerated

Pond 1B (0.20 ha [0.50 ac] intensively aerated) had a net yield of 1,569 kg (3,452 lbs) (Table 1). Mean (± SD) individual length was 14.3±3.0 cm (5.6±1.9 in) and individual weight was 39.3±22.4 g (1.4±0.8 oz) (Table 1) for an estimated 24.4 fish/kg (11.1 fish/lb). FCR for the 0.20 ha (0.50 ac) was 1.10 and total kg feed fed was 850 kgs (1,870 lbs). Survival is estimated at 97% and average K was 1.16. A 97% survival with an estimated end of season return of fish ≥7.6 cm (3 in) of 50.9% is similar (52.75%) to the 2017 production season. Yellow perch in the 0.20 ha (0.5 ac) pond had a size distribution of 6 cm – 20 cm (2.4 in – 7.9 in) (Figure 8) with the peak of the bell curve between 14 cm – 17 cm (5.5 in – 6.7 in).

0.40 ha (1.00 ac) intensively aerated

Pond 2 (0.40 ha [1.00 ac] intensively aerated) had a net yield of 4,636.50 kgs/ha (4,128 lbs/ac) (Table 1). Mean (± SD) individual length was 14.2± 2.2 cm (5.6±0.9 in) and individual weight was 34.0± 15.8 g (1.2±0.6 oz) (Table 1) for an estimated 29.3 fish/kg (13.3 fish/lb). FCR for the 0.4 ha (1.00 ac) was 0.98 and total kg feed fed was 1,835.5 kgs (4,038 lbs). Survival is estimated at 69% and average K was 1.00. Possibly in relation to survival, the 52.75% return of fish ≥7.6 cm (3 in) in 2017 was drastically increased to >67% in the 0.4 ha (1.00 ac) in 2018. Yellow perch in the 0.40 ha (1.00 ac) pond had a size distribution of 5 cm – 21 cm (2 in – 8.3 in) (Figure 9) with the peak of the bell curve between 13 cm – 15 cm (5.1 in – 5.9 in). Double (600 fish) were able to be sampled at Millcreek compared to Brehm's, which may have provided a better realistic size distribution.

Despite 69% survival estimated in Millcreek's 0.40 ha (1.00 ac), no mass or chronic mortalities were observed. Yellow perch never went off feed and had a similar length frequency distribution in comparison to Brehm's estimated 90% survival. It is possible that due to a high variation in sizes between male and female that our sampling efforts were not adequate leading to a miss representation of the actual survival in the pond.

Water quality

Parameters were within recommended levels for yellow perch (Table 2) in most occasions at both locations and all ponds. pH did reach a high of >10 one day in early August at Brehm's. Oxygen also reached a minimum of 3.2 mg/L at Brehm's (Figure 10). However, of 1,038 DO readings at Brehm's, only 11 times did the DO fall below 4 mg/L; even with minimum aeration applied. Millcreek's two intensively aerated ponds reached a minimum of 3.5 mg/L and 3.0 mg/L between the 0.20 ha (0.5 ac) and 0.40 ha (1.00 ac), respectively (Figure 11). Records show of the 286 recordings the morning DO was below 4 mg/L nine times in the 0.20 ha (0.5 ac) and five times in the 0.40 ha (1.00 ac).

Total ammonia-nitrogen was recorded >1 mg/L one time in Millcreek's 0.20 ha (0.5 ac) (and >2 mg/L in Brehm's split pond six times (11% readings >1 mg/L). Un-ionized ammonia was recorded as high as 0.95 mg/L in the split pond; although there is literature that yellow perch are fairly tolerant to higher ammonia concentrations (Espey, J.L. 2003); especially with a high DO concentration (Medberry 2014). Despite a few records of high ammonia concentration, yellow perch never appeared to be negatively affected as they never went off feed.

Feeding

In reviewing Millcreek's 15-yr history of feeding yellow perch at their normal rate (98,800 yellow perch/ha; 40,000/ac), fish consumed more food than expected (7% and 15% more). Millcreek historically averaged 1,560 kg (3,439 lbs) feed/80,000 first year yellow perch. In this project, the 0.20 ha (0.5 ac) pond received 1,676 kg (3,695 lbs) feed/80,000 fish and the 0.40 ha (1.00 ac) pond received 1,832 kg (4,038 lbs) feed/80,000 fish (Figure 12). Peek feeding occurred at the end of August for the project with the 0.20 ha (0.5 ac) pond receiving a max daily feed of 99 kg/ha (88 lbs/ac) and the 0.40 ha (1.00 ac) pond receiving a max feeding of 94.4 kg/ha (84 lbs/ac). Brehm's 0.40 ha (1.00 ac) split pond received a max feeding of 57 kg/ha (51 lbs/ac). Note that Brehm's yellow perch continued to eat heavy later in the project as Millcreek's fish were starting to slow down for the season even though the farms are only approximately 30 miles apart.

Interestingly, more than doubling the amount of feed, which includes the addition of more than double the amount of nitrogen, the ponds were relatively stable with fish apparently unaffected by the increased concentration in confinement. Also interesting is the pond's ability to digest the additional waste with seemingly little trouble. Oxygen concentration did noticeably drop during periods of extended cloudiness; however, the systems rebounded quickly once photosynthesis started following the cessation of the cloudy days.

