A REVIEW OF THE REGIONAL AQUACULTURE CENTER PROGRAM:

A UNIQUE, FARMER-DRIVEN PROGRAM ADVANCING U.S. AQUACULTURE

NATIONAL Aquaculture ASSOCIATION

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This report was written by an independent review team of aquaculture experts. The views expressed in this report are those of the authors and do not necessarily reflect the views of the National Aquaculture Association or the U.S. Department of Agriculture National Institute of Food and Agriculture (USDA NIFA).

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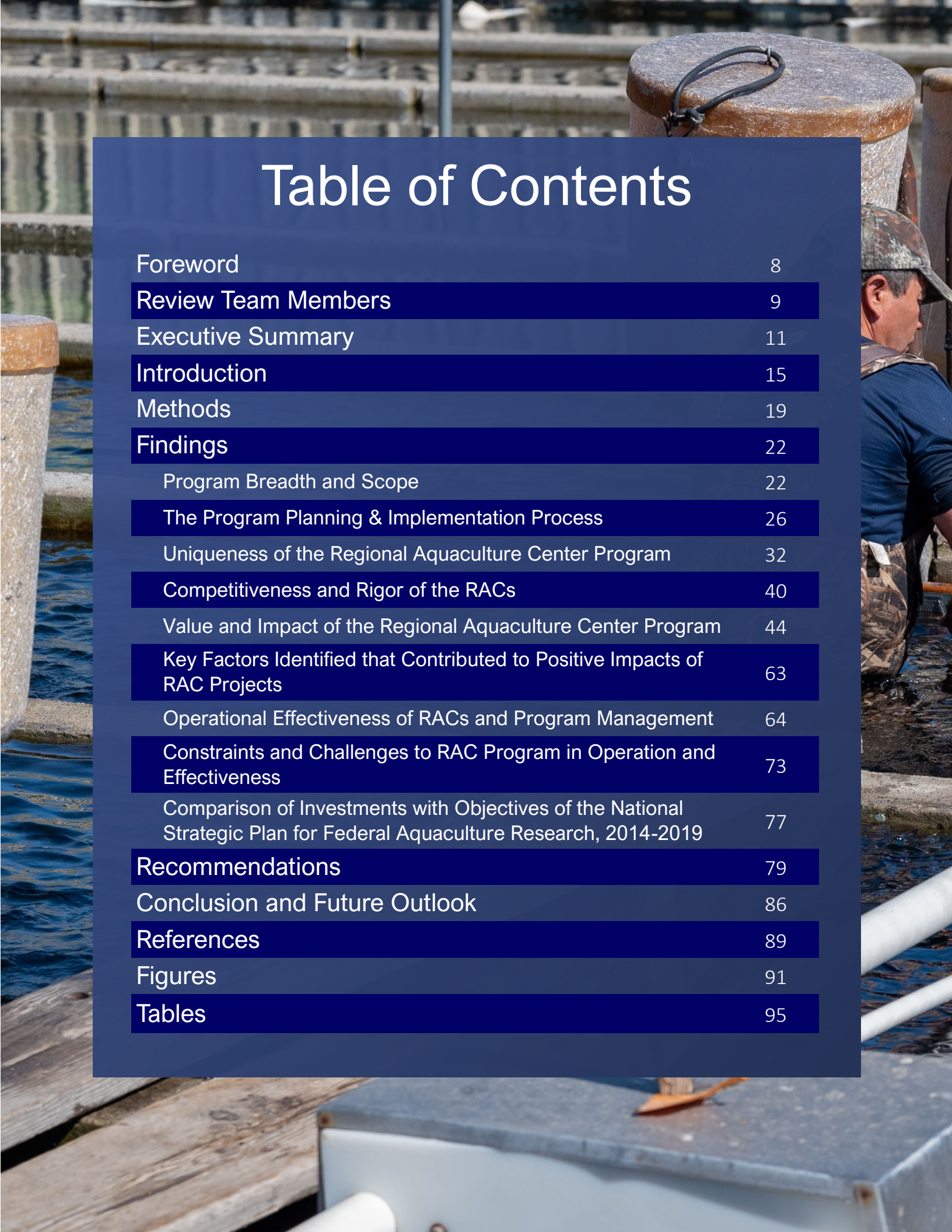

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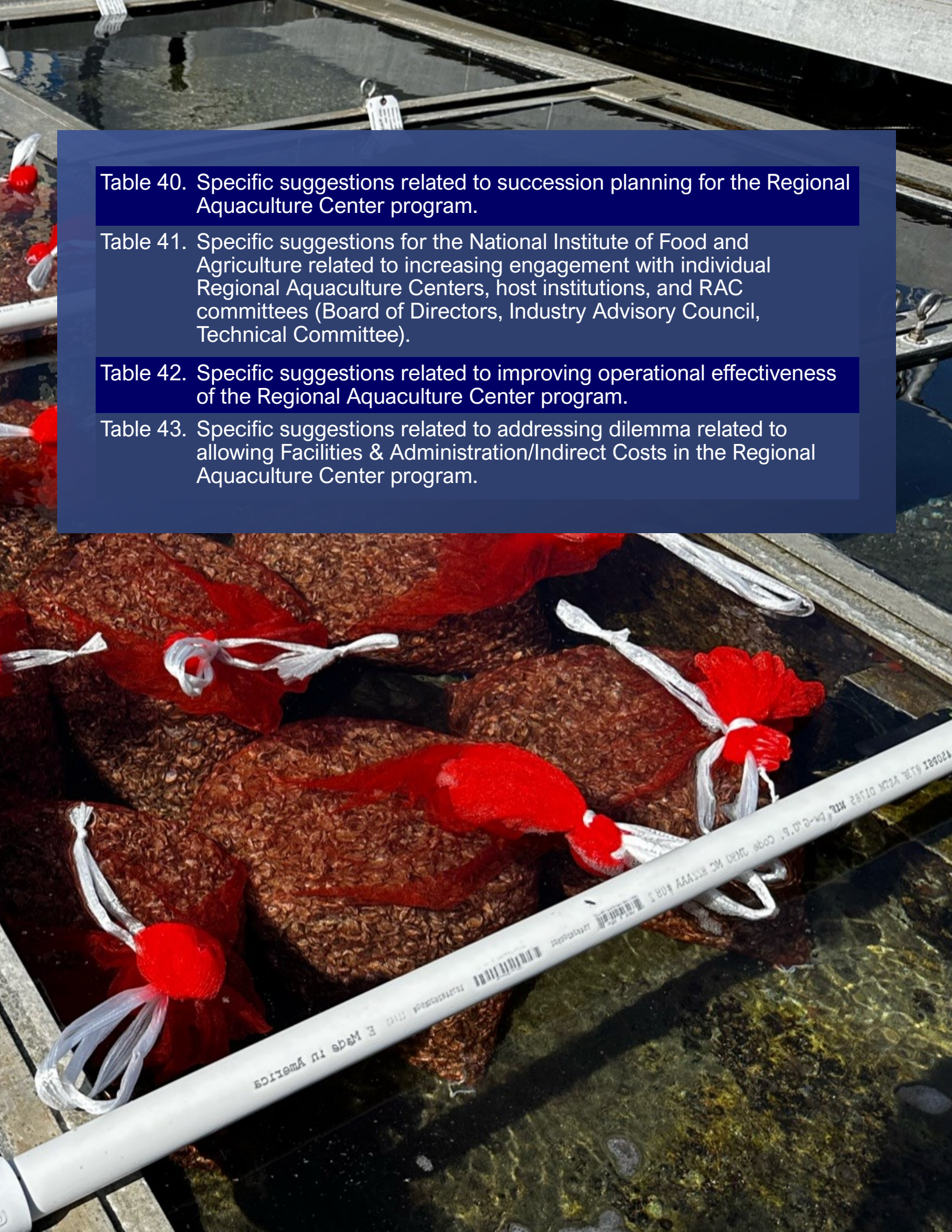

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FOREWORD

The National Aquaculture Association, as a nonprofit trade association formed and led by the U.S. aquaculture community, recognizes applied agricultural research is absolutely essential to our success as farmers to achieve the best animal and plant care, efficient production methods, and sustainable products while meeting and exceeding ever-increasing regulatory restrictions. As you will read, the five Regional Aquaculture Centers have contributed significantly to meeting society's and our goals of being unsurpassed stewards of land, water, plants and animals.

We were excited by the invitation by the National Institute of Food and Agriculture to organize a Regional Aquaculture Centers programmatic review. As noted in this report, the Centers are the "best kept secret" which we hope will be less so going forward with the publication of this analysis.

We were also honored by the commitment of Carole Engle, Gary Fornshell, John Hargreaves, and Gary Jensen to conduct and write the following independent, constructive review and analysis. Their collective experience, insights and knowledge are unmatched in the United States. When invited to engage in this work they immediately recognized, as we did, the scope and complexity of the task, and have met and exceeded this challenge.

Their deep dive into numerous reports, analyses and the applied science produced by the Centers in addition to interviewing 76 Center staff, farmers, researchers, and Extension representatives revealed:

- The five Regional Aquaculture Centers supported 618 projects in 55 states, territories, and countries with an estimated 1,283 participants at 170 distinct entities.
- Funded projects included more than 70 species of aquatic animals and plants and integrated efforts across more than 45 subject matter areas and academic disciplines.
- Of the funded entities, 64% were universities and of those universities, 51% were land-grant universities, 47% non-land-grant universities, and 2% un-specified. Of the land-grant universities, 9% were five 1890 universities and one additional, non-land grant, historically black university. It is notable that an 1890 historically black university received the fourth-greatest amount of funding by one of the Centers. Funded entities also included federal agencies, farmers, private companies, non-governmental organizations, and others.
- Top-funded states/territories/countries included Alabama, Arkansas, California, Federated States of Micronesia, Guam, Hawai'i, Idaho, Illinois, Indiana, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, Montana, New Jersey, Ohio, Oregon, Republic of Palau, Republic of the Marshall Islands, Rhode Island, Texas, Washington, and Wisconsin.

The wisdom of Congress to create the five Regional Aquaculture Centers in 1987 is more than reinforced in this report. We look forward to working with the host institutions, Centers, National Institute of Food and Agriculture, and Congress to ensure the next 40 years surpass these achievements and benefits and yield a country self-sufficient in farmed seafood, bait, aquarium, and recreational fish production.

Sebastian Belle, President
National Aquaculture Association

REVIEW TEAM MEMBERS

Carole Engle, Engle-Stone Aquatic$ LLC

Carole Engle's 45-year career has focused on the economic sustainability of aquaculture businesses. After retiring from 30 years of research, extension, and teaching in academia, she has continued to work with U.S. aquaculture farmers on economics, marketing, and regulatory issues through a consulting company. She has authored five books, numerous Extension and trade magazine articles, and published extensively in peer-reviewed scientific journals, with four best paper awards. Professional service has included serving as Director of the World Aquaculture Society, past-President of the U.S. Aquaculture Society, and past lead Editor of the *Journal of the World Aquaculture Society,* and *Aquaculture Economics & Management*. Engle has been honored with the Distinguished Service Award from the U.S. Aquaculture Society, the McCraren Award (three times) and Honorary Life Member of the National Aquaculture Association, Researcher of the Year (Catfish Farmers of America), Distinguished Service Award (Catfish Farmers of Arkansas, twice), and recognition for work related to the Farm Service Emergency Assistance for Livestock, Honey Bees and Farm-raised Fish Program.

Gary Fornshell, Aquaculture Consultant, Aquaculture Results LLC, University of Idaho Extension (retired)

Gary Fornshell began his 40-year aquaculture career as a volunteer in the U.S. Peace Corps. After graduating from Auburn University, he managed the Mississippi State University aquaculture research facility in Starkville. He was the first Extension Aquaculture Educator for the University of Idaho, retiring after 28 years. During that time, he served in various capacities with the Western Regional Aquaculture Center; 12 years total as Chair of the Extension Subcommittee and member of the Executive Committee, 2 years as Chair of the Executive Committee, and 12 years total as ex-officio on the Board of Directors. He served as Chair for the Flow-through Aquaculture Subgroup, Aquaculture Effluents Task Force, Joint Subcommittee on Aquaculture, USDA. He has contributed to Extension publications, book chapters, and scientific journal publications. He is past-President of the U.S. Trout Farmers Association and U.S. Aquaculture Society. His service has been recognized by the Idaho Aquaculture Association, U.S. Trout Farmers Association, State of Idaho, U.S. Aquaculture Society, U.S. Department of Agriculture, National Association of County Agricultural Agents, and the University of Idaho. For the past 3 years he has worked as an aquaculture consultant.

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John Hargreaves has worked in aquaculture for 43 years, including an 11-year stint in academia at Mississippi State University and Louisiana University. During that time, he served on the Technical Committee for Research for the Southern Regional Aquaculture Center. His research interests center on water and soil quality management and production systems engineering. For the last 17 years, he has been an independent consultant on commercial aquaculture and international development projects. In that capacity, he gained experience with the Monitoring and Evaluation system used for evaluation of USAID projects. He has broad international experience in Latin America, Africa, Asia, and the Middle East. He has worked with many commercially important finfish, crustaceans and mollusks in freshwater, brackish water, and marine systems. For 11 years he was the editor of World Aquaculture magazine, a quarterly publication of the World Aquaculture Society.

Farmer and researcher preparing to collect farm data. Credit: University of Idaho

Gary Jensen, Former National Program Leader for Aquaculture, USDA National Institute of Food and Agriculture and former Chair, Subcommittee on Aquaculture, National Science and Technology Council (retired)

Gary Jensen discovered aquaculture as a U.S. Peace Corps Volunteer and since had aquaculture positions at Auburn University, Kentucky State University and Louisiana State University. He was the first full-time National Program Leader for Aquaculture with the former Extension Service at the U.S. Department of Agriculture. He ended 44 years of his career in aquaculture as the National Program Leader for Aquaculture at the National Institute of Food and Agriculture at the U.S. Department of Agriculture and Chair of the currently named Subcommittee on Aquaculture of the National Science and Technology Council. He contributed scientific journal publications, Extension bulletins and fact sheets and several book chapters. He received industry service recognition from the National Aquaculture Association, U.S. Trout Farmers Association and Louisiana Catfish Farmers Association; professional service recognition from the U.S. Aquaculture Society, World Aquaculture Society and National Association of County Agricultural Agents; and government service recognition from Vice-President Gore, Secretary of Agriculture, National Science and Technology Council, and U.S. Agency for International Development.

EXECUTIVE SUMMARY

The National Institute of Food and Agriculture of the U.S. Department of Agriculture authorized and funded a programmatic review of the five Regional Aquaculture Centers in 2021 in response to a suggestion to the agency from the National Aquaculture Association. The project began in late 2021 and concluded in late 2023. The National Aquaculture Association, a non-profit trade association representing the U.S. aquaculture farming community, administered the review by commissioning a team of four experts to independently conduct an in-depth analysis.

The mission of the Regional Aquaculture Center Program is to support aquaculture research, development, demonstration, and education to enhance viable and profitable U.S. aquaculture production for the benefit of consumers, farmers, service industries, and the American economy.

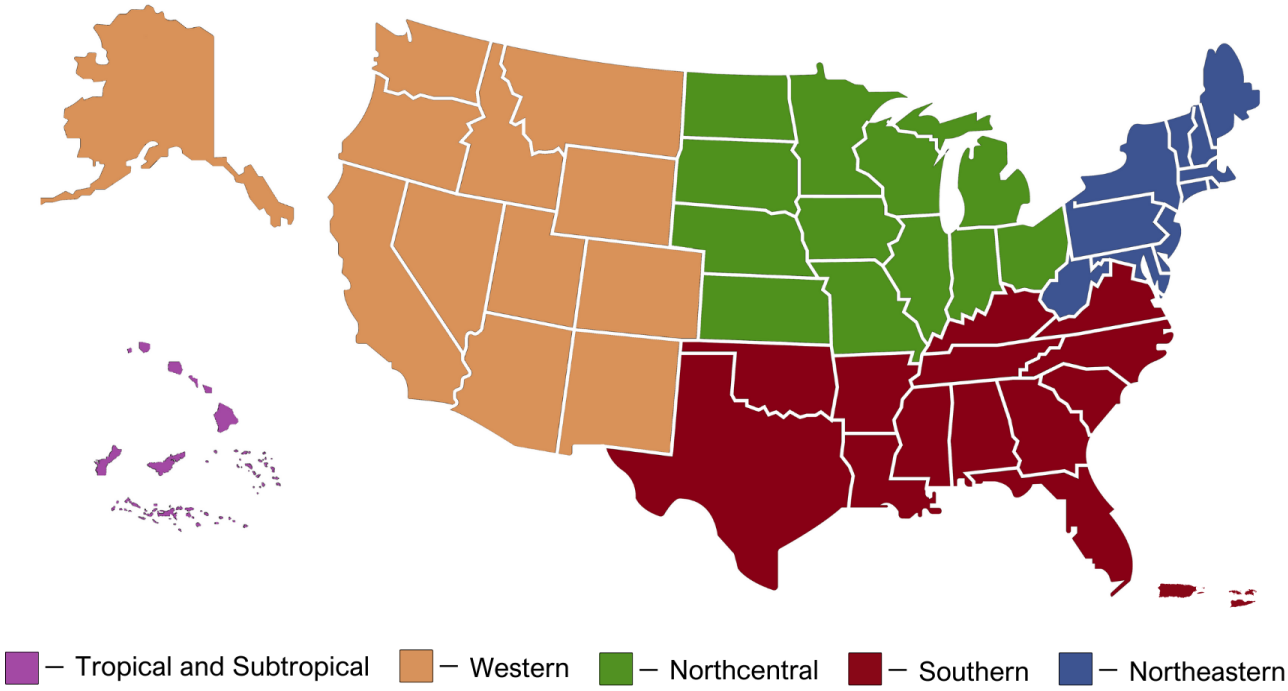
There are five Regional Aquaculture Centers:

The North Central Regional Aquaculture Center (north central regional center) is administered by Iowa State University and represents Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

"It's one of the best programs ever conceived on how to get industry, research, and Extension involved together to solve problems and keep industry moving forward."
- aquaculture farmer

The Northeastern Regional Aquaculture Center (northeastern regional center) is administered by the University of Maryland and represents Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, and the District of Columbia.

The Center for Tropical and Subtropical Aquaculture (Pacific regional center) is administered by the University of Hawai'i and represents American Samoa, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Guam, Hawai'i, the Republic of Palau, and the Republic of the Marshall Islands.



Map of U.S. states and territories within each of the five Regional Aquaculture Centers.

The Southern Regional Aquaculture Center (southern regional center) is administered by Mississippi State University and represents Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, U.S. Virgin Islands, and Virginia.

The Western Regional Aquaculture Center (western regional center) is administered by the University of Washington and represents Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

The overall goal of the project was to evaluate the Regional Aquaculture Center Program and develop recommendations to provide the best service to the aquaculture community. Specific objectives of the review included to: 1) analyze the projects funded at each Regional Aquaculture Center from 2014-2021; 2) analyze investments against the National Science and Technology Council Interagency Working Group on Aquaculture's National Strategic Plan for Federal Aquaculture Research (2014-2019); 3) assess farmer involvement in the Regional Aquaculture Center and in funded projects, determine if investments have addressed critical U.S. aquaculture needs, and if findings have been well disseminated to stake-holders; 4) develop recommendations for future funding that would provide the greatest benefit to U.S. aquaculture; and 5) and make recommendations to increase efficiency and impact of the Regional Aquaculture Centers.

The review team first conducted an extensive review of documents, including operation manuals, plans of work and annual reports, and further analyzed performance of projects funded from 2014 to 2021. Interviews were conducted via live video conference with 76 individuals from 35 states, territories, and countries who raised more than 70 different species (not including distinct baitfish, sportfish, and ornamental species) in various production systems, and encompassed expertise in 32 scientific disciplines. Representatives were interviewed from all Regional Aquaculture Center working committees in each region (Directors, Board of Directors, Industry Advisory Council, Technical Committee Research and Extension personnel), farmers not actively involved in the Regional Aquaculture Centers, and a group of prominent national leaders.

The Regional Aquaculture Center program is woefully and dramatically under-funded.

Key findings of the review were:

- The Regional Aquaculture Center program is woefully and dramatically underfunded. Limited funding has restricted the number of priority projects that can be addressed and has reduced the depth, scope, and duration of projects funded.
- There is strong and widespread support for continuing the Regional Aquaculture Center program from: farmers, researchers, Extension personnel, members of the Board of Directors, Directors, and other prominent national leaders.
- The Regional Aquaculture Center program has generated very strong economic impacts on major sectors of U.S. aquaculture by improving productivity with new technological developments, adaptation to climate change, and through development of new sectors of U.S. aquaculture.
- The Regional Aquaculture Centers have provided seed funds to initiate proof of concept studies to assess the feasibility of commercializing new aquatic species and to generate foundational research knowledge to overcome husbandry bottlenecks.
- The Regional Aquaculture Centers have benefitted U.S. aquaculture in these areas: a) contributing rigorous science to regulatory issues and processes; b) supporting Extension services; c) economics and marketing research to increase economic sustainability; d) responding to disease challenges; e) support to state aquaculture associations; f) workforce development and training; g) collaborative team building; and, h) networking across the region.
- The Regional Aquaculture Center model is unique among federal funding models to the extent that it incorporates all of the following: a) is driven by farmers who identify priority needs to be addressed and are engaged throughout the project; b) requires that projects be addressed by collaborative, interdisciplinary teams that fully integrate farmers, researchers, and Extension personnel to solve farmer-identified problems; and, c) is regional in that projects must involve at least two states or territories and address region-specific needs. It is the only national program available to address the many species- and region-specific issues of the very diverse U.S. aquaculture community.
- The scope and reach of the Regional Aquaculture Center program are quite broad and deep, a surprising finding given the very limited funding available to the program. The Regional Aquaculture Center program has supported projects in 55 states, territories, and countries with an estimated 1,283 participants at 170 distinct institutions (including 1862 and 1890 land-grant universities, non-land-grant universities, state and federal agencies, farmers, and non-governmental organizations). Projects have addressed needs of more than 70 species of aquatic animals and plants (including major aquaculture species) and have integrated efforts across more than 45 subject matter areas and academic disciplines to solve aquaculture farmer problems.
- The Regional Aquaculture Center project development process is competitive with a much more deliberate and inclusive system that extends from problem identification through final proposal decisions than that of other federal funding programs.