Economics

Millcreek 2017 (prior to the project) data and 2018 (current project) data were compared to investigate the costs of production differences (Table 3, Table 4, Table 5). In 2017, Millcreek recorded the cost to produce a single yellow perch to at least 7.6 cm (3 in) was $0.41 (Table 3). In 2018, the 0.2 ha (0.50 ac) pond revealed cost per fingerling of $0.36, and the 0.4 ha (1.00 ac) pond revealed a cost per fingerling of only $0.26 (Table 4 and Table 5). This case of real-world farm data is interesting as the farmer reached an electrical usage minimum which put them in a lower ¢/kW during this study. Not all farms will receive the discount per kW for using more electricity and doubling the cost of electricity to investigate the sensitivity in the 0.2 ha (0.50 ac) reveals that the cost per fingerling would be the same as 2017. However, it is important to note that doubling the electricity cost of the 0.4 ha (1.00 ac) pond reveals a discount still of $0.11/fingerling ($0.30) compared to 2017.

In 2017, feed, labor, and supplies (water quality consumables, pond dye, nets, hoses, etc.) were the highest three costs, respectively. In the 0.20 ha (0.5 ac), feed and supplies were the two highest costs, respectively, with electricity and labor both equaling $0.05/fingerling. In the 0.40 ha (1.00 ac), feed, supplies, and electricity were the three highest costs, respectively.

Impacts

- Stocked and harvested first-year yellow perch at twice the normal density with moderate to high typical survival and typical or higher average individual length and weight.
- Developed, with the producers leading, a successful small-scale split-pond system for yellow perch; at least short term.
- Developed a successful water quality monitoring protocol for the producers to maintain adequate parameter levels in these intensive production systems.
- Transferred the technology concept to producers in Ohio at a Millcreek on-farm workshop in summer 2018.
- Transferred the technology results in presentation form to producers in Ohio and Iowa.
- Transferred the technology results in print/audio/video recordings form for producers throughout the Midwest and other regions/countries.
- Producers happy enough with the rapid response results that the same protocol is being followed for the 2019 production season.
- Double production in the same

Conclusion

This on-farm Extension demonstration project indicates preliminary success in intensifying yellow perch pond production. It is documented that as the density of fish in a given body of water increases there will be an increase in total gross weight but a decrease in individual fish size (Avault 1996). Regardless of how well feed-habituated yellow perch are, in ponds it is apparent that a significant percentage will never even reach 7.6 cm (3 in) in the first year. However, in comparing 2017 (a typical production year at Millcreek) with 2018 (intensively aerated production) not only did the total gross weight harvested increase substantially, but the percentage of perch ≥7.6 cm (3 in) was also similar (0.20 ha [0.5 ac]; 51%) or substantially higher (0.40 ha [1.00 ac]; 67.3%). Yellow perch reaching a minimum of 7.6 cm (3 in) is not an arbitrary number as Millcreek has a market for fish with this minimum length; although perch of this size are clearly not likely to ever be food fish. No attempt at obtaining a sex ratio was attempted; although this is likely an important factor to consider during future research as it is well known that females grow substantially faster than males.

Farmers are cautioned during all presentations and write-ups that intensifying systems should not be adopted if the farm is not a primary focus where significant labor and capital can be invested. Kumar and Engle (2017) and Kumar et al. (2018) noted yield, catfish prices, and FCR were the three greatest risk factors to consider to catfish farmers in split ponds and intensively aerated ponds. While enough data has not been collected to determine that these three factors have the greatest impact on yellow perch producers, at a minimum FCR and yield need to be closely monitored as they will likely have a significant effect on the economics of these systems. FCR and yield concerns means farmers must be vigilant in their record keeping to adequately determine whether or not it is worth it to intensify their systems (i.e. cost of feed each year, kgs feed fed each day, number and size of fish at stocking, fish/kg net yield, and percentage of fish ≥7.6 cm [3 in]). Due to the preliminary success of this on-farm project, further research should be conducted to collect multi-year on-farm data as well as university replicated research with complimentary economics. These processes have the ability to assist Midwest producers in meeting the demand of locally-raised yellow perch for food.

Recommended follow-up activities

1. Encourage a further, more robust, study investigating the two systems in replicate with additional on-farm complimentary work.
2. Encourage a further investigation into the economics of the two systems.
3. Investigate other species that are important to the Midwest in these systems

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Figure 1. Google Maps aerial view of Brehm's Perch Farm LLC following construction of the split pond system. Yellow perch were traditionally stocked in all three ponds; however, in this project fish were retained in the pond indicated with a star at a rate of 197,684/ha (80,000/ac). The fish pond is 0.10 ha (0.25 ac) (yellow star) and the two waste treatment ponds total 0.30 ha (0.75 ac). Water flow direction is indicated by arrows. The blue rectangle indicates the location of the two submersible pumps used for circulating the water. The black triangle indicates the location of water sampling (temperature, dissolved oxygen, nitrite, and total ammonia-nitrogen); whereas the white circles indicates location of additional water sampling (temperature and dissolved oxygen). Note Google Maps has updated since construction and the construction can be viewed.