Farmer loading hybrid striped bass into a hauling truck. Credit: National Aquaculture Association

- Regional Aquaculture Center projects are subjected to extensive oversight throughout the duration of the project. Project oversight in the Regional Aquaculture Centers includes involvement of farmer liaisons in work groups who are kept apprised of progress, setbacks, and accomplishments.
- All Directors of the Regional Aquaculture Centers will be retiring in the next several years. Given the critical role played by the Directors in cultivating relationships and building teams across farmers, researchers, and Extension personnel, their impending retirement is a cause for concern for program continuity.

> The major overarching recommendation of this review is to:
> Increase the annual budget of the Regional Aquaculture Center program to $20 million per year, with periodic adjustments for inflation.

Secondary recommendations include:

- Improve effective communications of the Regional Aquaculture Centers internally and externally.
- Address the continued loss of Extension capacity for aquaculture.
- Increase engagement of the National Institute of Food and Agriculture with host institutions and with the Regional Aquaculture Centers.
- Streamline project development and implementation processes.
- Address dilemma related to allowing Facilities & Administration/Indirect Costs in the Regional Aquaculture Center program.
- Initiate succession planning for Directors, with full engagement of the Board of Directors, Industry Advisory Council, host institution, and the National Institute of Food and Agriculture. The National Institute of Food and Agriculture should be actively involved with host institutions to provide guidance throughout the transition to new Directors to successfully continue and improve the unique approach and needs associated with a Regional Aquaculture Center. Where Centers have been performing well, stability of the current administrative office and staff should be a priority through filling the Director position at the current host institution.

A renewed interest in aquaculture has become evident across the United States. This increased interest is reflected in efforts to farm new species, and recognition of the role of aquaculture to improve food security, develop a more climate-resilient food supply system, reduce the substantial seafood trade deficit in the United States, and to support rural economies in the United States. Expansion of the highly effective Regional Aquaculture Center program would address high priority administration issues related to rural economies, jobs, resilience, demand for U.S. grains, education, and food security.

The future of the Regional Aquaculture Centers and the fulfillment of their bold mission depend on increased funding and the commitment and desire of aquaculture research and Extension personnel to solve real-world U.S. aquaculture problems. The challenges and opportunities are ever-present for aquaculture advances in the United States, and the Regional Aquaculture Centers have demonstrated their value in each region. Recommendations and suggestions presented in this review are intended to further strengthen the effectiveness, value, and impact of the Regional Aquaculture Centers into the future.

INTRODUCTION

Aquaculture is agriculture: Farming of aquatic animals and plants.

Background and Purpose of the Review of the U.S. Department of Agriculture-National Institute of Food and Agriculture Regional Aquaculture Center Program

The National Institute of Food and Agriculture of the U.S. Department of Agriculture authorized and funded a review of the five Regional Aquaculture Centers (RACs) in the United States in 2021 in response to a suggestion by the National Aquaculture Association. The project began in late 2021 and concluded in late 2023. The review was administered by the National Aquaculture Association, a non-profit trade association representing the U.S. aquaculture farming community, by commissioning a team of knowledgeable and experienced experts to conduct the review.

The overall goal of the project was to review the RACs to develop recommendations to provide the best service to the aquaculture community. Specific objectives of the Regional Aquaculture Center Review were to: 1) analyze the funded projects at each Regional Aquaculture Center from 2014-2021; 2) analyze investments against the National Science and Technology Council Interagency Working Group's National Strategic Plan for Federal Aquaculture Research (2014-2019); 3) assess farmer involvement in the RACs and in RAC-funded projects, determine if investments address critical U.S. aquaculture needs, and if findings are well disseminated to stakeholders; 4) identify gaps and develop recommendations for future funding of regional aquaculture research that would provide the greatest benefit to U.S. aquaculture; and, 5) identify gaps and recommendations to increase efficiency and impact of individual RACs.

RAC researcher interviewing a catfish farmer on a pond bank. Credit: Danny Oberle.

The Context for U.S. Aquaculture Funding for Research and Extension

The U.S. imported 6.1 billion pounds of seafood in 2020, valued at $21.4 billion, resulting in a trade deficit of $17.0 billion (NMFS, 2022). The U.S. imports about 70 to 85% of its seafood, most of which, by value, is farmed shrimp, salmon, tilapia, and catfish. U.S. aquaculture is currently a minor contributor to the domestic seafood supply, and the seafood trade imbalance has been highlighted as a national security vulnerability by the Department of Homeland Security (Homeland Security, 2021). Interest in U.S. aquaculture has grown with increased recognition of its potential contributions to a more climate-resilient food supply system and to rural economies, jobs, and demand for U.S. grains (Rexroad et al., 2021).

Public spending on research and development for agriculture generally in the U.S. has not kept pace with that of China and the European Union (ERS, 2018, 2022). U.S. spending on agriculture research and development has been approximately $5 billion since 2013, approximately the same level as in 1970, as compared to $10 billion in China and $8 billion in the European Union. Moreover, spending levels in emerging economies such as India (~ $4 billion) and Brazil (~ $3 billion) are catching up to those of the United States.

Public spending specifically for aquaculture in the United States has similarly been stagnant since the early 2000s despite continued growth in the value of U.S. aquaculture (Love et al., 2017). The main sources of public spending for aquaculture research in 2022 were: 1) U.S. Department of Agriculture, including the Agricultural Research Service ($51 million), Small Business Innovation Research ($2.6 million USDA; $7.8 million across all agencies with SBIR programs), and National Institute of Food and Agriculture Special Grants ($1.9 million) and 2) National Oceanic and Atmospheric Administration - Sea Grant ($14 million). In contrast, public spending for the RAC program has been $4.6 million since 2018, approximately 5% of the total public spending for aquaculture research.

The U.S. Department of Agriculture - National Institute of Food and Agriculture Regional Aquaculture Center Program

The mission of the RAC Program is to support aquaculture research, development, demonstration, and education to enhance viable and profitable U.S. aquaculture production for the benefit of consumers, farmers, service industries, and the American economy. There are five Regional Aquaculture Centers.

The key function of each RAC is to ensure that regional needs of aquaculture farmers are identified and prioritized with subsequent development of interdisciplinary teams of researchers, Extension personnel, and industry that develop research/Extension projects to address the prioritized needs.

North Central Regional Aquaculture Center - north central regional center. The north central regional center is located at Iowa State University and represents Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

The Northeastern Regional Aquaculture Center - northeastern regional center. The northeastern regional center is located at the University of Maryland and represents Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, and the District of Columbia.

The Center for Tropical and Subtropical Aquaculture - Pacific regional center. The Pacific regional center is administered by the University of Hawai'i and represents American Samoa, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Guam, Hawai'i, the Republic of Palau, and the Republic of the Marshall Islands.

The Southern Regional Aquaculture Center - southern regional center. The southern regional center is located at Mississippi State University's Delta Research and Extension Center and represents Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, U.S. Virgin Islands, and Virginia.

Western Regional Aquaculture Center - western regional center. The western regional center is located at the University of Washington's School of Fisheries and represents Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

The structure of the RAC program includes 59 geographical entities that include 50 states, four territories, three countries, one commonwealth, and one district (District of Columbia). Of these, 55 have participated in at least one RAC project (Table 1). The RACs are administrative centers that nurture and provide applied aquaculture research, education, demonstration, and Extension capacities to address priority issues of U.S. aquaculture. Each RAC consists of at least a Director, an office manager or assistant, a Board of Directors, an Industry Advisory Council, and a Technical Committee that includes both research and Extension personnel.

The RAC program includes 50 states, 4 territories, 3 countries, 1 commonwealth, and 1 district.

The key function of each RAC is to ensure that regional needs of aquaculture farmers are identified and prioritized with subsequent development of interdisciplinary teams of researchers, Extension personnel, and farmers who develop research and Extension projects to address the prioritized needs. The RAC process ensures that project results are properly integrated across disciplines and functions (research/Extension) with timely delivery of results to stakeholders.

Specific guidelines for RAC regional projects include: 1) the institutions that receive program funds have demonstrated the capacity to perform the work on the level necessary; 2) the problem to be addressed occurs in two or more states or territories; 3) projects selected address priority farm-level needs that cannot be addressed by a single institution; 4) each project funded requires more resources

(i.e., scientific expertise, manpower, equipment, facilities) than are available in one state or territory; and, 5) the project can be organized and conducted effectively and efficiently on a regional level.

Funding allocations within each RAC are approved by the Boards of Directors. Each RAC submits an annual plan of work and an annual accomplishment report to the National Institute for Food and Agriculture. Reports submitted highlight progress towards meeting regional goals and objectives of U.S. aquaculture.

The RAC program became a reality in federal FY 1987 with the appropriation of $3 million. The congressional funding bill specified creation of four centers, one in each of the western, southern, northeastern, and Pacific regions. The north central region was added in 1988 along with the congressional specification for five Regional Aquaculture Centers. With the addition of the fifth RAC, the annual funding authorization increased to $4 million, resulting in $3.75 million (following the 6.25% set-aside mandated to support the Small Business Innovation Research program), or $0.75 million per RAC per year. The RAC program was level funded from FY 1988 through FY 2017. In FY 2018, funding received by the RACs totaled $4.6 million, or $0.92 million per RAC. Thus, other than the FY 2018 increase, the RAC program has been level funded since its inception. Indirect costs were disallowed by Congress.

The essentially level funding over time, compounded by inflationary effects that have reduced purchasing power, has dramatically limited the response of the RACs to the needs of U.S. aquaculture farmers. The review of the RAC program demonstrated that the RACs have provided strong benefits to farmers from its applied research focus on farmer-identified priorities. Direct farmer involvement from project development through implementation was referenced by many interviewees as a strength of the program that has contributed to strong impacts because priority problems of farmers were identified, solved, and adopted on farms.

The limited funding has drastically limited the number and duration of projects that can be funded, and the number of problems solved for U.S. aquaculture has been limited as a result. The RACs could accomplish much more within its current structure and administrative capacity if additional funding were available. The level funding over time has made it increasingly difficult to fully address the priority needs of the very diverse U.S. aquaculture community. High-quality project proposals that address high-priority needs identified by the Industry Advisory Council remain unfunded during each round of funding.

> The lists of priority research and Extension needs identified by farmers in each funding cycle of the RACs are a valuable resource if shared with other funding programs to also focus on those topics likely to contribute to growth and development of U.S. aquaculture.

Ornamental koi in a raceway.
Credit: National Aquaculture Association

METHODS

The review team conducted a comprehensive review of the RAC program, with an emphasis on recent performance. The overall goal was to evaluate RAC program effectiveness and impacts, efficiency and cost-effectiveness, and planning and management. The major activities conducted included an extensive document review, in-depth interviews with 76 individuals across the United States, and an analysis of project performance. Returns on investment and economic contributions were estimated for several examples of RAC-funded project impacts that were identified and verified as having been adopted on farms and for which sufficient data were available. The RAC Directors were asked to fact check an early draft of the report and identified errors of fact were corrected.

Document Review

The review team collected documents related to the RAC program as a whole as well as reports and other information specific to each RAC. Documents reviewed included operating manuals, annual plans-of-work, requests for proposals, annual accomplishments and progress reports, project termination reports, annual budgets, and contents of websites. The review of documents and briefing materials shed light on whether each RAC followed its operational procedures, whether farmer priorities were those selected for funding, and whether representatives of major species groups in each region have been engaged with the RAC.

The RAC review team requested information related to the operation and performance of each RAC program from the RAC Directors.

Information reviewed included:

- Proportion of funds allocated to funded projects from 1987-2020 by species, subject matter, state, and institution.
- Contact lists of host institution representatives, Boards of Directors, Industry Advisory Council, and Technical Committee members representing research and Extension.
- Examples of projects that mitigated or improved regulatory outcomes.

The review team further reviewed and summarized the National Science and Technology Council Interagency Working Group on Aquaculture's National Strategic Plan for Federal Aquaculture Research (2014-2019). The RAC Directors were queried as to its relevance and utility, whether they had input to the plan's development, whether RAC committee members were familiar with it, and how they referenced the Plan.

In all, 76 individual interviews were conducted, including individuals from 35 states and territories, who raised more than 70 species (not counting individual ornamental and baitfish species), worked across the range of production systems, and had expertise in 32 different disciplines.

Projects funded by RACs were cross-checked to assess alignment with the Plan. The review team further examined and compared characteristics of other regional centers.

Interviews

The review team devoted considerable time to live video conference interviews with relevant stakeholders of the RAC program. The intent of these interviews was three-fold: 1) to verify that the RACs followed established operating procedures; 2) to verify claims related to impacts and achievements of projects funded; and, 3) to understand how perspectives of the RACs and their performance were similar to or differed from those of other groups interviewed. Interviews were conducted with each of the five RAC Directors currently serving at the time of the interviews, each with permanent positions and a long history in this role[1]. Also interviewed were two members of each RAC's Board of Directors, Industry Advisory Council, and Technical Committee for research and Extension. The committee members interviewed were those nominated by the RAC Directors. Additional farmers and aquaculture stakeholders with no or limited involvement with the RAC program in their region were selected to represent species, production systems, and geographic areas not represented in the previous interviews and were designated as non-IAC farmers[2].

The final interviews were held with a group of prominent national leaders of various sectors of U.S. aquaculture. Interviews were conducted individually via video conference. Individuals in each group were scheduled within the same time frame to provide the review team with a collective perspective from each group before moving on to interviews with the next group. The RAC Directors were interviewed first, followed by the Board of Directors, Industry Advisory Council, non-Industry Advisory Council farmers and stakeholders, Technical Committee-Research, Technical Committee-Extension, and the group of other prominent national leaders.

In all, 76 individual interviews were conducted, including individuals from 35 states and territories, who raise more than 70 species (not counting individual ornamental, sportfish, and baitfish species), work across the range of production systems, and have expertise in 32 different disciplines (Table 2). By region there were 13 interviewees from the Pacific regional center, 12 from the north central regional center, 15 from the northeastern regional center, 17 from the southern regional center, 18 from the western regional center, and one from Washington, D.C. Each interview lasted from approximately one hour to more than three hours.

For farmers and aquaculture stakeholders with no or limited involvement with the RAC program in their region, a tiered interview questionnaire was prepared, with a series of general questions about research needs and where the stakeholder obtains technical information, followed by a series of questions about familiarity with and perceptions of the RAC program, if the interviewee had such knowledge.

[1]One RAC Director retired following the interview during the time when the review team had moved on to interviews with other groups.
[2]Included some individuals who had served on the Industry Advisory Council in the past and two who were serving at the time of the interviews.

The interviews explored the following:

- Planning and implementation: How well is the program planned out? How well is that plan put into practice? Are the RAC program's activities put into place as originally intended?
- Efficiency and cost-effectiveness: Are the program's activities produced with appropriate use of resources such as budget and staff time?
- Effectiveness and achievement of objectives: How well does the program meet its stated objectives? Does the program achieve the goals and objectives it intends to accomplish?
- Impacts: How much and what kind of a difference is the program making for U.S. aquaculture farmers? To what extent are project results adopted by farmers?
- Attribution: Can progress on goals and objectives be shown to be related to the program, as opposed to other things that have been occurring at the same time?

Similar questions were asked of each group where relevant to allow for comparison of responses across groups, but other questions were group specific. The main categories of questions were as follows:

- How the RAC responds to and supports the aquaculture community (question asked to Directors, Board of Directors, Industry Advisory Council, Technical Committee for Research and for Extension).
- How well the RAC is fulfilling the mission of the RAC program (question asked to Directors, Board of Directors, Industry Advisory Council, Technical Committee for Research and for Extension, other prominent national leaders).
- Integration of Extension into its overall program and projects (question asked to Technical Committee Extension and for Research).
- Host institution support (question asked to Directors, Board of Directors, Technical Committee for Research).
- Role of National Institute for Food and Agriculture (question asked to Directors, Board of Directors).
- Gaps and recommendations to increase efficiency and impact of the RAC (question asked to Directors, Board of Directors, Industry Advisory Council, Technical Committee for Research, Technical Committee for Extension, other prominent national leaders).

For each interview, one member of the RAC review team was designated as interviewer and two team members served as primary and secondary recorders. Recorders took notes of interview responses, which were collated and reviewed by the full team. No audio recordings of interviews were made. Once each group of interviews was completed, each RAC review team member summarized responses of each group. One review team member synthesized the results of the four group summaries. The syntheses of the four summaries for each group were the main output of the interview process and served as a main data source.

Project Performance Analysis

A project performance analysis was conducted of projects funded by each RAC that were initiated in 2014 and that were completed (with termination reports) by 2021. Websites for each RAC were reviewed for available information, with reliance on annual progress reports and final project termination reports. The available information on each project was used to assess relevance and farmer input, whether project objectives were met, and work was completed, and to tabulate benefits and impacts reported. Data collected included the numbers of projects and personnel funded, institutions, primary species addressed, subject matter/disciplines enlisted in the project, and the deliverables from each project.

To complement this project analysis, statistics on species grown, number of farms, and production by region were gathered from the most recent Census of Aquaculture (USDA-NASS, 2019). For select, high-impact projects identified and for which sufficient data were available, return-on-investment and economic impacts were estimated.

FINDINGS

From its inception, the RAC program has supported aquaculture research and Extension projects that have involved a very broad and diverse set of university, NGO, and business entities across the U.S. and its territories.

Program Breadth and Scope

The RAC program has had a substantial scope and broad reach nationwide. From its inception, the RAC program has supported aquaculture research and Extension projects that have involved a very broad and diverse set of university, non-governmental organizations, and business entities across the U.S. and its territories (Table 3). A total of 618 projects have been funded by the RAC program (Figure 1a) that have involved approximately 1,283 participants (Figure 1b).

Participants included scientists, Extension personnel, farmer advisors, aquaculture farmers, non-funded collaborators, and others. The data strongly suggest: 1) the RACs foster unique open collaboration among states and territories, institutions, scientific and educational communities and 2) meaningfully integrate research, Extension, and aquaculture farmer functions to address priority needs of U.S. aquaculture. Table 4 lists numbers of projects and participants by RAC.

Entities and institutions funded by the RACs

A total of 170 distinct entities have received funding and been involved with the RAC program. Of these, 64% have been universities, but various state and federal agencies, farmers, private companies, non-governmental organizations, and other entities have been involved as well. Of the universities that have participated as funded participants in RAC programs, 51% have been land-grant universities, 47% have been non-land-grant universities, and 2% were un-specified.

Map pinpointing location of the 170 distinct entities that have been involved with the RAC program.

Of the participating land-grant universities, 9% have been 1890 universities (five different universities). One additional, non-land-grant, historically black university has also been funded. It is notable that an 1890 historically black university in the southern region has received the fourth-greatest amount of RAC funding over time, a region that encompasses the nation's greatest volume of aquaculture production. All RACs have provided some amount of funding to entities outside the region when the necessary expertise to address farmer-identified problems was not available within the region. Participants have included three international entities.

Top-funded institutions[3] include Michigan State University, Southern Illinois University at Carbondale, The Ohio State University, Purdue University, and University of Wisconsin-Madison in the north central regional center; University of Rhode Island, University of Maine, Rutgers University, University of Maryland and Marine Biological Laboratory in the northeastern region; the Oceanic Institute, University of Hawai'i at Manoa, College of Micronesia, University of Hawai'i Sea Grant College Program, and University of Hawai'i at Hilo in the Pacific regional center; Mississippi State University, Auburn University, Texas A&M University, University of Arkansas at Pine Bluff, and Louisiana State University in the southern region; and University of California at Davis, University of Washington, University of Idaho, Oregon State University, and Washington State University in the western region (Tables 5 to 9). In general, funds go to the institutions or entities with the capacity to address and solve RAC project priorities and are located in states with an established aquaculture sector that advocates for those projects.

Species/sectors of aquaculture addressed by RAC funding

RAC funding has supported projects that have addressed aquaculture of more than 70 species.[4] The major emphasis in the projects funded varied by region, reflecting the regional differences in species farmed or with potential to be farmed in different regions. For example, the emphasis in the north central region has been on developing culture technologies for the regionally popular yellow perch

[3]Host institution funding includes both administrative costs and awards funded to research and Extension personnel at the host institution; thus, total research funding amounts may be over-estimated from inclusion of administrative costs.

[4]Not all projects specified species; some projects broadly affected numerous farmed species.

as well as various sportfish species, such as sunfish and walleye (Table 10). Shellfish has been the primary focus in the northeastern region. In the Pacific regional center, the emphasis has been on aquaculture of marine finfish, ornamentals, and specific-pathogen free shrimp, whereas the major emphasis in the southern region has been on catfish, baitfish, and ornamental fish farming issues. Trout/salmonids, sturgeon, and oysters have received major funding attention in the western region. Funding levels by species generally reflect the most important species groups in the region. Nevertheless, some major sectors such as trout and salmon in the north central and northeastern regions, ornamentals outside the Pacific and southern regions, algae in the Pacific region, and warmwater sportfish generally have been underserved by their respective RACs. Tables 11 to 15 list funding for each RAC by species.