Figure 2. Floating belt feeders used to encourage yellow perch to stay on feed post stocking. Automatic feeders were refilled daily and removed after 21 d.

Figure 3. Intensive aeration (3.7 kW/ha; 2 hp/ac) at Millcreek Perch Farm LLC with the 0.40 ha pond in the foreground and the 0.20 ha pond in the background. Paddlewheels ran 24/7 for the duration of the project.

Figure 4. Polyvinyl chloride pipes (two 15.2 cm [6 in]) connecting the yellow perch culture pond to the primary waste treatment pond with a screen to prevent fish from escaping from the culture pond.

Figure 5. Polyvinyl chloride pipes (two 15.2 cm [6 in]) connecting the primary waste treatment pond to the secondary waste treatment pond.

Figure 6. Submersible pumps and metal stand that were placed in the secondary waste treatment pond. The larger pump moved 1,249 lpm (330 gpm) and the smaller pump 984 lpm (260 gpm). A 100% water exchange occurred approximately every 21 hrs 50 min.

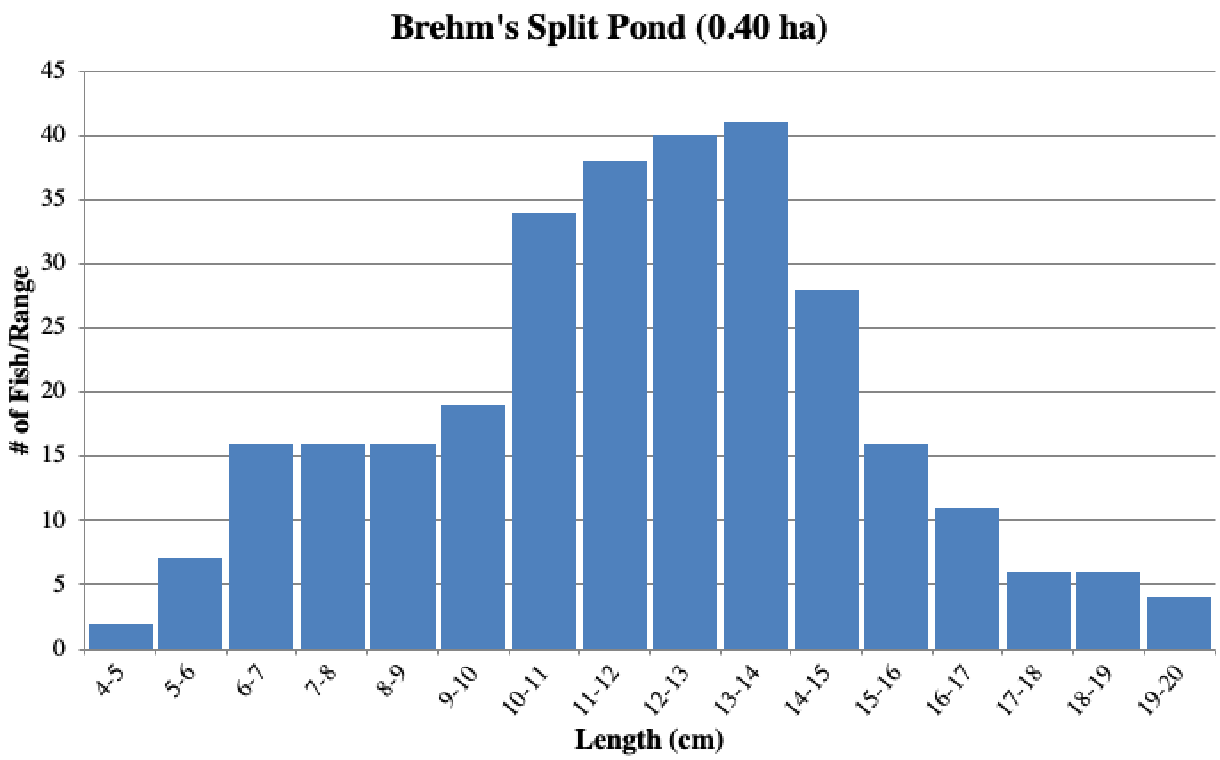

Figure 7. Length frequency of 300 yellow perch sub-sampled at Brehm's Perch Farm's in a split pond stocked at 197,684 yellow perch/ha (80,000 yellow perch/ac) following one growing season.

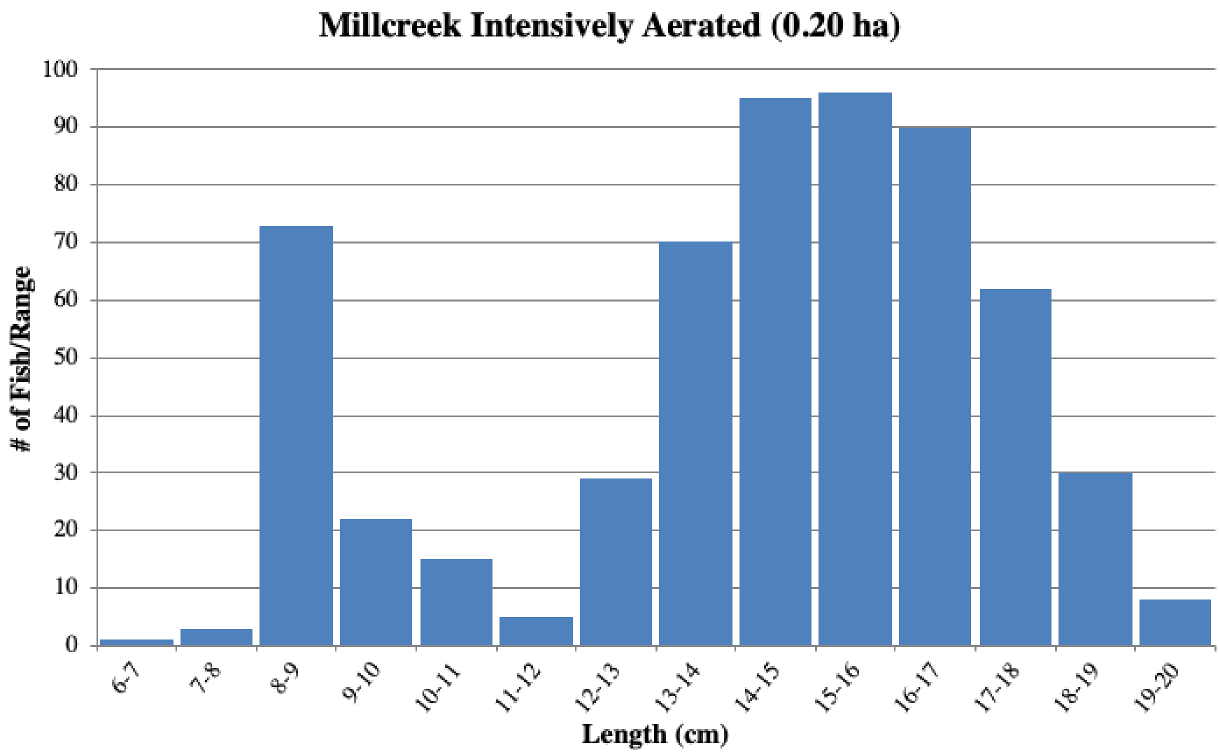

Figure 8. Length frequency of 599 yellow perch sub-sampled at Millcreek's 0.20 ha (0.50 ac) intensively aerated pond stocked at 197,684 yellow perch/ha (80,000 yellow perch/ac) following one growing season.

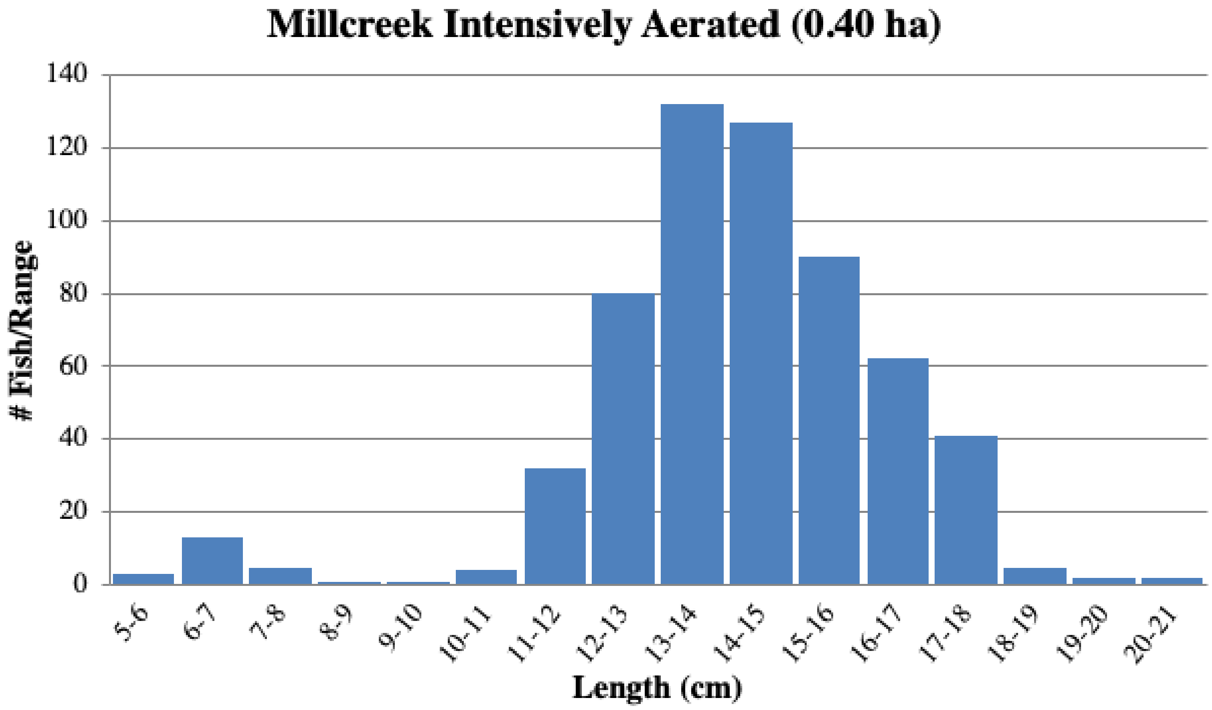

Figure 9. Length frequency of 600 yellow perch sub-sampled at Millcreek's 0.40 ha (1.00 ac) intensively aerated pond stocked at 197,684 yellow perch/ha (80,000 yellow perch/ac) following one growing season.