States, territories, and countries receiving funding from the RACs

Data on the states, territories, and countries that have been most active in each RAC reflect a combination of the relative size of the aquaculture community in the region in terms of total sales or number of farms and the degree of commitment that has been made by universities to developing aquaculture research facilities and hiring aquaculture scientists with the expertise to address aquaculture farmer problems (Table 16). Top-funded states/territories/countries include Wisconsin, Michigan, Illinois, Ohio, and Indiana in the north central region; Rhode Island, Maine, Massachusetts, New Jersey, and Maryland in the northeastern region; Hawai'i, the Federated States of Micronesia, Guam, the Republic of the Marshall Islands, and the Republic of Palau in the Pacific regional center; Mississippi, Alabama, Texas, Arkansas, and Louisiana in the southern regional center; and Washington, California, Oregon, Idaho, and Montana in the western regional center (Tables 17 to 21).

Adult tilapia. Credit: Les Torrans.

Subject matter topics addressed by the RACs

The topics funded and research disciplines applied also varied widely across the RACs, further reflecting the variation in farmer priority needs across the country (Table 22). Overall, projects have integrated efforts across more than 45 subject matter areas and academic disciplines to solve aquaculture farmer problems. While the Pacific, southern, and western regional centers have funded a fairly broad and varied portfolio of research/Extension topics, the north central and northeastern regional centers have allocated more resources to production methods for specific species of interest in the region (Tables 23 to 27; Figures 2 a, b, c, d, e).

Production systems studied by the RAC program

Production systems addressed by funded RAC projects included the major production systems for finfish and shellfish. The range of production systems for finfish in RAC projects included: ponds, concrete and earthen raceways, split ponds, intensively aerated ponds, in-pond raceways, tanks, recirculating aquaculture systems (RAS), net pens, hatcheries, and aquaponics systems. For shellfish, production systems included: on-bottom, off-bottom, floating gear/cages, and hatcheries. Horizontal long lines for kelp aquaculture were also included.

Funding leveraged by the RACs

The essentially flat funding of the RACs, the ensuing loss of purchasing power, and the need to stretch limited funds across multistate projects have led researchers to seek additional funding to complement or leverage funding from the RACs.

Although the RACs pose no obstacles to seeking additional funding to expand or follow-up on results of RAC-funded research projects, such complementary resources are not always available within a region. In some cases, RAC funding was

used as a seed grant to obtain preliminary data that was then used to apply for national funding for more comprehensive research.

One of the most striking and well-documented examples is an investment of $763,500 over six years in western regional center funds for projects on control of infectious hematopoietic necrosis virus on commercial salmonid farms. The researchers involved reported $3,783,845 in additional leveraged research funds to support this effort. Success in leveraging RAC funding depends on whether there is some direct connection of researchers with other funding sources. The RAC pre-proposal process includes a question as to whether the researcher is seeking other funding, and proposals are strengthened in cases where additional funding has been identified.

Oysters growing on tidal flats in Virginia. Credit: Gef Flemlin

RAC researchers have sought funding to leverage RAC funds from: U.S. Department of Agriculture (Hatch Act multistate agriculture research funding, National Institute of Food and Agriculture, Agricultural Research Service, Animal and Plant Health Inspection Service, and Sustainable Agriculture Research and Education), National Oceanic and Atmospheric Administration (Saltonstall-Kennedy Grant Competition, Sea Grant), and various Small Business Innovation Research programs. Researchers have also leveraged funds from aquaculture trade associations, and directly from farmers. Of the $14 million spent on 125 aquaculture projects between 1988 and 2019 in the north central region, fifty-nine of those projects attracted an additional $12.1 million in leveraged funding (Agyeman et al., 2023 a,b). In the western regional center, 13 of the 16 projects funded between 2013 and 2021 secured an additional $2.2 million to leverage the $5.1 million from the center. Leveraged funding support came from other federal agencies, universities, and other aquaculture stakeholders.

Such public-private collaboration has been essential to the successful development of aquaculture in the United States.

Researchers are regularly encouraged to involve farmers in their research and demonstration activities. Such engagement leverages RAC funds with in-kind contributions from cooperating farms. Although it is difficult to estimate the specific in-kind contributions that farmers make to projects, several farmers interviewed reported having invested thousands to hundreds of thousands of dollars of in-kind contributions to support RAC-funded research. Clearly, farmer contributions of labor, facilities, equipment, seed, fish, and shellfish used as experimental animals are substantial financial contributions to the RAC programs. Moreover, such contributions demonstrate strong support for the work done by the RACs.

"The farm has to be the final step in research. There are so many variables on the farm between ponds. You have to have controlled studies but then prove it on the farm."

- aquaculture farmer

Farmer harvesting steelhead trout from a tank. Credit: National Aquaculture Association

The Program Planning and Implementation Process

Structure of the RACs, roles of key positions, and committees

Each RAC consists of a Director, an office manager or assistant, a Board of Directors (BOD), Industry Advisory Council, and a Technical Committee (TC).

Director. Each RAC has a Director that is an employee of the host institution. The Director provides leadership, coordination, and administrative support for planning, development, implementation, reporting, and oversight of projects across the RAC committees and the region's aquaculture community. The proportion of the Director's time allocated to the responsibilities of administering the RAC varies from approximately 40% to 100% of the individual's time and salary.

The Director's position is critical to the success of the RAC and is unlike other university or grant management positions because of the uniqueness of the RAC program. In situations in which the Director's position includes a departmental faculty appointment, the individual must meet departmental expectations for faculty, but the Director must also function as administrator of grants that are more complex than many other grant programs. RAC funding requires multistate teams that involve multiple contracts that are re-issued every year of the project. The Director must further function as a scientist and intermediary capable of translating farmer-expressed problems into researchable projects.

Thus, the right mix of knowledge, skills and abilities are critical for the Director to successfully lead a RAC. This mix includes an advanced degree and/or extensive experience in aquaculture for the Director to be able to engage effectively with aquaculture farmer stakeholders, researchers, and Extension personnel.

The Director's position is critical to the success of the RAC and is unlike other university or grant management positions because of the uniqueness of the RAC program.

The role of the Director in building collaborative teams among farmers, researchers, and Extension personnel is essential to the success of the RACs. The Director must possess the skill to bridge considerable conceptual differences among various research disciplines, and across farmers, researchers, and Extension perspectives. Building trust and relationships among the various groups are essential for the annual meetings to successfully reach consensus on the priority needs of a region and to identify those projects most likely to develop solutions to the problems identified.

Host Institution. The host institution plays a key role in the success of each RAC in providing administrative office support for processing grants and subcontracts. The host institution is expected to provide broad programmatic leadership for regional research and Extension activities. In some cases, an administrator from the host institution serves as the chair of the RAC's Board of Directors.

The expeditious release and distribution of project funds or reimbursements for travel expenses is critical for a RAC to provide timely responses to aquaculture farmers' needs. The RAC's business or office manager manages the day-to-day operations and is vital for efficient program operation, as is the host institution's Office of Sponsored Programs that manages the contracting work necessary for funds disbursement. Clearly, internal communications of the host institution among departments, schools, and Offices of Sponsored Programs play an important role in whether RAC projects are funded expeditiously. The host institution is also expected to support or create a modern, effective home page for the RAC that includes all publications, grant documents, and information important to aquaculture farmers in the region.

Several members of the Board of Directors interviewed reported that their host institution valued the RAC program because it added value to their extramural funding portfolio, with approximately $1 million annually received by the host institution. Other Board members pointed out that they use the RAC as model to encourage greater multidisciplinary research and direct collaboration with stakeholders for the support of other agricultural sectors.

The majority of the Board of Director members interviewed reported that the host institution valued the RAC. Institutions that did not value the RAC strongly viewed it as a minor source of funding and a small part of the overall research portfolio of the university.

Breakout session at a RAC annual meeting. Credit: NCRAC

> *"Because it's USDA and no overhead is allowed, those direct dollars can go a long way compared to other funds earmarked for aquaculture."*
> - aquaculture researcher

The Congressional authorization of the RAC program prohibits payment of Facilities and Administration (commonly referred to as Indirect Costs) from RAC funds. Two Directors indicated that the lack of indirect costs was a concern for that host institution and another Director believed that the issue of paying indirect costs would be more of an issue in the future. In other interviews; however, farmers, researchers, and Extension personnel were not supportive of RAC funding being used for indirect costs because it would reduce the amount of funding available for the research and Extension work that could be done by principal investigators. Moreover, no research or Extension personnel could be identified who had not submitted a proposal because of the lack of indirect costs.

Board of Directors. Members of the Board of Directors are selected from within each RAC and are often employed by participating institutions. Board representation frequently includes administrators from Agricultural Experiment Stations and Cooperative Extension Services, 1890 universities, Sea Grant, federal, state, and territorial agencies, and non-profit private institutions. The chairs of the Industry Advisory Council and Technical Committee serve as ex-officio members of the Board but serve as voting members in at least one RAC.

Board members are involved in a variety of specific activities in the RACs. Board responsibilities begin with ensuring that necessary policies and procedures are in place to fulfill the mission of the RAC. In the RACs, policies and procedures are codified in the operations manual, and one of the activities of Board members is to review, modify, and create by-laws (policies) and procedures. In several of the RACs, the Board conducts an annual review of the Director and the RAC administrative office.

The Board of Directors meets at least annually to review the list of aquaculture farmer priorities for the year, approve problem statements and the request for proposals and to oversee the pre-proposal process. When review comments are received on pre-proposals, the Board considers the comments and approves recommendations on which pre-proposals are selected for full proposal development. Further, the Board reviews full proposals and external reviewer comments, and makes the final decision on funding with input from the Industry Advisory Council and Technical Committee.

The role of the Board varies across RACs. Some boards are highly engaged throughout the life of a project. Board members in all RACs approve pre-proposals and full proposals for funding and are generally engaged in the project planning process. However, some Boards are more engaged in monitoring and providing review oversight of project progress than are other Boards. In most cases, the degree of engagement of Board members depends on their area of expertise.

In those RACs, Board members serve as project monitors that keep projects on track and provide project oversight from mid-term and annual meeting reviews and by reviewing annual reports. Directors provide much of the oversight of project progress in other RACs.

Industry Advisory Council. Members of the Industry Advisory Council represent the interests of the diverse aquaculture community within their respective region. Industry Advisory Council members are nominated for their positions by university administrators, RAC Directors, state aquaculture associations, or current Industry Advisory Council members, and nominations are approved by the Board of Directors. The primary responsibilities of the Industry Advisory Council are to provide input on the needs and priorities of regional aquaculture sectors and to jointly review (with the Technical Committee) annual work plans and project progress.

Across the RACs, IAC members reported that industry voices were well received and acted upon, that the IAC is critical in determining industry priorities and needs, and plays a key role in recommending proposals for funding.

Industry Advisory Council members review pre-proposals and full proposals and serve as farmer liaisons and advisors for projects. Some Industry Advisory Council members further participate as cooperators on projects by providing sites for on-farm trials or demonstrations, or in a few cases, conducting on-farm research. Across the RACs, Industry Advisory Council members reported that aquaculture community voices were well received and acted upon, that the Industry Advisory Council is critical in determining aquaculture farmer priorities and needs and plays a key role in recommending proposals for funding.

Technical Committee. The Technical Committee of each RAC is structured as a single committee with equal numbers of researchers and Extension personnel or as two subcommittees, one for researchers and one for Extension personnel. Researchers and Extension personnel are nominated to serve on the Technical Committee on the basis of state representation, research or subject matter expertise, or both. Nominations are made by colleagues, the RAC Director, university deans, or agricultural experiment station or Extension Directors, which are then approved by the Board of Directors. Technical Committee members participate in discussions of priority needs with the Industry Advisory Council from the perspective of whether: 1) the work proposed would duplicate previous work or projects in progress; 2) the topic is researchable; and, 3) the approaches suggested are technically feasible. In some RACs, the Technical Committee makes recommendations to the Board, while in others, the Industry Advisory Council votes and makes project recommendations to the Board.

Program Planning and Implementation

Overall, the RACs followed their operating manuals in terms of program planning and implementation. The review team found ample evidence that RAC program activities have been put in place as proposed. While there are differences in some details of operating procedures across the RACs, such differences involve fairly minor processes.

All RACs operate within the following precepts:

1. Projects are responsive to farmer needs.
2. Projects encourage cooperative and collaborative aquaculture research, Extension, and educational programs that have regional or national application.
3. Projects should address and resolve, by team efforts, problems that are too vast, complex, require too broad an expertise base, or are too costly in manpower or funds for a single institution to address.
4. Projects and programs are generally implemented using existing institutional mechanisms and linkages in public and private sectors.
5. Information should be transferred quickly to aquaculture stakeholders, the research community, and the public in an appropriate format and at an appropriate level of expertise for each specific audience.

Three principal characteristics distinguish RACs from other types of research and outreach organizations and funding programs:

1. Efforts are focused on a specific and significant problem of concern to two or more states or territories within a region.
2. Participating scientists and outreach personnel are mutually responsible for planning and accomplishing the objectives.
3. Priorities are identified primarily by an Industry Advisory Council and solutions to practical problems of the aquaculture community are emphasized.

Farmers harvesting hybrid striped bass in Texas. Credit: National Aquaculture Association

Priority identification process

The RAC process of project identification differs from that of all other research funding programs. The extent of the RAC commitment to industry needs is a cornerstone of the RAC program. Across all RACs, the process begins with input from aquaculture farmers about priorities that leads to joint discussion with research and Extension personnel from which the request for proposals is developed. The Industry Advisory Council members interviewed by the review team indicated clearly that farmers have a major voice in the decision on priority needs, although most acknowledge that the Board has final say.

Comments from aquaculture farmers

- Everyone [farmers] provides input.
- The farmers vote along with researchers and Extension personnel.
- Farmers couldn't remember a time when an industry priority did not get included in the request for proposals.
- The Board's decisions are based on the Industry Advisory Council's recommendation.

Since various RACs have slightly different specific processes, the following highlights several examples of the priority identification process. The processes described below are only for the identification of topics that later become part of the request for proposals that is sent out and subsequently triggers several rounds of internal and external reviews of proposals submitted.

North central regional center. A "Targeted Research Area List" is developed, reviewed, and discussed by the Industry Advisory Council, researchers, and Extension personnel in listening sessions. These listening sessions have ensured greater farmer involvement in the process than in prior years. Farmers push for short-term, quick-response projects that represent applied research that will make a difference in the medium term (three to five years). A request for proposals is developed and sent out for solicitation of pre-proposals.
The pre-proposals are reviewed by the Executive Committee and recommended to the Board of Directors for full proposal development. Full proposals are reviewed by the Industry Advisory Council/Technical Committee and external reviewers and recommendations for funding made to the Board of Directors.

> The review team found ample evidence that RAC program activities have been put in place as proposed.

Northeastern regional center. The Industry Advisory Council and Technical Committee meet to go over the prior year's funding initiatives and priorities. Then the Industry Advisory Council and Technical Committee break out into their respective committees to identify new issues that have emerged over the previous year and what modifications should be made to the request for proposals. Each committee reaches a consensus, and the committees meet to finalize the list of priorities. Pre-proposals received are reviewed by the Industry Advisory Council/ Technical Committee and a decision made by the Executive Committee as to how many can be funded, given that year's budget. Those selected are invited to submit a full proposal. The Industry Advisory Council/Technical Committee review the full proposals received and present recommendations for funding to the Board of Directors.

> *"Human relevance of the research is baked into the process with the RACs."*
> - aquaculture researcher

Pacific regional center. A region-wide announcement is sent out requesting input from the aquaculture community on research needs and topics of current interest. The Industry Advisory Council reviews the previous year's priority list and revises it with additions or deletions. Based on this input and often with discussion and refinement via an *ad hoc* committee meeting of Industry Advisory Council and Technical Committee co-chairs, the input is grouped into appropriate topic areas and sent to the Technical Committee in a request for pre-proposals. The pre-proposals are reviewed by external experts, the Industry Advisory Council, and the Technical Committee, followed by the Board of Directors that makes the decision as to which pre-proposals are invited for full proposal development. The Industry Advisory Council and Technical Committee then review the full proposals submitted and make recommendations to the Board of Directors for funding, with the Board of Directors making the final decision.

Tractor-powered paddlewheel for pond aeration.
Credit: Les Torrans

Southern regional center. The process typically entails a solicitation that is sent out by the Director for research topics. The list developed is then prioritized in a meeting of the Industry Advisory Council into a short list of perhaps 10 to 15 topics from the initial list that often includes 30 to 45 project ideas. Those 10 to 15 topics are then discussed in a joint meeting of the Industry Advisory Council and Technical Committee, with the Technical Committee further meeting to determine whether or not a priority is researchable, to provide details on cost, and to discuss identification of scientists who have the expertise to do the work. In a follow-up meeting, the Technical Committee and Industry Advisory Council set the funding level and time frame for each of those projects. The Industry Advisory Council votes on the order in which the projects should be funded. The Director then shares the amount of funds available, and the Industry Advisory Council alone votes for which projects get funded. Projects often include multiple species, a factor that typically results in a higher ranking and greater funding level assigned. For example, the focus may be on water quality issues, recirculating system technology, larval culture, or marketing issues that then address multiple species and sectors in the region.

> The extent of the RAC commitment to industry needs is a cornerstone of the RAC program.

Western regional center. Questionnaires from the administrative office are sent to the aquaculture community representatives, requesting input on priorities. The Industry Advisory Council further solicits input from other farmers for priority research project needs. The lead responsibility for developing a list of priority needs is with the Industry Advisory Council. Those priorities are then discussed in a sit-down meeting with the Industry Advisory Council, Technical Subcommittee-Research, and Technical Subcommittee-Extension. Researchers and Extension personnel discuss whether there is expertise available and whether the problem is researchable. Once the final list is approved, a mix of representatives from the Industry Advisory Committee/Technical Committee form writing groups to develop problem statements for each priority that is developed into a request for pre-proposals. Pre-proposals are reviewed by the Executive Committee (chairs of each committee plus two representatives each from the Industry Advisory Council, Technical Subcommittee-Research, and Technical Subcommittee-Extension) and recommended to the Board of Directors for full proposals. Full proposals are reviewed by the Industry Advisory Council/Technical Committee and recommendations made to the Board of Directors for approval.

RAC proposal requirements

All projects funded are required to address a regional need and to be multistate, both of which are fundamental criteria of the RAC program.
Each project consists of a multistate work group that provides expertise to cover all areas needed by the project and to represent different perspectives. Work groups include the lead principal investigator, co-principal investigators, farmer advisor or liaison, and Extension personnel. All but one RAC requires Extension personnel on each project.

One of the key strengths of the work-group approach is having industry partners on the research team who are involved throughout the planning and implementation of research. The joint discussions among researchers from diverse disciplines and farmers who raise different species have resulted in greater emphasis on interdisciplinary participation on work groups to solve different farmer problems more effectively. Several of the RACs have learned to identify topics of importance to multiple species groups and sectors to facilitate multistate participation. The involvement of team members from different states and territories has stimulated researchers and Extension personnel to think more comprehensively and regionally on aquaculture needs rather than focus primarily on state or local issues.

Uniqueness of the Regional Aquaculture Center Program

The RAC program is among the few federally funded program that is farmer (stakeholder) driven and industry responsive, with grassroots participation and engagement at every stage in project development, implementation, and monitoring. As one aquaculture farmer stated in an interview, “farmers are at the table in the RACs.” Thus, among federal funding programs for aquaculture, the RAC program is a unique funding model that brings together the aquaculture community, research, and Extension to set priorities, and to develop and implement applied research projects designed to answer practical questions currently relevant to aquaculture farmers. The degree of farmer involvement has led to the RACs focus on results.

> *“I wish I had ten more centers like the RAC. The RAC is an ideal role model.”*
>
> *- university administrator serving on the Board of Directors*

Left to right, researcher, farm worker, farmer, Extension agent and students after harvesting an on-farm feed study from the Regional Aquaculture Center funded cutthroat trout project. Credit: Matt Powell

There was strong consensus from interviewees on the strong points of the RACs, with 76% of all interviewees reporting the following strengths:

- Being farmer driven.
- Addressing the need for regional priorities not met by other programs.
- Value of networking and diversity.
- Process used to identify problems.
- Quality of people involved.
- Extension services.
- Willingness of researchers to work with farmers.
- Researchers that do not look down on them [farmers].

The RAC program was reported by interviewees to be nimble and able to adjust to the annual changes in farmer priority problems. Interviewees further reported that this ability of the RACs was unlike that of other national programs that change little over time. As a result, interviewees viewed the RACs as a program that responded to immediate and short-term critical needs more effectively than other funding programs that are not based on direct farmer consultation. As a result, the problems addressed by the RACs were viewed as distinct from those addressed by other funding programs and an example of the value and uniqueness of the program.

The review team found that the RACs served as a bridge across academia, research, Extension, and aquaculture farmers. A key strength and uniqueness of the RAC program is the three-prong advisory group with farmer, research, and Extension representation that was described by an interviewee as a three-legged stool. The structure of the RACs builds capacity, networking, and collaboration among researchers, Extension personnel, and farmers within each region. The RAC is the only program in the nation that creates, fosters, and supports a regional aquaculture community consisting of the top researchers, Extension and outreach personnel, industry leaders, and university administrators in a region. As such, the RAC enables the free exchange of ideas and information across the aquaculture community in the region. The unique RAC structure has led to extensive partnerships, networks, and friendships that have contributed to the success of RAC-funded projects to the benefit of aquaculture farmers across the United States.

> The RAC program is among the few federally funded program that is farmer (stakeholder) driven and industry responsive, with grassroots participation and engagement at every stage in project development, implementation, and monitoring.