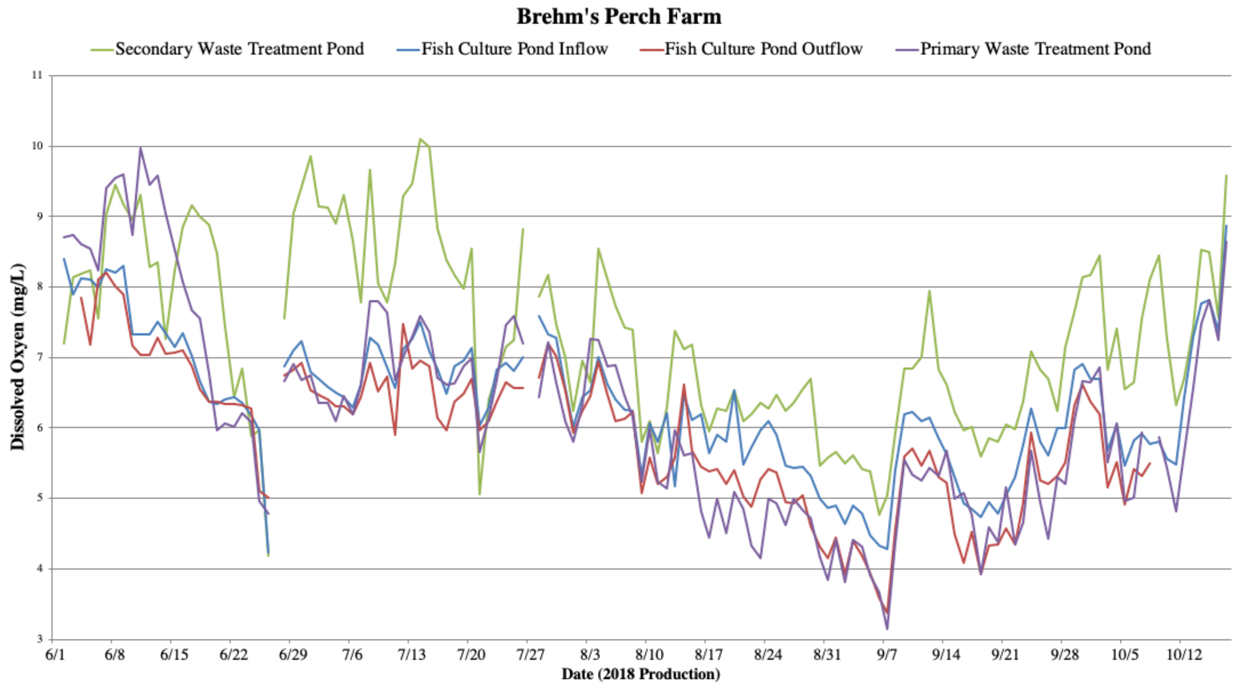

Figure 10. Dissolved oxygen concentration at Brehm's Perch Farm's split pond. The secondary waste treatment pond location is just prior to entering into the fish culture pond. The fish culture pond inflow is the location where the water exists from the submersible pumps that are located in the secondary waste treatment pond. The fish culture pond outflow is the location just prior to exiting the fish pond into the primary waste treatment pond. The primary waste treatment pond is the location just prior to the water entering into the secondary waste treatment pond.

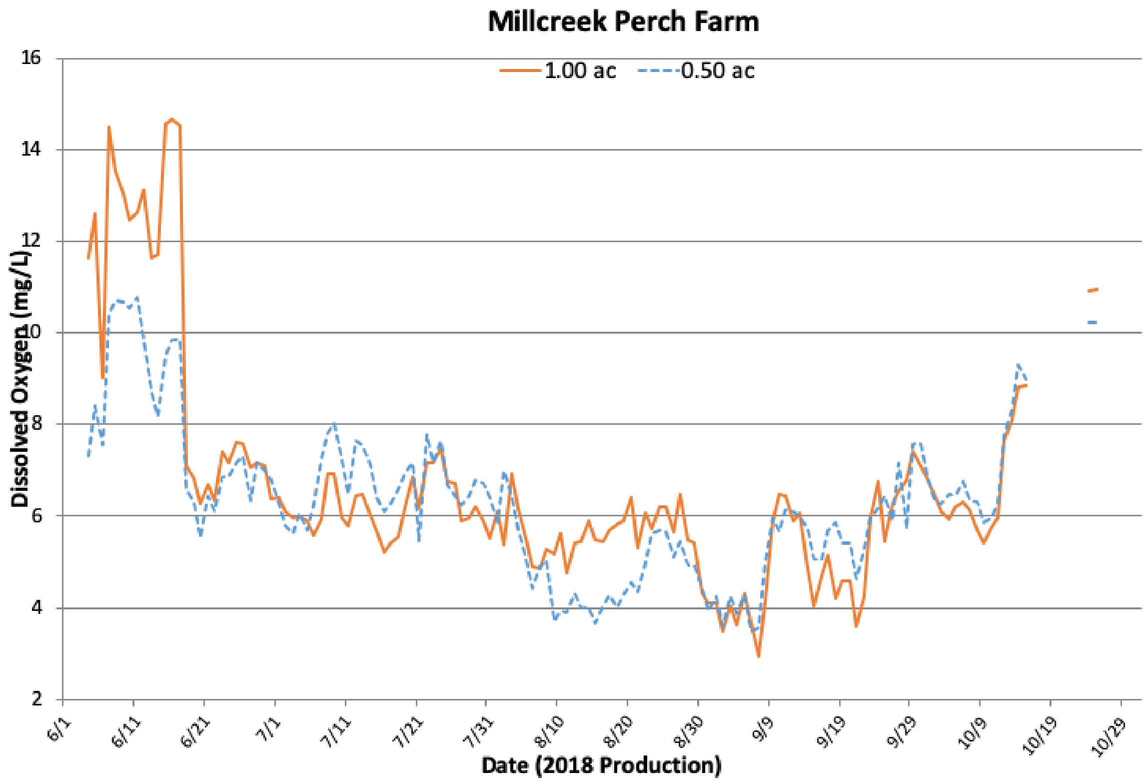

Figure 11. Dissolved oxygen concentration in Millcreek Perch Farm's intensively aerated (3.7 kw/ha; 2 hp/ac) ponds. Each pond was stocked at double the normal rate (98,842 yellow perch/ha; 80,000 yellow perch/ac).

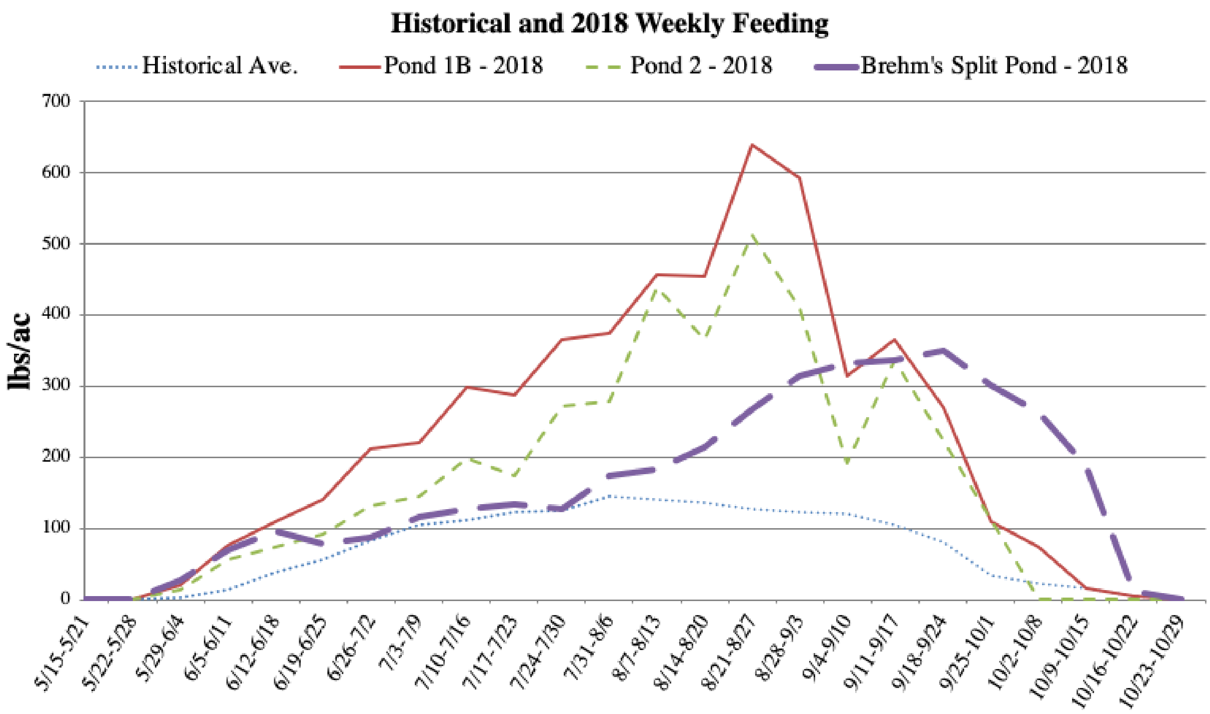

Figure 12. Weekly feeding at Millcreek Perch Farm and Brehm's Perch Farm. Historical average obtained from Millcreek is the course of 15 years. Pond 1B is 0.20 ha (0.50 ac) and Pond 2 is 0.40 ha (1.00 ac) both intensively aerated (9.6 kW/ha [2 hp/ac]) and stocked at twice the normal rate (98,842 perch/ha (80,000 perch/ac). Brehm's split pond is 0.40 ha (1.00 ac) and was stocked at twice the normal rate (98,842 perch/ha (80,000 perch/ac). Total poundage historically fed to first year yellow perch at Millcreek annually was 1,719.4 lbs (blue dotted line); whereas in 2018 the Millcreek 0.50 ac received 3,694.6 lbs/ac (red solid line), the Millcreek 1.00 ac received 4,037.70 lbs/ac (green dashed line), and Brehm's split pond (purple long dash) received 3,802 lbs.