The RAC program's uniqueness includes its regional emphasis that results in substantial scope and reach, reflecting the size and diversity of aquaculture within each region. The requirement for a regional approach ensures that research addresses the specific needs of the diverse species, production systems, and markets in a region. The resulting scope of the regional approach can be seen in the large number of segments of U.S. aquaculture that have been supported by the RAC program (Table 10). The RACs clearly have evolved to address the specific priority needs and issues of each region. The nuanced differences among the five RACs in-and-of-themselves reflect the success of the program to address the needs that differ widely from region to region.

The RACs are farmer-driven with engagement of farmers from priority identification through implementation

The Industry Advisory Council was found throughout the review to play a critical role in the function of all RACs. Industry Advisory Council members typically represent the diversity of aquaculture species and production systems in each region but have for the most part learned to work together to reach consensus on funding priorities and decisions. Other funding programs largely react to proposals by researchers that reflect their areas of interest and expertise. The Industry Advisory Council in each RAC maintains the focus on projects with potential for direct farmer benefits.

Interviews across all groups highlighted the farmer-driven structure of the RACs as a key driver of the program's uniqueness. All RAC Directors reported that aquaculture farmer stakeholders are involved in every aspect of the funding cycle, beginning with problem identification and prioritization, and extending through project implementation and dissemination of project results. Seven of ten Board of Director members responded with comments about the RACs being farmer-led and farmer-driven and reflected on the substantial extent of farmer involvement. Board members further pointed out that the farmer involvement leads to addressing fairly immediate regional needs that cannot or will not be funded by other funding agencies.

Ninety percent of the Industry Advisory Council members interviewed responded that the farmer-driven focus results in direct input and involvement, with farmers at the table throughout implementation of projects. Moreover, the most frequent response by farmers who were not on the Industry Advisory Council (41%; 7 of 17) to the question of how the RAC was unique was that it was "farmer-driven". The direct involvement of farmer cooperators was reported to be a characteristic that contributed to project success.

As a result of the unique structure and engagement among farmers, researchers, and Extension personnel, most RAC research is done where farmers are located in the region, under the climatic and other conditions of the region. Results are thus more applicable to farms and likelier to be adopted and demonstrate positive impacts.

Aquaponics in American Samoa. Credit: CTSA

Hybrid catfish evaluation research. Credit: SRAC

Ample evidence was heard from interviewees as to the cooperative relationships developed by researchers and Extension personnel with farmers. These relationships were reported to have increased the contributions of farms, frequently without compensation, to the projects funded by providing sites for on-farm research and demonstration as well as experimental animals. As further evidence of the effectiveness of the RAC model was the report by a farmer that the RAC approach to determining research priorities has been adopted in Florida for its state aquaculture competitive research program.

Degree of interaction and integration among farmers, research, and Extension personnel

The RACs stand out among other federal aquaculture programs not only because farmers are involved throughout the project, but also because research and Extension personnel come together with farmers in the RAC to annually assess farmer priorities and needs at regional levels. The RAC committee structure and the operations of identifying farmer priorities and review and discussion among farmers, researchers, and Extension personnel were found throughout the interviews to have led to a sense of teamwork and enhanced capacity through networking and collaboration among researchers, Extension personnel, and farmers within the region. The RAC model has created unique interactions among these different committees that is unusual for funding entities. Interviewees reported that the RAC process resulted in greater mutual respect and long-term relationships between researchers and farmers. These have led to other opportunities and initiatives that have persisted for many years.

The integration of the Industry Advisory Council throughout the review process and life of the projects was found to result in greater accountability of academic researchers to deliver project results and deliverables. Moreover, farmer Industry Advisory Council members reported having developed greater appreciation for what science can do in the short- and medium-terms. The integration and cooperation among research, Extension personnel, and farmer stakeholders were cited by interviewees as a key contributors to project success.

The interaction among research, Extension personnel, and farmers was reported by interviewees to have resulted in harnessing the collective expertise and knowledge base within a region to address problems that a single state or institution would not be able to do.

"Sometimes researchers get into their own world of research and forget about guys making a living and paying loans. That guy is thinking about more immediate results. Researchers have a long-term vision but, for the industry you're serving, they can't wait 20 years for results. It makes you think about the group you're serving."

- aquaculture researcher

The RACs, unlike other programs, were found through interviewees to have fostered unique open collaboration among states and territories, institutions, scientific and educational communities, and farmers that have resulted in clear benefits to U.S. aquaculture. As reported in interviews, the resulting free exchange of ideas and information has benefitted the regional aquaculture community. Interviewees mentioned the diversity and network of people involved with the RACs as a uniqueness and strength through bringing in different perspectives to seek solutions to regional problems.

The required role of Extension in each project in the RAC program is quite explicit, and its realization was confirmed by interviewees. Farmers, in particular, commented on the need for interaction with Extension personnel to increase adoption of research results on farms and also the importance of researchers to learn to work directly with Extension personnel. The RAC model blurs the lines between research and Extension and enhances the effectiveness of transfer of research results to farmers. The full integration of Extension within the RACs provides the commitment for results to be extended to farmers, not just a peer-reviewed scientific article, to maximize potential for adoption and positive impacts on aquaculture farms.

Multistate collaboration and partnerships

The RAC program requires that projects include at least two institutions and two states or territories (USDA, 1986). While respondents pointed out challenges associated with identifying collaborators in other states or territories, particularly where specific aquaculture sectors are concentrated in a single state, most pointed to a variety of benefits from this requirement. Many aquaculture issues are not bound by state borders and the nuanced differences between states/territories and different farming practices affords collective insight as to how to address problems that may be helpful to new entrants or established aquaculture sectors seeking to diversify their portfolio throughout the region. Moreover, the multistate requirement directly encourages farmer involvement so that proposals demonstrate broad applications of the work.

Challenges with the multistate requirement were reported to have arisen in cases where one aquaculture sector is predominantly located in a single state, or if a problem is very localized or site specific. In some RACs, projects have been funded to address overarching issues across sectors that have

Red swamp crayfish is the most popular crustacean produced in aquaculture in the U.S. Credit: Les Torrans.

included fish health, feeds, effluents, workforce training, new species, production efficiency, marketing, and economics, among others, that allow for inclusion of various species and systems.

"The value of the RACs is its regionality, which is a challenge, but in a good way. It gets us projects that get to what we want to achieve."
- aquaculture researcher

Farmer holding a catfish egg mass. Credit: Les Torrans

Multiple benefits were reported to the multistate requirement despite the challenges reported by interviewees in some RACs. The "purchasing power" of individual institutions is enhanced by teaming up with other organizations that may have better infrastructure, core equipment, or useful facilities. The RAC program was found to reduce institutional silos through team-building across institutions and states/territories. Seasoned faculty have opportunities to mentor new faculty with cutting-edge technologies that may not be available from a single institution or state. Several individuals reported professional career development benefits as an added value of participating in the RAC. The RAC forum introduced them to a broader regional community beyond their state that fostered new professional contacts, collaborations, enhanced networking, and career-lasting friendships. These connections were instrumental in helping to secure funds from other sources as well as peer-to-peer guidance and help. Regional Extension and multistate research projects produced a stronger response to farmer needs.

"It's a powerful approach. The work group approach forces one to think about why your research is relevant to management questions. It's not just multi-state researchers but also having industry involved."
- aquaculture researcher

Interdisciplinary collaboration

Throughout the interviews conducted by the review team, another uniqueness of the RAC program was the way in which the RACs capitalize on cross-disciplinary expertise from various institutions to focus on solving regional aquaculture farming problems. Individuals from a range of stakeholder categories (farmers, research, Extension) and institutions (public, private, 1862 and1890 land-grant universities, states and territories) have collaborated on the various projects funded. These individuals have not only shared their diverse disciplinary expertise, but have formed teams that cross the various boundaries of states and territories, disciplines, and institutions to address regional problems. One of the greatest values was reported to be the ability to engage with expertise from other institutions rather than being restricted to a single faculty member or institution. The cross-disciplinary teams formed through the RACs have created greater capacity in the region.

RACs capitalize on cross-disciplinary expertise from various institutions to focus on solving regional industry problems.

Regional nature of the RACs

The RACs, by definition, are regional centers. Committees are structured explicitly to represent aquaculture farmers in a region and the existing research and Extension capacity. Priority needs selected for project development are defined by aquaculture farmers in the region.

The U.S. Congress authorizes and appropriates federal funds for national programs. Each federally funded program responds to distinct authorizations and missions. As a result, federally funded programs differ in a variety of ways.

The RACs are a federally funded program, but the mission to be responsive to the needs of aquaculture farmers in a region has led to nuanced differences in structure and operating procedures. All RACs were found to function according to the program mission of supporting aquaculture development in their region. Aquaculture in the five regions; however, differs substantially. As indicated in the section on breadth and scope of the RAC program, some regions have more mature, established aquaculture farming sectors than do others and some have greater aquaculture research and Extension capacity than others. The species farmed, the production systems used, and the size of farms varies considerably across the various regions, reflecting the full diversity of aquaculture in the region.

The operating procedures of the RACs were found to be living documents that have been revised over time to improve RAC effectiveness. Operating procedures vary somewhat across the RACs as a result. Such nuanced differences in operations reflect the response of each RAC to regional differences and are further demonstration of how the RACs have responded to the needs of aquaculture farmers in each region.

U. S. Department of Agriculture-National Institute of Food and Agriculture funds and manages several other regional programs that focus on applied research, such as the Sustainable Agriculture and Research Education program, National Plant Diagnostic Network, Regional Integrated Pest Management Centers, and the Regional Food Business Centers. The Regional Food Business Centers; however, are very new, having been established only in 2022.

A comparison of the RAC was made with these other programs as part of the review process. These other regional centers are more focused on terrestrial agriculture, not aquaculture, but offer a basis for comparison of the regional component of the RAC.

The other centers have some degree of farmer involvement, but none approach the extent of farmer involvement of the RAC program. In the RAC program, farmers are involved in all aspects of project planning and implementation, including identification of priorities and decisions on funding. Farmers serve on key committees within the RAC structure, including the Industry Advisory Council and the Board of Directors. In the Sustainable Agriculture and Research Education program, farmers can serve as a technical advisor and on the regional administrative council, the governing body of the region somewhat akin to the RAC Board of Directors, and can apply for grant funding, but are

The other centers have some degree of industry involvement, but none approach the extent of industry involvement of the RAC program. In the RAC program, farmers are involved in all aspects of project planning and implementation, including identification of priorities and decisions on funding.

Farmers harvesting fish from a net pen in Republic of Micronesia. Credit: CTSA

not directly involved in priority need identification. The Regional Integrated Pest Management Centers include farmers as technical advisors, but farmers are not involved in any other phase of the Regional Integrated Pest Management Centers.

The National Plant Diagnostic Network interacts with farmer stakeholders as their client base and there is some involvement directly in scientific meetings by commercial diagnostic laboratories, but farmers have no direct input into the National Plant Diagnostic Network budget or funding decisions.

The RACs formally integrate Extension with all projects, and Extension personnel are fully engaged in project planning, implementation, and outreach. The Sustainable Agriculture and Research Education program requires Extension involvement, with Extension partners serving as staff, grantees, principal investigators, and as reviewers, but only Extension directors can serve on the administrative governing councils. Extension involvement is also required for the Regional Integrated Pest Management Centers, with Extension personnel serving on the advisory committee, as partners with the centers and as principal investigators on grants. Many of the National Plant Diagnostic Network diagnosticians hold partial Extension appointments or work closely with Extension personnel.

The four other regional center programs allow indirect costs, whereas the RAC program does not. Nevertheless, the extent of indirect costs that can be charged is capped at 10% in the Sustainable Agriculture and Research Education program and the National Plant Diagnostic Network, but the Regional Integrated Pest Management Centers allow institutions to negotiate with respect to indirect costs. The Regional Food Business Centers allow a *de minimis* rate of 10% without justification, but an institution can advocate for a higher rate.

Other differences from the RAC program include support for graduate student tuition costs and support for faculty salaries. The Sustainable Agriculture and Research Education program, National Plant Diagnostic Network, and Regional Food Business Centers allow graduate student costs, but the size of the grants is so small that paying tuition costs is not feasible. The RAC program does not allow graduate student tuition costs. The Sustainable Agriculture and Research Education program is the only program that allows faculty salary support on their grants; the National Plant Diagnostic Network, Regional Integrated Pest Management Centers, and the Regional Food Business Centers do not. The RAC program allows some faculty salary, but only in limited amounts.

Demand feeders in a raceway with golden rainbow trout. Credit: Samuel Chan

Competitiveness and Rigor of the RACs

> *"More funding agencies or organizations or processes should follow this model."*
> - aquaculture researcher

Scientific review of the RAC program differs from other programs in that it occurs at multiple stages of project development and includes ongoing review of scientific and overall project progress to a greater extent than other competitive grant funding programs. In the RAC program, review and scrutiny by scientists are enhanced and complemented by inclusion of farmers throughout the review process. Moreover, scientific review begins with scrutiny of initial project ideas, and continues through pre-proposals and full proposals. Both internal (within the RAC) and external scientific review processes occur in the RACs. Moreover, the RAC program has explicitly built in ongoing review and monitoring of project progress to a greater extent than other federal competitive grant funding programs. Figure 3 compares the scientific review processes for federal competitive grant programs generally (Figure 3a) and for the RAC program (Figure 3b).

Competitiveness of federal competitive grant programs

National federal competitive grant programs generally begin with agency staff establishing administrative requirements and topic areas to be addressed by those seeking to submit a proposal. The U.S. Department of Agriculture typically holds occasional listening sessions to obtain stakeholder input on general issues, but not necessarily for specific funding programs. Agency staff draft a request for proposals for each program in which the eligibility requirements and the priority topic areas to be addressed are specified. The topic areas selected tend to be more general than those of the RACs and allow for researchers to define and propose specific research problems that tend to be aligned with the researcher's interests, not necessarily those defined by a specific stakeholder group.

Figure 3(a). Decision and input processes for federal competitive grant programs generally.

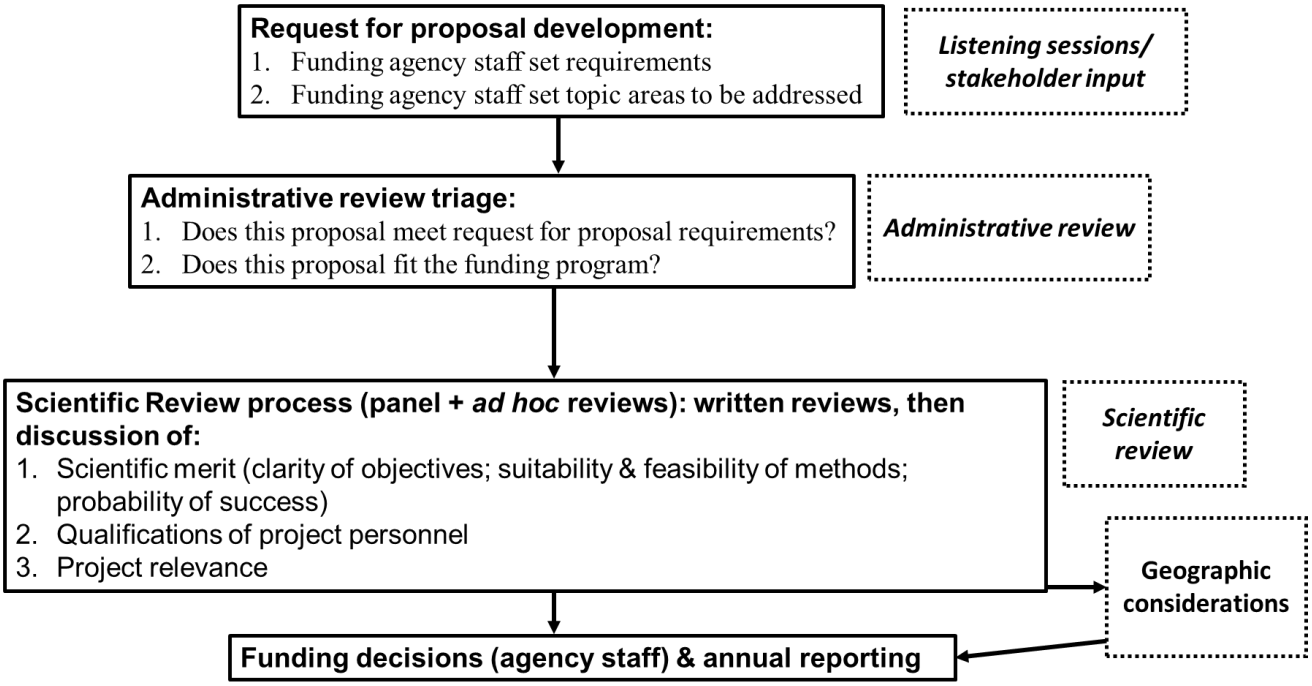
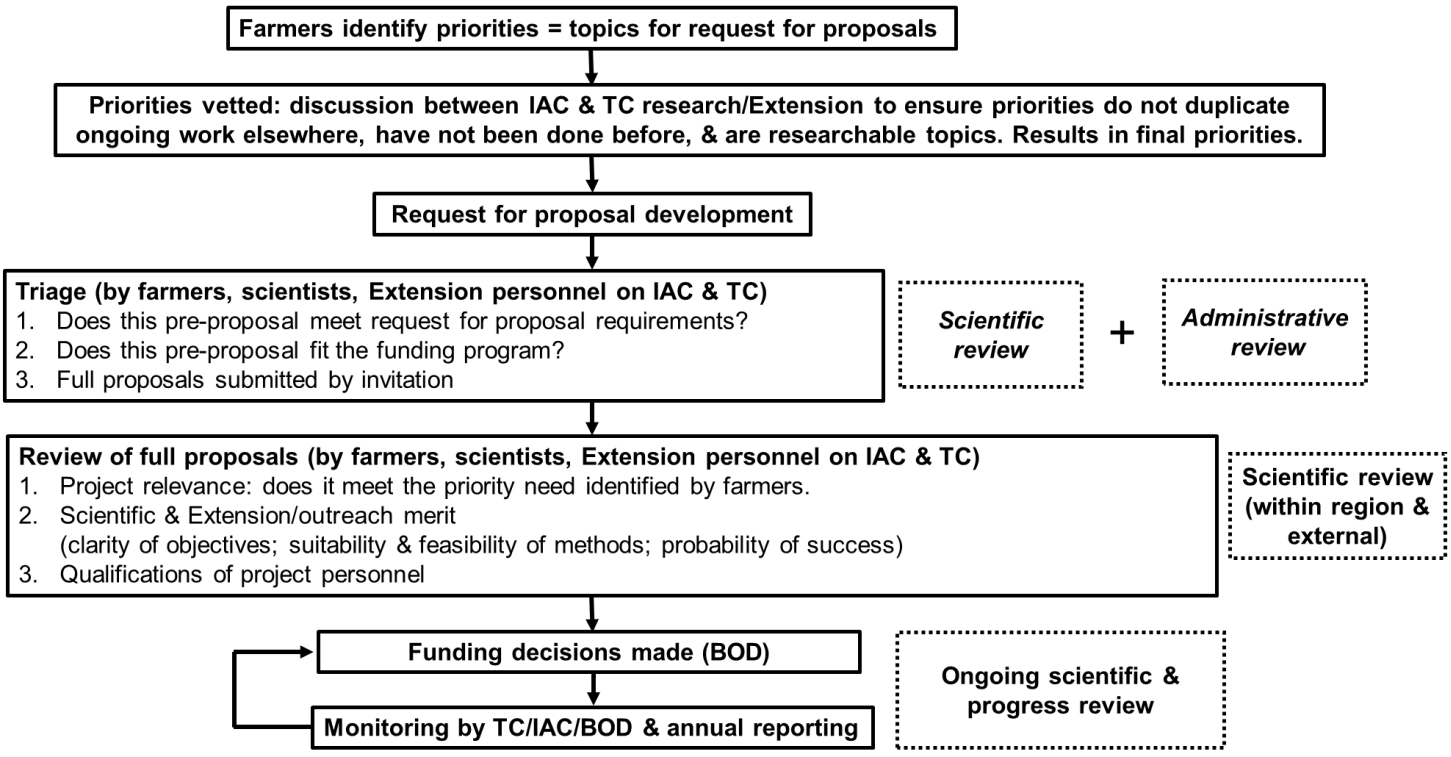


Figure 3(b). Decision and input processes for the RAC program.



Farmer flipping an oyster cage. Credit: Kevin Fitzsimmons

As a result, the projects funded through other federal grant programs tend to address more basic research topics of academic interest to the researcher, but are not focused on solving the practical problems of aquaculture farmers.

The request for proposals is distributed nationally to solicit proposals, generally full proposals (although in some cases there is an initial phase of a letter of intent submitted, with follow-up invitations to submit full proposals). Upon receipt of full proposals, most federal competitive grant programs undergo an initial agency administrative review to ensure that the proposal meets the basic requirements specified in the request for proposals and whether it fits the funding program relative to the specific goals, objectives, and topic areas of each program. When there is a letter of intent, agency staff choose those proposals to invite for development based on program administrative requirements and alignment with priority topics of the request for proposals.

The scientific review process typically involves solicitation of written reviews by scientists invited to participate on a review panel, sometimes accompanied by *ad hoc* reviews by additional scientists not on the panel but who submit written review comments prior to discussions.

Review panels include only research scientists, with a few exceptions that include some Extension personnel. Farmers typically are not involved in the proposal review. When the full review panel meets for discussion of relative merits of the various proposals, the panel typically first discusses a list of proposals on a triage list of those that received the lowest scores in the written review process and are proposed by agency staff to be eliminated from discussion. The panel discussion among scientists focuses on the remaining proposals and discusses the scientific merit (clarity of objectives, suitability and feasibility of methods, probability of success), qualifications of project personnel, and the relevance of the project to the goals and objectives of the program.

Some review panels are asked to rank projects; others are not, but proposals often are put into categories as to whether they should be funded or not. Final funding decisions are made by agency staff, often following internal discussions on geographic and other considerations. Annual reports are required of all projects, but principal investigators rarely receive feedback on the reports submitted.

Competitiveness of the Regional Aquaculture Center Program

The RAC program was designed to respond directly to the needs of aquaculture farms in each region. In the RACs, the farmers identify priority needs and choose topics for the request for proposals. The priorities suggested by farmers are vetted through open discussion among farmer representatives on the Industry Advisory Council and the research scientists and Extension personnel who serve on the Technical Committee. In this discussion, farmers explain the problems they face and the Technical Committee scientists discuss whether research findings already exist that address the problem, if there is ongoing research that would be duplicated, whether the topic is "researchable," and what types of skills and expertise would be needed to address the problem. Farmers set the final priorities, subject to approval by the Board of Directors.

The resulting request for proposals is distributed widely within the region to solicit pre-proposals. Pre-proposals undergo a thorough triage review by scientists within the region and those external to the region, farmers, and Extension personnel to address

whether the pre-proposal meets the requirements of the request for proposals and whether it fits the funding program. This first step addresses the same triage questions as in other federal grant programs; it not only includes agency administrative personnel but also research scientists, Extension personnel, and farmers. Those pre-proposals that meet these requirements are then selected to be developed into full proposals.

Full proposals are reviewed again by groups of farmers, research scientists, and Extension personnel internal to the region and others who are external to the region. The review criteria typically include: 1) project relevance (whether it meets the priority need identified by farmers); 2) scientific and Extension/outreach merit (clarity of objectives; suitability and feasibility of methods; probability of success); and 3) qualifications of project personnel (whether the proposal's investigators have adequate facilities and appropriate expertise). Those proposals that are ranked highest are then recommended for funding to the Board of Directors.

In the RAC program, there is additional monitoring of funded projects that goes well beyond that of other federal funding programs. In addition to the annual reporting requirements of all federal grant programs, there also are aquaculture farmer representatives who serve on the work groups and provide oversight. In one RAC, the principal investigators make formal presentations to the joint Industry Advisory Council and Technical Committee (research and Extension scientists) each year as part of the annual review. With multi-year projects, principal investigators receive funding one year at a time with subsequent years' funding contingent upon the previous year's performance. In instances when there have been problems with a project, principal investigators must demonstrate that corrective action has been taken prior to receipt of additional funding. In one RAC, a project monitor is assigned to provide additional oversight along with a mid-project review by a member of the Board of Directors. Thus, there is ongoing scientific and administrative review throughout the life of the project in the RAC program. The multiple levels of scientific review in the RAC program result in an even greater degree of scrutiny and oversight than in most national federal competitive grant programs because multiple sets of scientists and farmers review and comment at all stages of the proposal review but also throughout the implementation of the project.

Researchers collecting data from a RAC funded feed study on a trout farm. Credit: Gary Fornshell

The multiple levels of scientific review in the RAC program result in an even greater degree of scrutiny and oversight than in most national federal grant programs because multiple sets of scientists and farmers review and comment at several stages of the process.

Value and Impact of the Regional Aquaculture Center Program

There have been many positive benefits from the RAC program, but not all benefits described can be quantified formally in terms of economic impacts. Nevertheless, the RAC program has clearly contributed in a variety of ways to U.S. aquaculture currently, and some contributions may provide a foundation for future development.

Fulfillment of mission of addressing critical aquaculture farming needs

Responses from interviewees clearly demonstrate that the RACs have fulfilled the mission of addressing critical farmer needs. Overall, 90% of the Board of Directors (n[5]=10), 90% of the Industry Advisory Council (n=10), 56% of non-Industry Advisory Council farmers (n=16), 89% of researchers (n=9), 70% of Extension personnel (n=10), and 29% of prominent national leaders (n=7) reported that the RAC program has fulfilled its mission (Table 28).

Overall, the RAC program has fulfilled its mission.

Several interviewees made comments about not wanting to think where U.S. aquaculture would be without the RAC program. The evidence provided by interviewees points strongly to the support that the RACs have provided to develop new sectors (such as sturgeon, yellow perch, and walleye) but also

Cormorants are one of the primary causes of depredation on aquaculture ponds. Credit: National Aquaculture Association

[5]n=number of individuals interviewed in each category.

strongly supports major sectors of U.S. aquaculture such as catfish, oysters, trout, and others to remain competitive and viable. Interviewees mentioned that the RAC program funds projects that keep people in business by solving their problems. Sustaining existing businesses constitutes an economic value and impact that occur primarily in rural communities and economies. The $1.5 billion U.S. aquaculture sector owes much to the RAC program as illustrated by the examples described below.

> The RAC program funds projects that keep people in business by solving their problems.

Project performance analysis and assessment of project input and output relationships

The primary inputs to the RAC program are the congressionally appropriated funds through the U.S. Department of Agriculture-National Institute of Food and Agriculture to each of the five RACs. Other inputs include the un-compensated volunteer time of those involved in the RACs from those who serve on the various committees (Board of Directors, researchers, Extension personnel, and farmers) to the principal investigators and other project participants, including farmers, who do not receive compensation from projects. Depending on the project, cooperating farmers often donate significant time, facilities, workers, feeds, and other operating expenses without compensation.

The review team analyzed projects funded with a start date of 2014 and for which termination reports had been submitted by 2021 (Table 29). These included 19 in the north central regional center, 17 in the northeastern regional center, 27 projects in the Pacific regional center, 19 in the southern regional center, and 5 in the western regional center. The number of projects reflected the diversity of aquaculture in each region, the varied approaches regarding funding numerous short-duration projects or fewer longer-term projects, and differences in program planning cycles.

Project analytics included: funding amount, principal investigators, institutions, primary aquatic species targeted, topic or discipline area, deliverables completed and planned, inclusion of Extension components, farmer collaborators, demonstrations, identified outcomes and any qualitative impacts.

> *"That bird depredation study saved us hundreds of thousands of dollars."*
> - aquaculture farmer

Projects were completed for the most part. When needed, a re-direction or amendment was made to keep projects on track. The inclusion of project monitors and annual reviews of progress reports allowed for evaluation and approval to continue the work. The output of deliverables was variable by RAC but the program performed well overall in publishing scientific journal articles that reflect the scientific merit of the research. Deliverables typically included Extension fact sheets, and in numerous cases, how-to manuals with step-by-step methods and practices. The mix of deliverable outputs from most projects reflects the value of the integration of researchers and Extension personnel. Researchers tend to be output-driven and focused on scientific articles, while most of Extension personnel are outcome-driven and focus on outputs to disseminate results in a way that facilitates adoption. The principal investigators of the projects analyzed were active in making presentations at scientific and aquaculture association venues. Most importantly, individuals interviewed identified projects in their region that had impacts on aquaculture farming practices and conditions as well as contributions to scientific knowledge.

The productivity of outputs was calculated by dividing the total number of journal articles and the total number of presentations and Extension materials (i.e., fact sheets, infographics, videos) by the funds (in units of million dollars) invested over that time period. Overall, 7.2 scientific journal articles and 20.5 presentations or Extension materials were produced per million dollars invested.

Farmers harvesting sugar kelp. Credit: Maine Aquaculture Association

The RACs make a substantial contribution to science through the farmer-driven applied projects funded. It should be noted that not all projects funded over this period were research projects. Several projects funded supported Extension efforts and various regional conferences, and administrative costs are paid to the host institution from this budget. However, the integration of projects across research and Extension functions made it difficult to subtract non-research costs from the total funding, and the metrics calculated thus underestimate program productivity.

Quantitative estimation of economic impacts from several RAC-funded projects

Impacts from investments in research generally have lengthy lag times from completion of research until adoption on farms, as long as 15 to 20 years (Alston 2002; Alston et al., 1998). The decision to adopt a new technology by farmers often is based on a complex set of factors, but the rate and extent of adoption tends to accelerate with greater effects on profitability (Griliches 1957).

Returns on investment and economic impacts were calculated for several examples of impactful projects for which reliable reference data were available. Commonly used metrics were calculated that included the simple return on investment (ROI), the internal rate of return, and the most accurate rate of return metric for RAC investments, the modified internal rate of return. The modified internal rate of return is the most accurate because it accounts both for the time value of money (not accounted for by the simple rate of return) and the likely reinvestment of positive returns over the period of analysis. The modified internal rate of return is interpreted by comparing it with the cost of capital, that currently ranges from 7.5% to 10%. Thus, a modified internal rate of return greater than 10% is a worthwhile investment. Direct, indirect, and induced economic effects and effects on employment and tax revenue were calculated for these examples. The projects selected were those for which adoption of results had been verified through farmer interviews and for which reliable data were available.

Southern regional center: Returns on investment and economic impacts of the adoption by catfish farmers of intensive production systems and the complementary hybrid catfish technology. Funding from the southern regional center for improved production technologies for catfish production, the largest sector of U.S. aquaculture, dates to a 1988 project to improve aeration technologies (Table 30). Subsequent projects led to the development of more intensive systems such as split ponds and intensive aeration management along with high-performance hybrid catfish. The combined impact of the rapid adoption of these technologies has been substantial.

The simple return on the investment calculated for cumulative returns from 2010 (the year in which measurable adoption by farmers began; Hegde et al., 2022a) to 2019 of the southern regional center investment in intensive production systems and the complementary hybrid catfish was 16,152% (Table 31). When annualized, the annual return on the southern regional center investment in these projects was 32% per year. Net present value over the period from 2010-2019 was $1.1 billion, with an internal rate of return of 2039%, and a modified internal rate of return of 123%. A rate of return of 123% indicates that the southern regional center investments yielded a very high rate of return to U.S. aquaculture. The rate of return metrics were calculated only on the year-to-year increases in productivity as farmers adopted the new technologies and subtracted out the continuing research investment as a cost in each year of southern regional center funding. Thus, the analysis only charges the southern regional center dollars against the increased yields, not the total yields and sales of catfish.

Intensely aerated and split ponds for catfish production. Credit: Danny Oberle

One catfish farmer reported in an interview that he does not know if there would be a catfish industry without the southern regional center-funded projects that led to the dramatic increases in productivity and efficiencies.

The additional yields and sales of catfish from adoption of the new technologies added $1.7 billion in direct economic impact, $0.86 billion in indirect economic impacts, and $0.396 billion in induced impacts on households across the 9-year period from 2010 to 2019[6] (Table 31). Direct employment in catfish farming (including supply chain partners) was estimated to have increased by 3,666 jobs as a result of the adoption of new technologies. This increase in employment included 1,719 jobs of additional direct employment, 1,226 of indirect employment, and 721 from additional induced employment. Additional federal tax revenue over the 2010 to 2019 period from increased productivity was $53 million with state and local tax revenue over the 9-year period of analysis of $68 million.

Pacific regional center: Return on investment and economic impacts of development of oyster hatcheries in Hawai'i to supply oyster farms on the West Coast. Oysters are the second-largest aquaculture product farmed in the U.S. Ocean acidification on the West Coast has led to declines in the supply of seed of the Pacific oyster, the major species of oyster raised on the West Coast. In response, the Pacific regional center began a pilot program focused on production of triploid oyster seed that led to the development of oyster hatcheries in Hawai'i to supply Pacific oyster seed to farmers in Washington (#1 oyster-farming state), California (#4 oyster-farming state), Oregon (#6 oyster-farming state), Alaska, and Hawai'i. Without an alternative supply of oyster seed, many oyster farmers, including some of the major shucking-packing plants on the West Coast faced increased risk of going out of business. Details on the projects funded are included in Table 32.

The simple return on investment calculated for the cumulative returns from 2006 (second half of year) to 2023 (first half of the year) was 100,961% (Table 33). When annualized, the annual return on the Pacific regional center investment in these projects was 2.3% per year. Net present value over the period from 2006 to 2023 (first half of the year) was $214.8 million, with an internal rate of return of

Oyster farmers working on a floating upweller system. Credit: National Aquaculture Association

[6]Multipliers used in the economic impact analysis were those from Hegde et al. (2022b).

78%, and a modified internal rate of return (that accounts for the likely reinvestment of positive cash flow from year to year) of 57%.

The sales of oyster seed and those of final product from oyster growout farms as a result of the ongoing availability of oyster seed contributed $380.1 million in direct economic impact, $143.3 million in indirect economic impacts, and $167.8 million in induced impacts on households across the 16-year period from 2006 to 2023 (first half of the year) for a total cumulative economic impact of $691 million[7] (Table 33). Direct employment in the oyster sector, including the supply chain partners of hatcheries and shucking/packing plants, was 7,121 jobs, with additional jobs created indirectly of 1,462 jobs, and 1,574 jobs in induced employment, for a total of 10,156 total jobs supported.

> *"The pilot project we did with the Pacific regional aquaculture center was invaluable. It opened up our oyster seed supply. I'm not sure I'd be in business if it were not for that project."*
>
> - aquaculture farmer

In summary, the $376,112 investment made by the Pacific regional center from 2006 to 2017 resulted in substantial returns on the investment and economic and employment impacts across at least five states, a more than 1,000-fold increase in value from the investment. Interest has been expressed from farmers on the Gulf Coast and East Coast states in oyster seed from Hawai'i such that benefits from these projects will likely continue to accrue and expand in the future.

The timely response by the Pacific regional center to an emerging problem that resulted in sustaining a major sector of U.S. aquaculture is the most important aspect of this example. The efforts by the Pacific regional center helped to sustain and advance oyster businesses on the West Coast and in Alaska. Without an effective response to an important farming need, substantial damage may have occurred to the West Coast oyster sector, with ensuing major economic losses that would have included loss of jobs and tax revenue. Timely responses to regional farmer needs, as in this example, are the core mission of the RAC program. These projects exemplify the benefits of a farmer-driven, integrated research and Extension program that continues to be responsive to needs of farmers. It is also an excellent example of benefits generated from research and development in one RAC extending to other regions, in this case, the West Coast.

RAC projects exemplify the benefits of an industry-driven, integrated research and Extension program that continues to be responsive to industry needs.

Juvenile geoduck in nursery trays.
Credit: National Aquaculture Association

[7] Multipliers used in the analysis were taken from Northern Economics (2013).

Western regional center: Development of a white sturgeon industry in the U.S. Farming a new species requires technologies to successfully grow a species through all life stages, referred to as closing the life cycle. In the case of sturgeon, one of the major bottlenecks to growth and development of sturgeon farming was managing the reproductive, spawning, and early rearing stages. With sturgeon, this problem was more challenging because of the length of the maturation period, requiring 6 to 8 years in some states to 10 to 13 years in cooler regions for broodstock to reach maturity for successful spawning. The research that led to development of effective ways to spawn and raise sturgeon in captivity subsequently led to sturgeon farming in California, Florida, Georgia, Hawai'i, Idaho, North Carolina, and internationally.

Funding from the western regional center was instrumental in closing the life cycle of white sturgeon, subsequently leading to the development of sturgeon farming in the U.S. Table 34 lists sturgeon projects funded by the western regional center that began in 1993 and continued through 2018, successively addressing various aspects of bottlenecks and efficiencies needed for sturgeon farming to become economically viable. In all, from 1993 through 2018, the western regional center invested more than $2.5 million in sturgeon farming technologies. Sturgeon sales began to increase rapidly from 2018 to 2022, as sturgeon broodstock matured on the increasing numbers of farms, and caviar production and sales grew.

The simple return on investment calculated for the cumulative returns of sturgeon sales from the first documented sales in 1995 through 2022 as a result of the more than $2.5 million in research and Extension investments was 4,394% (Table 35). When annualized, the annual return on the western regional center investment in these projects was 2.3% per year.

> *"The sturgeon industry would not exist today without western regional center support."*
> - aquaculture Extension specialist

Sturgeon farmer and Extension agent handling broodstock. Credit: University of Idaho

Net present value over the period from 1993 to 2022 was $118 million, with an internal rate of return of 669%, and a modified internal rate of return (that accounts for the likely reinvestment of positive cash flow from year to year) of 35%.

The sales of farmed sturgeon meat, caviar, and live sturgeon from the growth of the sturgeon sector in the U.S. contributed $114 million (2023 $) in direct economic impact, $264 million in indirect economic impacts, and $139 million in induced impacts on households across the 29-year period from the first investments in 1993 to 2022, for a total cumulative economic impact of $517.2 million[8] (Table 35). Direct employment in the sturgeon sector was estimated to be 53 with an additional 973 jobs created indirectly through the supply chain, and 685 jobs in induced employment, for a total of 1,711 total jobs supported.

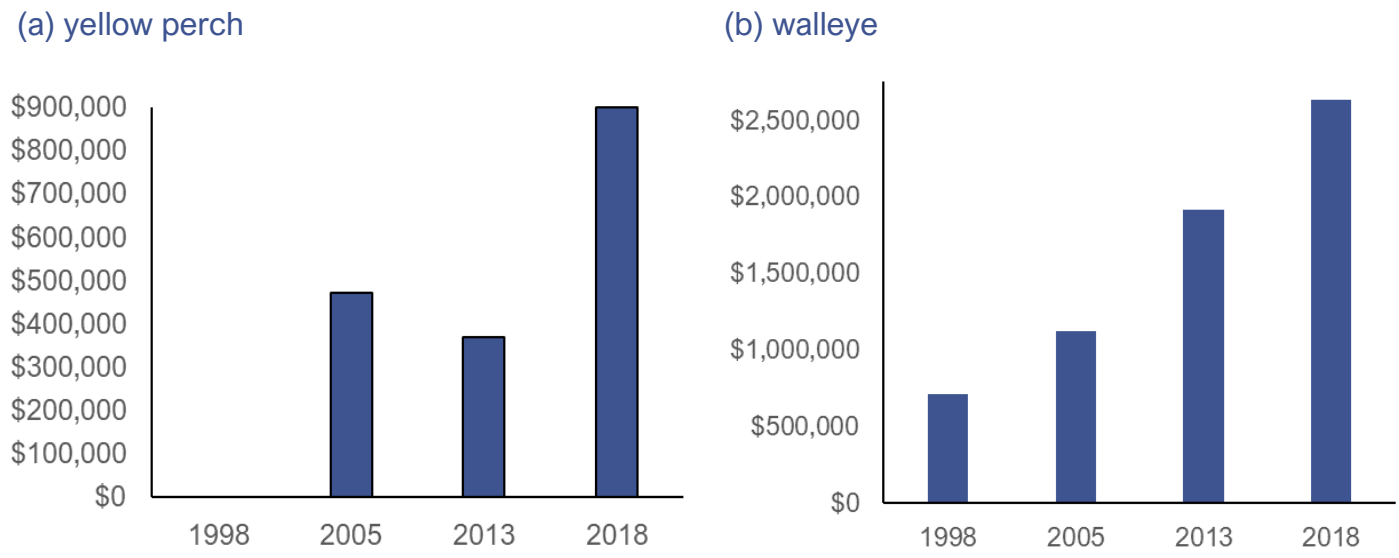
North central regional center: Development of yellow perch and walleye sectors. The North Central Regional Aquaculture Center has invested in the development of farming technologies for several new species. This research and Extension investment has led to growth in production of yellow perch and walleye farming and has also contributed to increased production by state and federal hatcheries of walleye for enhancing fish stocks to support recreational anglers in the region.

From 1988 to 2019, the north central regional center funded 12 projects for a total of $1.96 million with additional investment of $1.2 million in eight walleye production studies (Agyeman et al., 2023 a,b). A 2021 survey of aquaculture farmers in the north central region found that farmers had adopted yellow perch and walleye farming practices that contributed to the emergence of commercial farms for these species. Yellow perch farmed production was first reported in the 2005 Census of Aquaculture (USDA-NASS 2006) with sales increasing by 91% to 2018 (Figure 4a). Farmed production of walleye was reported in the 1997 Census to be $710,000, with sales increasing by 270% by 2018 (Figure 4b). Using the multipliers reported by van Senten (2016), the total annual economic impact of yellow perch farms was estimated to be $2.7 million and that of walleye $8.0 million.

Impacts from seed funding and proof-of-concept work as RACs respond to needs of farmers

The review team also found evidence that RAC projects have served as seed or proof-of-concept funds for subsequent lines of research developed with other funding sources. Several examples are described below.

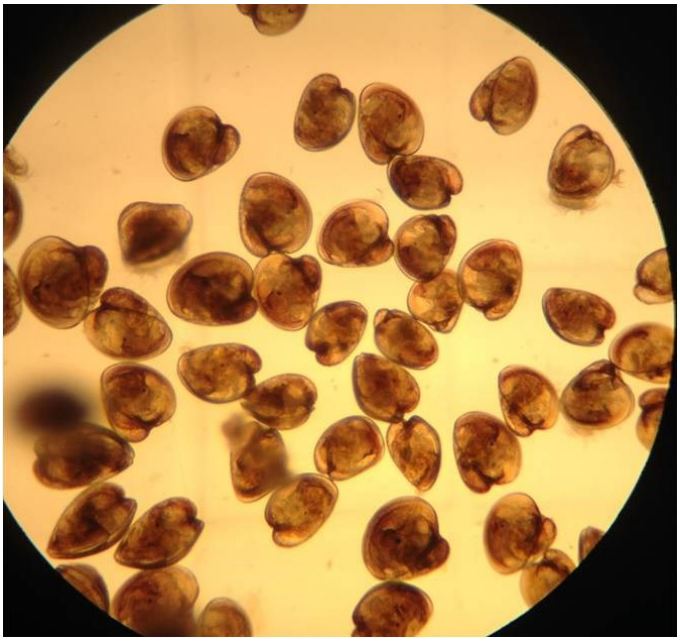
Figure 4. Growth of yellow perch (a) and walleye (b) sales over time.