Table 1. Stocking and harvest of yellow perch (*Perca flavescens*) in 0.20 ha (0.50 ac) Millcreek (intensively aerated), 0.40 ha (1.00 ac) Millcreek (intensively aerated), and 0.40 (1.00 ac) Brehm's Split Pond stocked at 98,842/ha (80,000/ac) following one growing season. Feed conversion ratio = total lbs feed fed/lbs fish at harvest. Fulton's condition factor = 100*(weight g/length cm)^3.

Production parameter	Millcreek (0.20 ha)	Millcreek (0.40 ha)	Brehm's (0.40 ha)
Stocked (n/pond/ac)	79,398	80,039	79,954
Yield (lbs/ac) (net)	3,503 (3,452)	4,209 (4,128)	3,941 (3,849)
Ind. harvest length (cm) (in)	14.3 (5.6)	14.2 (5.6)	11.9 (4.7)
Ind. harvest weight (g)	39.3 ± 22.4	34.0 ± 15.8	25.1 ± 21.2
Fish/lb	11.1	13.3	18.2
Total feed fed (lbs)	1,870	4,038	3,802
Feed conversion ratio	1.07	0.96	0.96
Fulton's condition factor	1.16	1.00	1.11
Survival (%)	97	69	90

Table 2. Mean seasonal water quality variables for 0.20 ha (0.50 ac) Millcreek Pond 1B (intensively aerated), 0.40 ha (1.00 ac) Millcreek Pond 2 (intensively aerated), and 0.40 (1.00 ac) Brehm's Split Pond stocked at 98,842/ha (80,000/ac) following one growing season. Data displayed as average | maximum | minimum. Alkalinity and hardness at Brehm's were recorded only at the beginning of the project.

Variable	Millcreek (0.20 ha)	Millcreek (0.40 ha)	Brehm's (0.40 ha split pond)
Temperature	74.7 | 85.8 | 46.9	73.9 | 85.5 | 47.1	76.3 | 86.7 |63.7
Dissolved oxygen (mg/L)	6.4 | 11.6 | 3.5	10.0 | 14.7 | 6.3	IN: 6.6 | 10.1 | 3.2
Dissolved oxygen (mg/L)			OUT: 5.9 | 8.2 | 3.4
pH	8.5 | 9.7 | 7.7	8.3 | 9.2 | 7.8	8.8 | 10.2 | 7.0
Total ammonia-nitrogen (mg/L)	0.2 | 1.2 | 0.0	0.2 | 0.6 | 0.0	0.5 | 2.3 | 0.0
Nitrite (mg/L)	0.2 | 0.7 | 0.0	0.1 | 0.6 | 0.0	0.02 | 0.07 | 0.00
Un-ionized ammonia (mg/L)	0.0 | 0.3 | 0.0	0.0 | 0.1 | 0.0	0.1 | 1.2 | 0.0
Alkalinity (mg/L)	159 | 206 | 110	175 | 238 | 103	154
Hardness (mg/L)	542 | 612 | 478	553 | 598 | 462	222

Table 3. Cost of production in 2017 for Millcreek Perch Farm LLC to culture 52,750 first year feed-habituated yellow perch fingerlings to ≥7.6 cm (3 in). Millcreek has five acres of production and three one ac ponds were used for first year perch.

Item	Annual expense	Cost per fingerling	Description
Depreciation	$1,222.80	$0.02	Ponds and building; 3/5 of depreciation attributed to first year fish as they were only cultured in three ponds
Feed	$6,982.35	$0.13	Costs of feed only in the three ponds
Supplies	$3,140.19	$0.06	Costs (water quality consumables, nets, etc.) attributed to the three ponds
Electric	$2,154.16	$0.04	Costs attributed only to the three ponds
Land rental	$900.00	$0.02	Costs attributed only to the three ponds
Insurance	$284.00	$0.01	Costs attributed only to the three ponds
Permits	$69.00	$0.00	Permitting to culture yellow perch in Ohio in ponds; Costs attributed only to the three ponds
Professional services	$1,891.88	$0.04	Disease testing, vet services, and accounting costs attributed only to the three ponds
Conference fees	$306.00	$0.01	Costs attributed only to the three ponds
Labor	$3,634.00	$0.07	2018 Department of Labor estimated $/hr; costs attributed only to the three ponds
Truck lease	$1,200.00	$0.02	Costs paid to the farmer for the farm's use of their personal vehicle to conduct work at the three ponds
Cost of production	**$20,300.38**	**$0.41**	

Table 4. Cost of production in 2018 for Millcreek Perch Farm LLC to culture 20,218 first year feed-habituated yellow perch fingerlings in an intensively aerated pond to ≥7.6 cm (3 in). Millcreek has five acres of production and one-half ac was used for first year perch.