[8]The economic impact analysis completed was an original analysis completed as part of the review based on cost structures from previous surveys and sales information provided by U.S. sturgeon farmers.

North central regional center. The north central regional center has supported development of new commercial aquaculture species over the years. Seed studies funded have focused on performance improvements that may increase commercial feasibility. Examples include: a) identification of fast -growing lines of largemouth bass; b) determination of nutritional requirements of bluegill and crappie; and c) identification of the most suitable strains of white bass for production of hybrid striped bass.

Northeastern regional center. The northeastern regional center invested early funding that led to the development of disease-resistant oyster lines in direct response to a region-specific farmer issue that was not being addressed by other funding programs. The initial tests provided incremental information on the development of lines and markers for resistance. Although only three to five lines were tested, this work provided the foundation for follow-up work at Rutgers University and the Virginia Institute of Marine Sciences that resulted in oyster lines resistant to multinucleated unknown or multinuclear sphere X (MSX) disease. Further work developed a cold water adapted MSX-resistant line, known as NEH (New England × Haskin) that was adopted widely in New England in the 1980s and 1990s. The explosive growth in oyster farming in New England and in Virginia (5 to 7% per year) in the last decade is largely attributed to the development of the MSX-resistant lines.



Oyster larvae. Credit: Julie Davis

The northeastern regional center also funded work that led to development of an effective gear coating to deter biofouling in shellfish production. Biofouling organisms on shellfish gear restrict water flow and exchange that are essential for shellfish growth and health. Finding a compound that would effectively deter biofouling that is safe for shellfish and the environment has been a difficult problem. Called NetMinder, the gear coating developed effectively prevented biofouling by all organisms other than barnacles. The supplier of the base material; however, ceased production, and the coating was not further developed. Although this innovation was not commercialized, the technology is available for potential commercialization if a supply of the base material would once again become available.

The northeastern regional center also funded projects that developed and demonstrated hatchery methods for razor clams. A Razor Clam Roundtable was created as a result of these projects with participation from more than 20 growers in the region to learn first-hand about the biology, culture and market potential for razor clams.

Other projects funded by the northeastern regional center focused on the potential to expand mussel farming in the region, with project results shared at workshops. The information developed provides a foundation of information that would be required for eventual permitting for mussel farming in the future.

Research led to development of rearing protocols and guidelines for lumpfish, a valuable cleaner fish used to mitigate sea lice parasite problems on salmon net pen farms. A lumpfish hatchery with a captive broodstock program and a U.S. Lumpfish Consortium grew out of this research.

Pacific regional center. Projects funded by the Pacific regional center have added to the knowledge base on how to culture a variety of new species. Although many of these species have not yet been developed into commercial businesses, key technologies for culture now exist. Examples include culture of swordtails, giant clams, bath sponges, soft and hard corals, ogo (native macroalgae in Hawai'i), amberjack (kahala), opihi, sea cucumber, coral grouper, rabbitfish, and mangrove crab, and

Researcher holding a cultured moi.
Credit: World Aquaculture Society

marine ornamental animals such as the yellow tang, harlequin shrimp, and the feather duster worm.

Funding for culture of the Pacific threadfin (moi) contributed to development of a commercial farm offshore in Hawai'i, although the farm was later closed from regulatory pressure. Commercial moi cage culture was also demonstrated in the Republic of Marshall Islands.

Southern regional center. The Southern regional center has funded projects on commercial production of selected native freshwater ornamental species. Introducing new ornamental fish species is an important component of the marketing strategies of commercial ornamental fish farmers. The bottleneck to new species development often is the reproductive and larval fish rearing stages. The southern regional center projects have developed new methods for spawning and successful rearing of several ornamental fish species. These projects have been extended to develop improved and more efficient hatchery methods for other sectors, such as baitfish and goldfish.

Western regional center. The western regional center has invested in several new species with commercial potential. Examples include research on farming burbot (i.e., freshwater cod), cutthroat trout, and purple-hinge rock scallop. Western regional center research developed basic husbandry practices, estimated production costs, and assessed commercial feasibility of farming burbot. On-farm trials by farmers with burbot were promising, and researchers have partnered with a private company that has established the first commercial burbot hatchery in the U.S. Western regional center research on cutthroat trout developed farming techniques and diets that have been adopted by several rainbow trout farmers who raise and sell cutthroat trout for stock enhancement. State, federal, and tribal hatcheries have also adopted the western regional center research results to improve success in their cutthroat trout rearing programs. A third example is the early research of the western regional center on purple-hinge rock scallops that led to two Pacific States Marine Fisheries Commission grant awards directly connected to the western regional center project work group. These follow-on projects are working to resolve bottlenecks to commercial rock scallop aquaculture and development of a rock scallop hatchery for California. The western regional center provided the proof of concept that catalyzed further work toward commercialization.

Juvenile burbot at University of Idaho. Credit: Luke Oliver

Trout raceways in Snake River Canyon, Idaho. Credit: National Aquaculture Association

Regulatory issues: Development and dissemination of best available science to inform deliberations on regulatory issues.

U.S. aquaculture farmers have long identified duplicative and overly complex regulatory systems as a major cost burden, but there was little understanding of the magnitude of the effects of the regulatory framework on U.S. farms. Throughout the RAC program review process, many interviewees identified issues associated with regulatory action as a key problem, often citing the lack of familiarity of regulatory personnel with aquaculture farming methods and practices, with other data already being collected, or proposing requirements unlikely to achieve intended outcomes. The RACs have developed and disseminated science-based information and farm-level data over the years to local, state, and federal agencies to inform decisions made with the best available science. Several examples are described below.

The Environmental Protection Agency and the 2004 Effluent Guidelines for Concentrated Aquatic Animal Production.

RAC research and Extension personnel were instrumental in providing the U.S. Environmental Protection Agency with expertise and scientific data in a nationally coordinated effort throughout the Environmental Protection Agency's deliberations regarding regulation of effluent discharge from aquaculture facilities. The Pacific regional center initiated efforts related to aquaculture effluent discharge as early as 1987. In the southern region, RAC projects characterized finfish and shellfish effluents from intensive on-farm sampling of water quality in ponds and receiving waters and evaluated alternative practices to manage aquaculture effluents. Similarly, the north central regional center studied and analyzed the characteristics of effluents along with testing removal methods and potentially beneficial uses.

A conservative estimate of the economic value of the farms (catfish, salmonids, hybrid striped bass, baitfish/sportfish) that remained in business because of RAC research and engagement in the 2004 effluent rulemaking effort is **$600 million** in annual sales. Applying multiplier values, the total economic impact could potentially have been a loss of **$960 million** in lost total economic effect and a loss of **2,760 jobs**.

The northeastern regional center funded several projects to analyze water quality, effluent management technologies, and various methods to treat effluents with biological organisms with potential to be a secondary crop on farms.

The western regional center invested in the development of low-phosphorus feeds that reduced discharge of phosphorus from rainbow trout farms to receiving streams. Low-phosphorus feeds have been adopted widely in the trout sector and resulted in an aquaculture sector-wide reduction of phosphorus use. Adoption of these feeds has also been estimated to result in cost savings of $6 million annually.

Several of the rulemaking initiatives that prompted these RAC projects had the potential to put many fish farmers out of business. An economic analysis of the proposed effluent treatment options showed that all small- and medium-scale trout farms would likely be put out of business with the proposed options. Under the cost estimates suggested by the Environmental Protection Agency that were reported by industry experts to be unrealistically low, net returns (profits) would have decreased by 85%, and the risk of losing money would have increased from 16% to 90% even for the largest farms in the industry (Engle et al., 2005). Large farms would also have exited the business if required to implement all recommended changes. With production costs based on farm data collected by independent analysts, the largest farms would go out of business under all proposed scenarios. A conservative estimate of the economic value of the farms (catfish, salmonids, hybrid striped bass, baitfish/sportfish) that remained in business because of RAC research and engagement in the 2004 effluent rulemaking effort, is $600 million in annual sales. Applying multiplier values, the total economic impact could potentially have been a loss of $960 million in lost total economic effect and a loss of 2,760 jobs.

The Food and Drug Administration and access to therapeutants for disease treatment. Concern over the use of therapeutants and the potential for exceeding threshold levels of residues in aquatic food animals led to increased scrutiny of U.S. aquaculture farmers. As a small agricultural sector, few therapeutants have been approved for use in aquatic animals. Given the need for an interim process, the RACs provided financial support for a National Aquaculture New Animal Drug Application Coordinator who assisted companies and researchers to develop the data needed to submit formal applications for approvals to the Food and Drug Administration. In addition, the north central region funded several research projects

Feed storage silos on a catfish farm. Credit: Les Torrans

Oyster shucking stations at a shellfish processing facility. Credit: National Aquaculture Association

that directly supported new animal drug approvals. The southern regional center funded projects on food safety residues that demonstrated the safety of U.S. aquaculture products as compared to imported sources, and another that developed new hazard analysis of critical control point plan[9] approaches to meeting the Food and Drug Administration requirements for farmers and processors. The RAC projects further identified potential funding sources for drug research, and tracked and reported the status of submissions to the Food and Drug Administration. The efforts by the RACs relieved Food and Drug Administration pressure on farmers and helped foster a positive working relationship with the Food and Drug Administration.

Shellfish food safety regulations. Shellfish can pose a food safety risk if the public waters where shellfish are grown become contaminated with pathogens that pose risks to human health. In response, the western regional center funded several Extension projects that resulted in the development of a new software program, Aquarius, that simulated conditions of public waters based on rainfall (that introduces pathogens of concern such as *E. coli* that emanate from terrestrial runoff into tidal areas) to use for decisions on closures of shellfish harvesting. When first applied by health service agencies in California, annual revenue for California shellfish farmers increased by $1 to $2 million. The Aquarius models have since been applied in other shellfish growing regions.

2008 Viral Hemorrhagic Septicemia Rule, USDA-Animal and Plant Health Inspection Service. An outbreak of viral hemorrhagic septicemia in the Great Lakes resulted in attention drawn to the movement of farmed fish as a potential vector for disease transmission. The 2008 rule restricted interstate movement of fish and caused considerable economic harm to the many fish farms whose markets were in other states. The north central regional center funded projects that focused on biosecurity measures, hazard analysis of critical control point plans, transport regulations, and developed a list of state import regulations hosted on

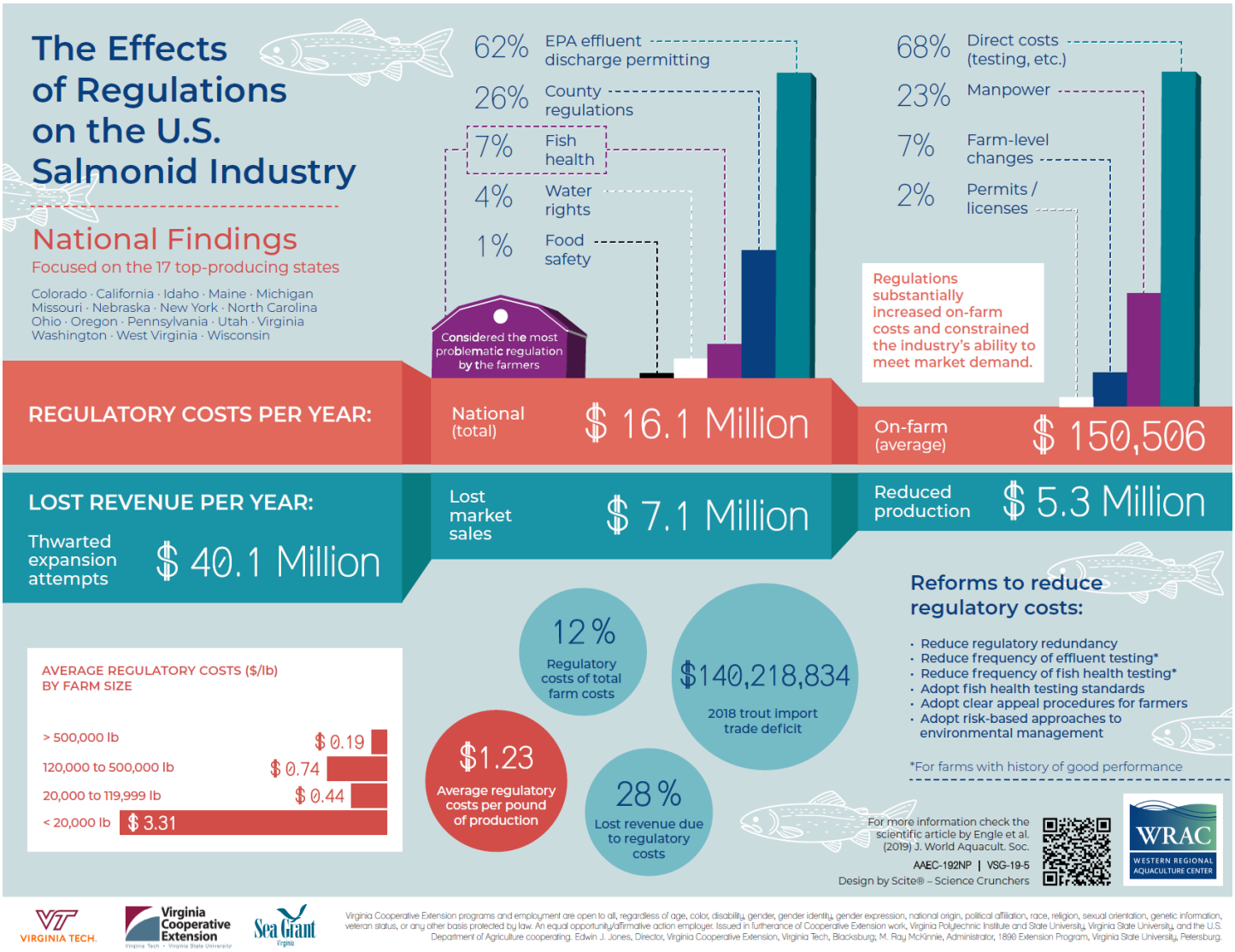
[9]A systematic preventive approach to analyze a step-by-step production process for potential hazards, prevent their occurrence, and record the effort.

the north central regional center website. The western regional center also evaluated viral hemorrhagic septicemia as a potential threat. Dissemination of project results allowed farmers to meet state regulations for interstate transport of fish.

Potential shellfish farming impacts on estuarine ecological systems. While shellfish farming has traditionally been viewed as an indicator of a healthy estuarine environment, growth of shellfish farming on the West Coast led to increased concern from resource agencies regarding potential environmental impacts. In response, the western regional center funded two cornerstone projects to better understand the complex ecological interactions among shellfish and eelgrass in estuaries. Project findings resulted in reducing regulatory concerns and possibly prevented restrictive actions that could have severely reduced shellfish farming. Some findings of the studies were incorporated into shellfish farming best management practices. The northeastern regional center also funded an assessment of environmental impacts of oyster farming and further quantified farm-scale ecosystem services from oysters in the northeast. A model for conflict resolution and management was developed along with a code of practice and best management practices for East Coast shellfish farmers.

Measuring on-farm regulatory costs of U.S. aquaculture farms. The western regional center funded a study to measure the on-farm economic effects of the complex set of rules as applied specifically to trout and shellfish farmers.
The western regional center project catalyzed a national salmonid survey that eventually included 17 states that produced 99% of the value of salmonids nationally. Findings showed that the regulatory system increased aggregated on-farm costs of salmonid production by $16.1 million/year and resulted in additional lost sales of $52.5 million from the inability to expand to meet growing demand for their locally produced trout. For Pacific Coast shellfish farmers, the annual regulatory burden was estimated to be $15.6 million with additional lost sales and market opportunities from the inability to expand to meet market demand of an estimated $179.9 million.

Oyster farmers flipping cages from boat. Credit: Jada Pearson



Regulatory costs accounted for 29% of total costs of producing shellfish on the West Coast and 12% of total costs of farming trout and salmon in the U.S.

Findings of these studies have been used in discussions with state and federal agency regulators with the in-depth farm-level data providing valuable insight into the permitting and other challenges faced by aquaculture farmers. Another western regional center project estimated the economic impacts of fish farms that supply fish to support recreational angling. Results showed a very high multiplier value of $36 of economic activity for every dollar of sales from a trout farmer selling fish for stocking to support recreational angling.

Classification of coastal areas for aquaculture farming in Hawai'i. The Pacific regional center funded a project that supported classification of various coastal waters to provide a legal basis for shellfish farming and safe harvesting. Another Pacific regional center study showed that tilapia were already present in waterways in Hawai'i. That project resulted in the delisting of tilapia from a restricted status and allowing farmers to produce tilapia commercially.

RAC support for Extension services

The RAC program has been structured from its inception to advance development of U.S. aquaculture. The structure of the RAC explicitly recognizes that full integration of Extension services is essential to fulfilling its mission. The review team heard many comments throughout the interviews about the essential role of Extension personnel to: 1) keep projects grounded in farm realities to generate results likely to be effective under commercial conditions; 2) ensure that project results were disseminated to farmers; and 3) provide assistance on farms to adapt research results to farming conditions. Extension personnel interviewed cited the contribution of the RACs to their career and professional development. The RACs have provided support for this critical role of Extension in a variety of ways, with several examples described below.

Development of libraries of information on aquaculture. The southern and north central regional centers have responded to the need for readily available, science-based information presented in farmer-friendly formats. The southern regional center has produced more than 350 technical fact sheets (246 in the current catalog), 100 updated revisions, 7 web presentations, 7 software programs/web tools, 31 videos, and has a YouTube channel. In addition, the AquaPlant website, produced and hosted by the southern regional center, is a well-regarded resource for identification of aquatic weeds and their management options. The north central regional center production manuals were cited by many interviewees as providing essential information not available elsewhere that guided new farmers in starting their aquaculture businesses. The aquaculture libraries hosted by RAC programs are used as educational resources in high school and college aquaculture programs. States and territories without strong aquaculture university programs benefit from the availability of regionally appropriate, science-based information, representing a significant cost savings to those university programs. The RAC publications are also used by regulators and policy makers to better understand aquaculture practices.

Aquaculture workshop at University of Wisconsin-Milwaukee. Credit: NCRAC

Regional Aquaculture Center and Sea Grant sponsored National Aquaculture Extension Conference attendees on a farm tour. Credit: David Cline 2017

Consumer education information. RAC-funded Extension education information has included information for consumers. U.S. consumers, for whom seafood is not a staple protein source, typically are not well-informed about seafood choices. The north central and southern regional centers have published information series, with the southern regional center series available in English and in Spanish. The northeastern regional center developed a model quality assurance program targeted to U.S. consumers in the northeast.

Direct support for aquaculture Extension personnel in the region. The northeastern, north central, and Pacific regional centers have provided direct support for aquaculture Extension in response to needs of farmers for greater Extension capacity. The northeastern regional center created the Northeastern Regional Aquaculture Extension Network in 1990, resulting in a variety of outputs consisting of workshops, videos, short courses, publications, farm tours, newsletters, and web-based home pages.

However, the greater impact likely was access to expertise from across the region for individual Extension personnel. Several interviewees expressed that access to regional expertise resulted in greater responsiveness to farmers in their particular state. Northeastern regional center funding was also used to help initiate the well-attended Northeast Aquaculture Conference & Exposition that is held annually in the region. The north central regional center funded a regional aquaculture Extension coalition to serve the region that included educators from both land-grant and Sea Grant institutions. The north central and Pacific regional centers have also directly funded Extension personnel positions to respond to the lack of Extension support in their regions.

The RACs funded the first National Aquaculture Extension Conference in 1992 and have continued to support this interregional initiative about every 5 to 6 years since. In recent years the RACs have partnered with the National Oceanic and Atmospheric Administration National Sea Grant Program to co-fund and co-sponsor this event.

Economics and marketing research to guide aquaculture farms to increase economic sustainability

Farmers interviewed by the RAC review team emphasized the importance of projects integrating economics and marketing criteria in projects to ensure that recommendations from research are likely to result in positive economic benefits to their businesses. The southern regional center has included objectives for economic analysis in many of the production-oriented projects funded. The RACs have also funded stand-alone economics projects that addressed a variety of issues, including:
1) economic impacts of bird predation on aquaculture facilities (northeastern and southern regional centers); 2) economic forecasting for catfish and trout (southern regional center); 3) economic impacts of catfish technology adoption and trout produced for recreational fishing (southern and western regional centers, respectively); 4) economics of aquaponics (Pacific regional center); and 5) feasibility of aquaculture in the Commonwealth of the Northern Mariana Islands (Pacific regional center).
Stand-alone marketing projects have examined:
1) market opportunities for aquaculture products generally (north central, northeastern, and southern regional centers); and 2) market assessment for specific species such as nori (northeastern regional center), live bay scallops (northeastern regional center), giant clams (Pacific regional center), and sunfish and walleye (north central regional center).

Responding to disease challenges

Projects funded by the western regional center led to development of a monoclonal antibody for detecting the bacteria that causes coldwater disease. The antibody is now available commercially through Immuno-Precise Antibodies in Canada for use by diagnosticians as a confirmatory test or diagnostic tool. Other western region center research resulted in a licensed vaccine for infectious hematopoietic necrosis and a patent for a vaccine for coldwater disease.

RAC support for state aquaculture associations

The northeastern, north central, and Pacific regional centers have provided small grant funding to state aquaculture associations with limited finances. This developmental assistance has provided the means to increase educational outreach activities and assisted new aquaculture associations become more firmly established. The north central regional center further provided professional development training for state aquaculture associations.

Researcher collecting information about fish disease. Credit: SRAC.

Workforce development and training

Workforce development has become a critical need in many sectors across the U.S. economy. The RAC program has funded several workforce related projects in response to this need. The north central regional center funded an effort to match skill needs with U.S. career and technical education. The Pacific regional center has developed a curriculum and educational resources for the Quest to Understand Aquaculture program in Hawai'i and has invested in workforce training in several U.S.-affiliated Pacific Islands.