Item	Annual expense	Cost per fingerling	Description
Depreciation	$204.00	$0.01	Ponds and building; 3/5 of depreciation attributed to first year fish as they were only cultured in the 0.50 ac pond
Feed	$2,316.00	$0.11	Costs of feed only in the 0.50 ac pond
Supplies	$1,578.00	$0.08	Costs (water quality consumables, nets, etc.) attributed to the 0.50 ac pond
Electric	$1,037.00	$0.05	Costs attributed only to the 0.50 ac pond
Land rental	$47.00	$0.00	Costs attributed only to the 0.50 ac pond
Insurance	$150.00	$0.01	Costs attributed only to the 0.50 ac pond
Permits	$11.80	$0.00	Permitting to culture yellow perch in Ohio in ponds; Costs attributed only to the 0.50 ac pond
Professional services	$642.00	$0.03	Disease testing, vet services, and accounting costs attributed only to the 0.50 ac pond
Conference fees	$50.00	$0.00	Costs attributed only to the 0.50 ac pond
Labor	$1,010.75	$0.05	2018 Department of Labor estimated $/hr; costs attributed only to the 0.50 ac pond
Truck lease	$200.00	$0.01	Costs paid to the farmer for the farm's use of their personal vehicle to conduct work at the 0.50 ac pond
Cost of production	**$6,999.55**	**$0.36**	

Table 5. Cost of production in 2018 for Millcreek Perch Farm LLC to culture 54,106 first year feed-habituated yellow perch fingerlings to in an intensively aerated pond to ≥7.6 cm (3 in). Millcreek has five acres of production and one-half ac was used for first year perch.

Item	Annual expense	Cost per fingerling	Description
Depreciation	$408.00	$0.01	Ponds and building; 3/5 of depreciation attributed to first year fish as they were only cultured in the 1.00 ac pond
Feed	$5,002.00	$0.09	Costs of feed only in the 1.00 ac pond
Supplies	$3,156.00	$0.06	Costs (water quality consumables, nets, etc.) attributed to the 1.00 ac pond
Electric	$2,075.00	$0.04	Costs attributed only to the 1.00 ac pond
Land rental	$94.00	$0.00	Costs attributed only to the 1.00 ac pond
Insurance	$300.00	$0.01	Costs attributed only to the 1.00 ac pond
Permits	$23.60	$0.00	Permitting to culture yellow perch in Ohio in ponds; Costs attributed only to the 1.00 ac pond
Professional services	$1,284.00	$0.02	Disease testing, vet services, and accounting costs attributed only to the 1.00 ac pond
Conference fees	$100.00	$0.00	Costs attributed only to the 1.00 ac pond
Labor	$1,221.50	$0.02	2018 Department of Labor estimated $/hr; costs attributed only to the 1.00 ac pond
Truck lease	$400.00	$0.01	Costs paid to the farmer for the farm’s use of their personal vehicle to conduct work at the 1.00 ac pond
Cost of production	**$13,570.10**	**$0.26**	

Publications, Manuscripts, Workshops, and Conferences

See the Appendix for a cumulative output for all NCRAC-Funded Yellow Perch activities.

Some Commonly Used Abbreviations and Acronyms

AIS	aquatic invasive species
APHIS	Animal and Plant Health Inspection Service
ARS	Agriculture Research Service
AREF	Aquaculture Regional Extension Facilitator
AquaNIC	Aquaculture Network Information Center
BOD	Board of Directors
BW	body weight
□C	degrees Celsius
CES	Cooperative Extension Service
COD	chemical oxygen demand
CSFPH	Center for Food Security and Public Health
CVM	Center for Veterinary Medicine
FSR ft, ft^2, ft^3	final study report foot, square foot, cubic foot
FY	fiscal year
g	gram(s)
gal	gallon(s)
h	hour(s)
ha	hectare(s)
HACCP	Hazard Analysis and Critical Control Point
HCG	human chorionic gonadotropin
IAC	Industry Advisory Council
INAD	investigational new animal drug
ISU	Iowa State University
KAA	Kansas Aquaculture Association
LU	Lincoln University
m, m^2, m^3	meter(s), square meter, cubic meter
MAI	motile *Aeromonas* infection
MAS	motile *Aeromonas* septicemia
MDNRE	Michigan Department of Natural Resources and Environment
µg	microgram(s)
mg	milligram(s)
MC	Mill Creek
min	minute(s)
mL	milliliter(s)
mm	millimeter(s)

MSU	Michigan State University
MT	methyltestosterone
N	number
NAA	National Aquaculture Association
NADA	new animal drug application
NASAC	National Association of State
NCC	National Coordinating Council
NCR	North Central Region
NCRAC	North Central Regional Aquaculture
NIFA	National Institute of Food and Agriculture
NOB	nitrite oxidizing bacterial
OCARD	Ohio Center for Aquaculture Research and Development
OSU	The Ohio State University
oz	ounce(s)
PAH	Phibro Animal Health
PCR	polymerase chain reaction
PFU	plaque-forming units
POW	Plan of Work
ppm, ppt	parts per million, parts per thousand
Purdue	Purdue University
RAC(s)	Regional Aquaculture Center(s)
RAES	Regional Aquaculture Extension
RAET	Regional Aquaculture Extension Team
RAS	recirculating aquaculture system
RS	Rimler-Stotts
SPAH	Schering-Plough Animal Health
TC	Technical Committee (TC/E = Technical
™	trademark
TSA	Tryptic Soy Agar
UMESC	Upper Midwest Environmental Sciences
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
UW-Madison	University of Wisconsin-Madison
UW-Milwaukee	University of Wisconsin-Milwaukee
VHS	viral hemorrhagic septicemia
VHSv	viral hemorrhagic septicemia virus
WATER	Wisconsin Aquatic Technology and Environmental Research

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