Collaborative team-building

An un-anticipated benefit identified in this review was the finding from interviewees of the importance and value of personal relationships created through the RAC process, not just among research scientists, but among farmers, research scientists, and Extension personnel. The collaborative process mandated by the RAC program requires cooperation throughout the project development and implementation process.

The RACs may be the only federally-funded program that is farmer-driven and responsive with grassroots participation and engagement at every stage of project development, implementation, and monitoring. Over the life of the program, hundreds of individuals have served on RAC committees and forged new working relationships that bridged perspectives and needs of farmers and businesses to increase mutual understanding.

> An unanticipated benefit identified in this review was the finding from interviewees of the importance and value of personal relationships created through the RAC process, not just among scientists, but among farmers and across farmers, research scientists, and Extension personnel.

Farmers interviewed described the benefits of having developed an appreciation of the challenges of research and requirements for rigorous experimental methods that lead to robust scientific results that address farmer-identified priority needs. Researchers interviewed reported having developed greater respect for farmers, greater appreciation for their motivations, and the challenging nature of farming in an aquatic environment. Collaborative input from farmers often forces researchers to think "out-of-the-box" rather than pursue an individual researcher's personal interests. Many interviewees across all groups praised the RACs for assembling such a broad diversity of individuals with the common interest to advance commercial aquaculture in the U.S.

The full engagement of Extension personnel on collaborative teams provides the "boots on-the ground" necessary to accurately identify and articulate farmer needs, design more relevant and practical experiments, and assist with follow-up for information dissemination.

Aquaculture feed formulation research at University of Wisconsin-Milwaukee. Credit: NCRAC

Such extensive collaborations would not likely have occurred across the U.S. in the absence of the RAC program.

The RACs are not dependent on a single discipline, state, or regional boundary. The RACs have demonstrated the impact and benefit of an interdisciplinary approach to farmer needs. The use of work groups for project planning and implementation facilitates team-building and integrated methods.

Networking across the region

Researchers reported valuing the RACs not just for funding opportunities but perhaps more so for the networking that occurs among participants as they form new work groups and collaborative projects. Over the 35 years of the program, hundreds of individuals have volunteered to participate on committees and/or received RAC funding.
The RACs provide a forum to bring together the next generation of aquaculture professionals and young farmers for the future benefit of U.S. aquaculture. The RACs have helped new researchers work with more experienced colleagues to augment their productivity and pursue the best science. For example, the northeastern regional center funded a Regional Aquaculture Extension Project that united the Extension capacity in the Northeastern region for long-standing collaborations beyond any RAC project.

The north central regional center organizes and sponsors the North Central Regional Aquaculture Conference every two years and the northeastern regional center has been a long-time supporter of the Northeast Aquaculture Conference & Exposition. These conferences provide an opportunity to strengthen the aquaculture community network at a regional level with their diversity of participants.

"The most valuable thing from RAC was the network of people he got to know. Special because it was not only other farmers, but people from universities and all different walks of life, with different perspectives that he might not have had otherwise."

- aquaculture farmer

Key Factors Identified that Contributed to Positive Impacts of RAC Projects

Farmer respondents were asked to identify factors that they believed contributed to the success of RAC-funded projects.

Responses included:

- Integration and cooperation among research.
- Extension, and farmer stakeholders.
- Rigorous science that results in peer-reviewed publications, with projects completed on time.
- Direct involvement of farmer cooperators in project implementation.

Many regional problems are not readily solved by a single institution and RACs integrate resources, facilities, and expertise not available in one state or territory on a regional level.

Successful projects mentioned by farmers were those that focused on benefits to aquaculture farms in the form of solving their problems, improving the bottom line for commercial farmers, producing results that can be used on farms, helping farms be more profitable, use less labor, and operate at a reduced cost, among others. Also mentioned was that the project was relevant, doable, logical, and affordable, with a measurable impact on production.

Other characteristics mentioned reiterated the core RAC criteria of:

- Cooperation among research, Extension personnel, and farmer cooperators.
- A committed and effective outreach program with products that are useful and relevant to farmer stakeholders.
- Projects that have a direct positive impact on U.S. aquaculture.

"Success means: did you solve an issue? And what was the result of that research? Did it propel sales? Did it save the farm? What did it do economically for the company is a big one along with how it affects the bottom line."

- aquaculture farmer

Farmers commented that no other program is as flexible as the RAC program to pivot and shift priorities that meet immediate farmer-identified research priorities. RACs have a mechanism to fast-track projects that address an immediate need or problem rather than use its standard project development process. The RACs were recognized by many interviewees as a better funding model than centralized funding that is competed on a national basis with broad priorities and without farmer participation.

Oyster farmers working crop on Chesapeake Bay. Credit: Keri Rouse

> *"The RACs comprise diverse groups of people and farming operations and they have the ability to get down to a local level."*
> - aquaculture farmer

Farmers interviewed reported a variety of specific factors as having contributed to positive impacts from RAC-funded projects. The factors mentioned began with the focus of the project and the need for it to address priority needs of farmers from the perspective of finding practical, cost-effective solutions. To do so requires active engagement with farmers and with Extension personnel as well as a diverse work group composed of experts in the relevant disciplines, including economics. Successful projects were reported to be those that got results out quickly and made the information readily available to farmers. Most of all, farmers reported that a successful project is one that produces results that are adopted on farms and result in positive impacts.

Operational Effectiveness of RACs and Program Management

The review team heard many positive comments about the overall effectiveness of program management and operational effectiveness of the RACs. Many of the comments; however, were qualified with the caveat of "given the limited funding available." Even comments that were more critical were based mostly on the increasing proportion of administrative costs that have been created by level funding over time or the small number of projects funded or the small amount of funding per grant, all of which result from inadequate funding. This section discusses the inadequacy of funding, but also describes suggestions for ongoing improvements.

"RACs give an incredible bang for the buck. So much money going into other research groups. For the dollars going into RAC, the impact and the way they make the farmers feel represented and a voice in the research process is much more valuable than dollars spent by other research agencies."

- aquaculture researcher

Inadequacy of funding

One of the strong points of the RAC program is the unique funding model that brings together farmers, research, and Extension personnel to address farmer priorities. The RACs combine the purchasing power of multiple institutions to access the best expertise and facilities in a region. Program activities are well matched with farmer needs and the program is well integrated across institutions and disciplines.

Aquaculture farm priorities change from one year to the next but the RAC program is sufficiently nimble to be able to address pressing farm problems, unlike other national programs with little change in priorities over time.

Most RAC funding is for projects that address current, urgent, emerging, or short-term needs. Investments in medium- or long-term needs are not as common and are approached by sequential grant submissions that address long-term needs incrementally. The RAC program funds projects to address aquaculture farm needs that cannot or are not funded by other funding agencies.

RAC funding is important to regional aquaculture sectors and economies. The regional focus is a particular strength of the program that is often not considered by other funding sources. The multistate and farm relevance requirements are unique to the RAC program and are not shared with other funding programs. For example, National Oceanic and Atmospheric Administration aquaculture funding does not necessarily require that research be relevant to aquaculture farms.

Compared to other federal funding sources, the RAC program provides a high value for the funding allocated because farmers are directly represented and involved in the project development and implementation process. RACs also provide good value because indirect costs are not allowed, and therefore a greater proportion of grant funds can be directed to research. Nonetheless, despite being well operated, the value of the program is limited because much less funding is available than in other federal grant programs.

It is difficult for aquaculture researchers to compete with other, larger animal commodity groups for U.S. Department of Agriculture-National Institute of Food and Agriculture funding. The size of the domestic aquaculture sector is relatively small, making it difficult to justify funding. There is not a large amount of aquaculture-specific funding in the U.S., and other funding sources for aquaculture are larger than the RAC program.

In general, the review team found that, while the RAC program was focused on its mission goals and objectives, the current funding levels have drastically limited the number of projects that can be funded, and hence also limited the number of problems solved for U.S. aquaculture.

However, for many aquaculture researchers, the RAC program provides about 15 to 20% of the value of their research portfolio. Often the RAC program is the only option to fund certain kinds of aquaculture research of high value to specific sectors of U.S. aquaculture.

Several states have sufficient aquaculture research infrastructure and capacity while other states/territories have very small aquaculture sectors, with few aquaculture programs and research and Extension personnel. For most RACs, the flow of funding resources is insufficient to maximize use of the available capacity.

In general, the review team found that, while the RAC program was focused on its mission goals and objectives, the current funding levels have drastically limited the number of projects that can be funded, and hence also limited the number of problems solved for U.S. aquaculture. Not all issues identified as priorities by the Industry Advisory Councils can be addressed because of the limited funding, thereby preventing the RACs from solving some of the more difficult problems faced by farmers. The RACs could do much more within its current structure and administration if additional funding were available. The mechanisms to develop research projects are in place and the process is working efficiently, but the effectiveness is limited by the small amount of funding that limits the number of farm priorities that can be addressed by each center.

Annual funding for the RAC program has increased by only $921,600 since 1988. This equates to only $184,320 of new funding per RAC since 1988. Inflation adjustments alone would have nearly doubled the current funding levels. Inflation has increased the costs of research and thereby eroded the funding available for projects, leading to a dramatic reduction in the number, size, scope, duration, and complexity of funded projects. Flat funding precludes expanding projects into new disciplines like economics, food science, or business, or broadening the diversity of species supported by the program. If level funding continues much longer, the relevance and future of the program would be jeopardized severely.

By comparison, the USDA Agriculture and Food Research Initiative, Sustainable Agricultural Systems program has awarded grants of $10 million for single projects focused on highly theoretical topics, that may or may not lead to impacts. Funding for a single Agriculture and Food Research Initiative project is more than double the funding of the entire RAC program.

Consumer perceptions research at a seafood market. Credit: Keri Rouse

> *"Every funding round, good projects get left on the table."*
> - prominent national leader

Funding uncertainty also challenges the program. The frequent threat of no-funding forces RACs to fund entire multi-year (2 to 3 years) projects up front, resulting in fewer new projects added each year. Insecurity of future funding of the RACs takes a toll on morale of administrative staff, but also of research and Extension personnel.

With limited funds that are spread thinly among multiple states/territories and species, it has become increasingly difficult to fully address the priorities of the very diverse U.S. aquaculture sectors. High-quality project proposals that address high-priority needs identified by the Industry Advisory Council remain unfunded during each round of funding. This adds to the challenge of providing balanced support for all species groups. Sectors that indicated a lack of funding support include baitfish, sportfish, and ornamental farmers in several regions, and trout farmers outside the western region.

For example, a typical multistate RAC project is funded at $300,000-400,000. When funds are divided among all participating institutions and principal investigators, an individual investigator may receive only $30,000 to 50,000. Principal investigators must find additional support for graduate student stipends, tuition, and other project costs.

Limited funds leave the RAC program operating functionally as a "seed grant" funding program to develop preliminary information that may lead to new opportunities to develop larger, more comprehensive grants. Researchers seek additional funding, often of necessity, to complement or leverage RAC funding, but complementary resources are not always available within each region. RAC researchers have sought complementary funding from various programs in USDA (Hatch, National Institute of Food and Agriculture, and Sustainable Agriculture Research and Education), National Oceanic and Atmospheric Administration (Saltonstall-Kennedy, Sea Grant), and Small Business Innovation Research programs.

Limited funding has constrained many RAC grants to a maximum duration of 2 to 3 years. The RACs must take a building-block approach to longer-term projects because funding limitations lengthen the time required to solve problems. Some of the most successful RAC projects are those that have been funded for several cycles, but the current funding limitations likely result in the inability to fund follow-up projects that are necessary to take research results through to adoption by farmers and the consequent beneficial impacts.

Other readily apparent manifestations of the very low level of funding include insufficient funding for critical involvement of Extension personnel. Sufficient resources are not always allocated in budgets to develop and disseminate the outputs and deliverables from projects because researchers struggle to adequately fund graduate students and other costs needed in projects. Moreover, there is insufficient funding to document and measure knowledge gains, adoption, or other impacts of short-term projects.

Farmer beside goldfish holding tanks in Missouri.
Credit: National Aquaculture Association

The relatively small amount of available funding, considering the effort required to prepare proposals, is not sufficiently attractive to some aquaculture research scientists, to the point of serving as a deterrent or disincentive to their participation. As universities move to 9-month (or less) appointments, research and Extension personnel are increasingly required to support more of their own salary. RAC limitations on funding salaries may discourage faculty from competing for funding and restrict the time available to faculty to dedicate to a project.

Land-grant university administrations support the RACs and appreciate their role as a funding source for faculty researchers and graduate students. Their support is tempered by not being able to charge indirect costs to RAC grants. However, paying indirect costs amounts to a tax on grant funding and takes away funds that can be used for program activities. Allowing indirect costs would require legislative action to change the authorizing language for the RAC program.

Administrative costs of the RAC program are fixed costs. As the budget has shrunk in real terms as a result of inflation, the proportion of costs for administration has increased. Existing administration capacity at host institutions can manage higher levels of grant funding and greater numbers of projects, as they did in the past. To leverage management costs across a larger total budget would make more efficient use of program funding.

> *The support and engagement of NIFA are important to the success of the RACs.*

Adequacy of support from National Institute of Food and Agriculture

National Institute of Food and Agriculture is the federal manager, national leader and partner in the function and operation of the RAC program. The RAC program is a unique part of the National Institute of Food and Agriculture's aquaculture portfolio.

Paddlewheel aerators in catfish pond. Credit: Les Torrans

The National Institute of Food and Agriculture provides programmatic guidance to the RACs in the form of an annual request for applications that solicits proposals from the RACs for each year's appropriated funding. The funding opportunity description of the request for applications articulates the goals and mission of the RACs. The request for applications also provides guidance on reporting requirements for the RACs. The National Institute of Food and Agriculture provides final approval of project workplans and budgets.

The support and engagement of the National Institute of Food and Agriculture are important to the success of the RACs. Through the National Coordinating Council, the National Institute of Food and Agriculture provides a link to partnerships with other federal entities like the National Oceanic and Atmospheric Administration-Sea Grant, and USDA-Agricultural Research Service.

Administrative support for the RAC program from the National Institute of Food and Agriculture has varied over the years, but the current National Program Leader for Animal Health and Aquaculture has been very supportive. Administrative support at higher levels in the National Institute of Food and Agriculture has not been demonstrated at the level of the federal coordinating Subcommittee on Aquaculture.

The National Institute of Food and Agriculture can facilitate support needed from the U.S. Department of Agriculture to assist the RAC program by engaging at higher administrative levels in the U.S. Department of Agriculture to advocate for the importance of the RACs. However, the RAC program does not have good visibility within the National Institute of Food and Agriculture and limited efforts have been made by the National Institute of Food and Agriculture to draw greater attention to the impacts and value of the RAC program. Greater visibility and awareness of the RAC program within the National Institute of Food and Agriculture is needed at the agency (not the program) level to provide greater support, including seeking inclusion of RAC funding in the President's annual budget request to Congress.

The National Institute of Food and Agriculture has not been involved in the annual program planning meetings of each RAC for nearly 10 years, and there has been little to no communication or interaction of RAC Boards of Directors with the National Institute of Food and Agriculture until perhaps recently.

Similarly, there has been limited engagement by the National Institute of Food and Agriculture with upper administration at host institutions with respect to the RAC program. Increased engagement from the National Institute of Food and Agriculture with host institutions will be necessary to ensure smooth transitions following the upcoming retirements of RAC Directors.

The National Institute of Food and Agriculture could provide improved support for the RAC by hosting a home page for the RAC program and referencing the RACs on the National Institute of Food and Agriculture social media, including the National Institute of Food and Agriculture Update newsletter. The National Institute of Food and Agriculture can also use the Aquacontacts listserv to disseminate information nationally about RAC projects. Further useful support from the National Institute of Food and Agriculture would be to submit an annual report to Congress on the various projects funded, accomplishments, and annual highlights received from the RACs.

Clam farmers harvesting crop in Florida. Credit: University of Florida

RAC Director

Active and committed support from the Director to the RAC and its foundations is essential to the success of each RAC. The uniqueness of the RAC approach poses challenges that Directors must address. These challenges revolve around the more common research paradigm of researchers following their specific interests and their lack of experience with responding to farmer needs, to active engagement with Extension personnel from inception to implementation of projects, and to the degree of oversight by farmers and others throughout RAC projects. It is the Director who must help each RAC committee not only understand but actively engage with each other, listen to each other, and form the multistate coalitions essential to achieving the impacts that the RAC has generated.

The review team was impressed generally by the commitment of the RAC Directors to fully addressing the RAC mission and their understanding of the need to spend time engaging with farmers, researchers, and Extension personnel to help integrate them fully into the RAC process.

Farmer checking rainbow trout eggs before shipment.
Credit: National Aquaculture Association

The recent history of the RAC program; however, has demonstrated the serious problems that can occur in the absence of this level of commitment by the Director. The retirement of the Director of the north central regional center in May, 2022, and the inability of the host institution to have filled the Director's position by late 2023 (the time of this report) is a major cause of concern. Across the various categories of individuals interviewed, those interviewed from the north central region expressed a great deal of frustration with the handling of the process of filling the north central regional center Director's position by the host institution. The lack of a sense of urgency to have the position filled, the apparent lack of understanding of what is required for an effective RAC Director, and a lack of concern for the effects of the extreme delays in having a fully functional Center on aquaculture in the north central region are of great concern.

> Three of the RACs (Pacific, north central, and northeastern regional centers) have changed host institutions in the past.

Host institution support

The host institution provides critical direct support functions to the RAC. Table 36 provides greater detail on expectations for institutions that host the RAC administrative offices. The host institution provides office space for the Director and administrative staff, but also provides administrative support from the institution's Office of Sponsored Programs that handles the grants and contracts that enable disbursement of RAC project funds. There is also an expectation that the host institution will provide assistance by its internet technology specialists to ensure that the RAC website is designed and maintained as a modern, effective website for the hosted RAC.

The review team found the effectiveness of support from host institutions to be variable. Seventy percent of researchers serving on the Technical Committee said that there was good support from the host

Baitfish are produced throughout the U.S. Credit: SRAC.

institution, and one said there was support from the dean but not at higher levels. The greatest number of comments related to improving host institution support was related to technical support needed for the RAC website where RAC materials were made available. Many interviewees mentioned shortcomings of the RAC websites and the need to maintain them on a higher level. In addition, only one example was found of a host institution that provided communications support in university newsletters or in the form of press releases highlighting new projects funded, results of projects funded, or other news of RAC accomplishments.

Some institutions absorb more of the overall RAC support costs than do others, and, thus, the degree of host institution support varies across RACs. For institutions that were reported to value the RAC program highly, RACs were considered an integral part of the university, a highly valued and respected program that served as a model for other colleges, departments, and agencies. These institutions tended to also value aquaculture farming in the region. For institutions that expressed only marginal valuation of the RAC, the program was viewed as a minor source of funding, a small part of the research portfolio, and thus not heavily promoted.

Issues associated with the lack of indirect costs, limited principal investigator salary, and prohibition of providing graduate student tuition, limited the degree of support. The degree of host institution support was also affected by the depth of the personal relationships between the RAC Director and host university administration.

The support of the host institution depends on just a few individuals, often at the level of a department head or dean. In some cases, an administrator from the host institution serves as the chair of the RAC Board of Directors. In other cases, key university administrators have only superficial knowledge and understanding of aquaculture and the RAC program. Turnover among university administrators is normal, requiring ongoing contact between RAC Directors, new university administrators, and the National Institute of Food and Agriculture to improve familiarity, gain trust, and garner support.

Three of the RACs (Pacific, north central, and northeastern regional centers) have changed host institutions in the past. Only the southern and western regional centers have been hosted by the same institution from the inception of the RAC program to the present.

The first transfer of the RAC administration to a different institution occurred in 2004 when the University of Massachusetts Dartmouth informed USDA of its decision to terminate its role as host institution for the northeastern regional center. USDA developed and circulated broadly a request for proposals to eligible institutions in the region. All proposals submitted were evaluated by an independent external review panel based on criteria outlined in the request for proposals. Following the recommendations of the panel, USDA Cooperative State Research and Extension Service conducted a site visit to the institution that submitted the top-ranked proposal. Based on the findings of the review panel and site visit, the University of Maryland was selected as the new host institution for the northeastern regional center in 2005.

A period of transition occurred to close out all pending grants under the former center while awarding new subsequent grants under the latter.

In 2011, Michigan State University informed USDA, that upon the Director's retirement in 2012, that it no longer wanted to serve as host institution for the north central regional center. Iowa State University had co-administered the center and had been responsible for Extension activities, producing center publications without editing or printing costs, and managing the RAC website. To select a new host institution for this region, rather than the United States Department of Agriculture National Institute for Food and Agriculture soliciting proposals through a formal competitive request for proposals process, the North Central Cooperative Extension Association and the North Central Regional Association of State Agricultural Experiment Station Directors solicited letters of interest from institutions in the region, then by consensus they agreed that Iowa State University should assume full administrative responsibilities. The United States Department of Agriculture-National Institute for Food and Agriculture agreed with this recommendation. The transition of all center host institution responsibilities was easily undertaken by Iowa State University because of the previous co-administration. The Associate Director at Iowa State University had many years of experience with the program and facilitated a seamless change in administration as the new Director of the north central regional center in 2012.

Farmer holding upside-down catfish, a novel ornamental species. Credit: Gary Fornshell

The third transition of host to a different institution occurred in 2014. The original host of the Pacific regional center, the Oceanic Institute, was reorganized under the Hawai'i Pacific University, but the continued host role was short-lived because of the expectations, requirements, and demands of the Center. In 2019 the University of Hawai'i assumed the responsibilities of hosting the Pacific regional center, following its demonstrated capability and desire to administer the program, and now the Pacific regional center is administered by the University of Hawai'i. The Executive Director for the Pacific regional center has integrated well into the University of Hawai'i by starting an aquaculture program, teaching aquaculture courses, and helping to build new aquaculture capacity.

Researchers and Extension specialists learning about catfish raceways. Credit: Bob Robinson

Constraints and Challenges to RAC Program in Operation and Effectiveness

Declining Extension capacity at land-grant universities

Farmers expressed the need for project participants or Extension personnel to meet and interact with them personally at farmer meetings, farm visits or direct communication via phone or email.

A real challenge is limited resources for Extension capacity and programs and the increasing lack of Extension personnel and services in numerous states and territories. Today, many states and territories lack a reliable aquaculture contact at a university or institution who interacts regularly with farmers.

> *"Extension is the glue that makes this whole thing happen. The Industry Advisory Council told the board that this whole thing doesn't happen without Extension."*
>
> - aquaculture Extension specialist

Advancement and growth of U.S. aquaculture require adequate Extension personnel. The Extension function is a two-way street in which the Extension personnel communicate and translate farmer problems into the language of discipline-specific researchers, and then translate and communicate research results back to farmers. The adoption of new technologies or research results often requires adapting those results to farm conditions.

Thus, the active engagement of Extension personnel on farms to adapt results to farm conditions is a critical step in the adoption process. The active involvement of Extension personnel results in more rapid adoption of new technologies and research findings.

Farmer holding a harvest-size Atlantic salmon. Credit: Bob Robinson

The declining Extension capacity is a substantial concern that extends beyond aquaculture. As a newer sector of agriculture; however, and with the rapid development of new aquaculture methods and species, growth and development of U.S. aquaculture requires active engagement of Extension personnel.

Lack of awareness of the RAC program and access to RAC project results: inadequate communications internally and externally

Findings of the review team revealed that many farmers who are the targeted stakeholders or beneficiaries of this farmer-driven program are unaware of the existence of the RAC, and more importantly, its potential economic benefits. Some commented that RACs are invisible in the minds of farmers because they relate RAC-funded projects to the researchers and their institutions much more than to a RAC. The general lack of awareness of the RAC program requires more concerted efforts among many groups and individuals to raise awareness. Numerous farmers mentioned the need to improve Extension efforts to communicate RAC project results to them. Farmers are busy with their daily work of running a business so a variety of communication methods are needed to increase awareness of the program and extend its benefits.

> *"The RAC program is a hidden pearl for U.S. aquaculture."*
> - aquaculture Extension specialist

There is a desire to get project information out quickly and available at the fingertips of famers. A concern expressed by some was that information transfer from research projects was too slow. Some farmers are not comfortable with today's communication technologies while others prefer using digital platforms, although individual preferences for specific platforms are highly variable.

RACs are encouraged to use the range of communication tools to reach a wide range of farmer age groups more effectively. The most effective ways to communicate with farmers were reported by many to be: face-to-face farm visits and direct interaction, direct communication via email, field days, farmer association meetings, conferences, websites, Extension workshops, Extension personnel and researcher farm visits, newsletters, virtual online meetings, social media, and hands-on activities.

Individuals have preferences on which method(s) work best for them; however, there are constraints with each method. For example, time and money are required for conferences, field days, and demonstrations. Emails are useful but need a flag or alert of its importance so that it does not get lost. Websites need to be user-friendly so that farmers can find desired information quickly and efficiently. Farmers if needed, should be more demanding of RACs if they have difficulty getting information they seek because the projects are conducted for their benefit.

The lack of awareness of the RAC program extends beyond just farmers. From the National Institute of Food and Agriculture administrators to the general public, many people are unaware of the RAC program, its contributions, projects, and potentially useful results. Concerted efforts and strategies to dramatically enhance communications are needed: 1) within each RAC (among the various groups outside the annual meetings); 2) across the RACs to share priorities, initiatives, and project results; 3) within the host institution (beyond the Director's immediate supervisor); 4) within the National Institute of Food and Agriculture; 5) with state and federal agencies; 6) with congressional offices; and 7) with the general public.

Lack of succession planning for RAC Directors, given pending retirement plans

The review team was made aware of the imminent and pending retirement of all current Directors of the RACs over the next couple of years. Of concern was that the review team did not hear of specific plans for succession of the Directors either within the RAC

Farmers harvesting clams in Washington State. Credit: Kristian Marson

committees or from the host institutions. In interviews with current Directors, it became clear that the transition to a new Director is most successful when there is an extended period of overlap between the outgoing and incoming directors, ideally of at least one complete program planning and funding cycle. It is imperative that detailed succession planning be undertaken in the near future with active engagement of the host institution with the Board of Directors, with the Industry Advisory Council, and with the National Institute of Food and Agriculture for each RAC.

The position announcement, designation of responsibilities other than the RAC directorship, the interview process, initial screening of applicants, and final choice of director must be based on full recognition of the need to meet both the university's expectations but also fully meet those of the RAC program. For RACs that have been performing well and supported by the host institution, succession planning should include retaining the current administrative office and staff and recruit the new Director at the current host institution.

The need to improve host institution support for the RAC

Host institution support depends on a few individuals at the university, often at the level of the department chairperson or the dean. The Directors are evaluated by their host institution supervisors who may not be familiar with aquaculture or the RAC itself. The individuals in these university administrative positions change often and their replacements may not be familiar with either the RAC or with aquaculture farms in their state or region.

Comments from those interviewed by the review team indicated that many believed that the host institutions should provide better support specifically with website development and maintenance and also with publicizing outcomes and impacts of the various RAC projects funded.

Farmer crowding rainbow trout for harvest. Credit: National Aquaculture Association

Comparison of Investments with Objectives of the National Strategic Plan for Federal Aquaculture Research, 2014-2019, of the National Science and Technology Council

The National Strategic Plan for Federal Aquaculture Research was developed by the Interagency Working Group in Aquaculture under the National Science and Technology Council as an updated component of the National Aquaculture Development Plan.

The strategic goals were to:

- Advance understanding of the interactions of aquaculture and the environment.
- Employ genetics to increase productivity and protect natural populations.
- Counter disease in aquatic organisms and improve biosecurity.
- Improve production efficiency and well-being.
- Improve nutrition and develop novel feeds.
- Increase supply of nutritious, safe, high-quality seafood and aquatic products.
- Improve performance of production systems.
- Create a skilled workforce and enhance technology transfer.
- Develop and use socioeconomic and business research to advance domestic aquaculture.

Relevant to the RAC program, the Plan also stated that "while there is currently excellent research and technology development ongoing in federal, university, and private research facilities, the plan recognizes that multidisciplinary research and coordination of federal research programs are needed to improve competitiveness, production efficiency, economic viability, and long-term environmental sustainability through advances in genetics, nutrition, health, and technology."

The federal aquaculture programs were to provide funds to: 1) support effective Extension education functions that help translate and deliver new knowledge for the public good and facilitate farm-level adoption of new technology;
2) fill research gaps in a sector dominated by small companies with limited ability to conduct research and advance farming and societal interests; and
3) support rigorous science for policy, regulatory, and permitting decisions that allow sustainable aquaculture development. Scientific knowledge is required to understand the environmental effects of private and public sector aquaculture and mitigation options for sustainable development that are acceptable to the public.

> Over the years, the RACs have been one of very few federal aquaculture programs that address regional priorities for farms in inland areas, coastal marine waters, and across the wide diversity of species, systems, and regulations.

Farmers preparing net pens for sablefish stocking.
Credit: National Aquaculture Association

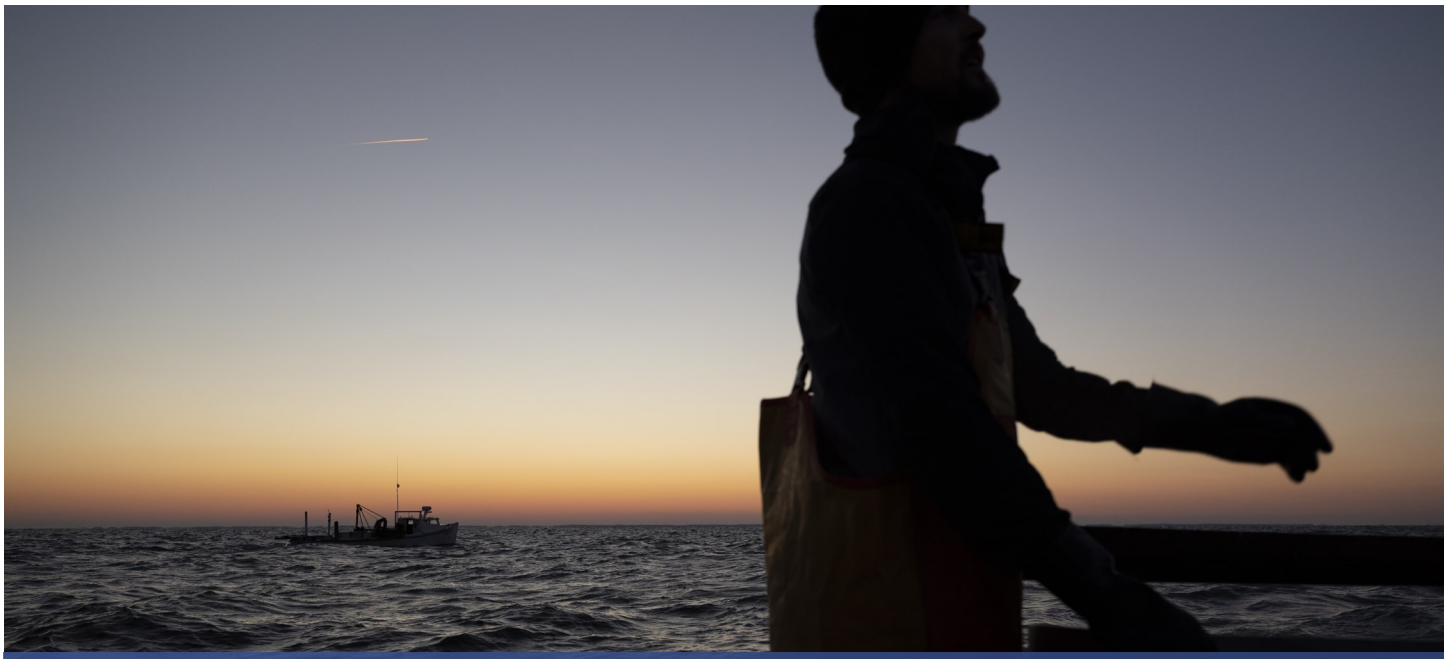
Farmers harvesting bait minnows using seine net. Credit: Matt Smith

The RAC program has clearly addressed each of the nine strategic goals in the 2014-2019 plan including workforce development and training, consumer education, economic and marketing studies, and regulatory-related projects.

The review team found that the RACs, as a combined national program, have clearly addressed each of the nine strategic goals in the 2014-2019 Plan including workforce development and training, consumer education, economic and marketing studies, and regulatory-related projects. The scope and breadth of research topics funded from 1987 to 2020 presented in Table 22 clearly indicate the relationship to the strategic goals of the Plan and support for Extension education and policy-related issues. The RACs have further developed several interregional projects, including aquaculture effluents, viral hemorrhagic septicemia, national aquaculture Extension conference, and coordination for new animal drug approvals. Over the years the RACs have been one of very few federal aquaculture programs that address regional priorities for farms in inland areas, coastal marine waters, and across the wide diversity of species, systems, and regulations.

Table 29 provides a list of projects started in 2014 and completed by 2021 for each Center that demonstrate the wide diversity of topics that align with strategic goals of the Plan and targeted areas of funding.

Interviews with the RAC Directors revealed that all were familiar with the Plan. Several directors stated that their program planning and implementation processes aligned with the goals in the Plan. All RACs relied on farmers to set regional priorities but this review showed that farmer priorities were well aligned with the Plan. For the period 2014-2019, the National Institute of Food and Agriculture did not require that the RACs report how funded projects addressed the Plan's goals. Doing so in the future will increase visibility of the RACs among federal agencies as important contributors to the implementation of the Plan.



RECOMMENDATIONS

Overarching recommendation

Increase the annual budget of the RAC program to $20 million per year, with periodic adjustments for inflation

The primary, overarching, recommendation is to increase annual funding for the RAC program. The need for additional funding was reported by nearly all respondents but was also manifested in comments that referred to the need for expansion of farmer-driven support for aquaculture in the regions. The RAC program has essentially been level funded since its inception, and inflation has eroded the purchasing power of the funding available to support the farmer-driven, applied research and Extension work of the RACs that have produced outstanding impacts. A concerted, continuous effort needs to be mobilized across all levels of the RACs and their stakeholders to avoid further erosion of funding for the program and to provide the support to farmers that is essential for continued growth of aquaculture farming.

Additional funding would support larger numbers of projects funded each year over longer periods of time to address more problems than is currently possible. Additional funding could also be used to increase Extension capacity, as needed, in the RACs.

"The RAC Program is practical. We're not trying to find a new particle in an atom. Billions? Spend a few million to find better ways to make best use of our precious water, to have food to eat."

- aquaculture farmer

The administrative structure is in place to handle a larger volume of grants than can be funded with the very limited funds currently available.

The RAC program needs to have a higher profile in Washington, DC. The National Institute of Food and Agriculture should support inclusion of the Regional Aquaculture Centers in the President's annual budget request to the U.S. Congress and promote the RACs within the U.S. Department of Agriculture and to the U.S. Congress.

> The RAC program has essentially been level funded since its inception, and inflation has eroded the purchasing power of the funding available to support the farmer-driven, applied research and Extension work of the RACs that have produced outstanding impacts.

The host institution should take an active role in advocating increased funding for the RACs through the university congressional affairs office and the state's congressional delegation. Table 37 lists additional suggestions related to increasing funding for the RACs for consideration by the RAC.

Secondary Recommendations

Improve effective communications internally and externally

The RACs were described as a "best kept secret." The U.S Department of Agriculture-National Institute of Food and Agriculture and the RACs need to share and disseminate program accomplishments and impacts widely.

Larval channel catfish. Credit: Les Torrans

The review team heard a wide variety of comments from many individuals about the need to enhance communication from the RACs to many different groups, including to:

- Subcommittee on Aquaculture.
- U.S. Department of Agriculture-National Institute of Food and Agriculture.
- Congressional offices.
- State and federal agencies.
- The general public.
- Farmer associations in the region.
- Farmers across each region.
- Researchers.
- Extension personnel.

RACs need to promote their centers. More outreach is needed to expand awareness of the RAC program and its benefits to aquaculture farms. Websites need to be improved and upgraded with real-time information, new projects approved, results of recently completed projects, publications (scientific and Extension), and Extension materials (fact sheets, infographics, videos, newsletters). Farmer testimonials, farmer stories and experiences with RAC projects are needed to better relate to and connect with the farmer community, and ensure their voices are heard.

Suggestions for improving communication include:

- Working through farmer associations.
- Working through the Extension community.
- Increase the scope and frequency of email communications.
- Revise and improve RAC websites.
- Increase social media presence.

The U.S. Department of Agriculture-National Institute of Food and Agriculture website should include an updated and more prominent home page for the RACs to raise the visibility of the program within the National Institute of Food and Agriculture and its partner communities.

The websites of the individual RACs need to be updated and modernized with an emphasis on making key information readily discoverable.

At a minimum, the following types of information should be posted on the RAC website:

- Lists of aquaculture farm priority needs following each annual meeting, indicating which were funded by the RAC and which priority needs were not funded.
- New projects funded, with starting and ending dates.
- Accomplishments reported in each annual report.
- Deliverables from each project as they are produced, including journal articles, fact sheets, infographics, videos.
- Adoption of project results.
- Impacts identified.

These announcements should be made by the National Institute of Food and Agriculture and by individual RAC administrative offices.

Press releases need to go out on all new projects funded and of key results and accomplishments reported by principal investigators.

Increased communication is needed within individual RACs and across each region. Information relevant to farmers must be disseminated using a variety of social media to inform farmers of new information and recent website postings.

Greater communication is further needed among RACs. There was strong interest among the various committee members of each RAC in learning more about the work and initiatives of their counterparts in other RACs. Organizing one or more virtual meetings of chairs or other members of committees across all the RACs would be beneficial.

RAC research findings with relevance to regulations, policies, and laws that impact aquaculture farmers and development should be communicated directly to regulators and policymakers at the appropriate level.

Extension agent training farm technicians in hatchery practices. Credit: CTSA

A cross-RAC committee should be formed through the National Coordinating Council to design and implement a comprehensive communications strategy that more effectively communicates activities, outputs, and impacts of the RACs.

Additional suggestions offered by interviewees for improving communications from the RACs are included in Table 38.

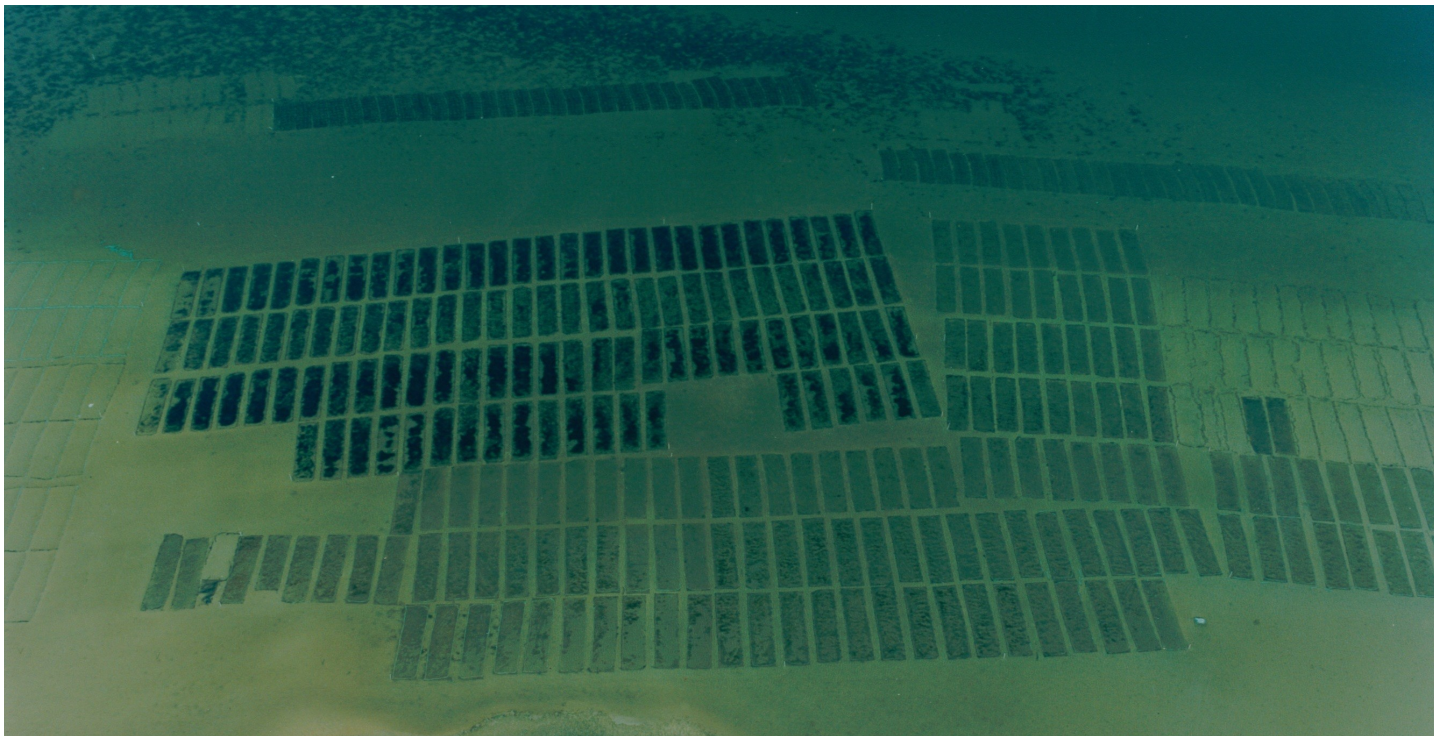
Address the continued loss of Extension capacity for aquaculture

A key to success of the RAC model and program is the full integration of Extension personnel from project inception through implementation and adoption of research results. Concerns were expressed across all RACs of the loss of Extension support for aquaculture. Aquaculture Extension positions were either not being filled or were being diluted by adding substantial research expectations to what previously were full-time Extension positions. The problem is more acute in some RACs than others, but even in regions with more Extension support, concerns were expressed about the extent to which those positions would be continued in the future. While the RACs did not create the problem of the erosion of Extension support, they understand clearly the problem posed for aquaculture development in their region.

Concerns were expressed across all RACs of the loss of Extension support for aquaculture.

Thus, each RAC should devote attention to developing an effective strategy to cope with this problem. It needs to be on the agendas for discussion by the Boards of Directors and the Technical Committee. At least one RAC has already formed a committee that is examining strategies to cope with diminished Extension support in their region, and other RACs should consider approaches that direct attention to strategies to address this growing problem.

A key component of such a strategy would involve meetings and discussions with the Cooperative Extension Directors of land-grant universities throughout the region and with upper administration to seek solutions. Specific strategies and plans need to be developed and implemented in the near future. Table 39 lists additional suggestions related to addressing the loss of Extension capacity.



Aerial photo of clam farm plots in coastal waters of Virginia. Credit: Gef Flimlin

Freshly harvested hybrid striped bass being packaged for sale. Credit: National Aquaculture Association

Initiate succession planning for Directors, with full engagement of U.S. Department of Agriculture-National Institute of Food and Agriculture, Board of Directors, Industry Advisory Council, Technical Committee, and the host institution

The U.S. Department of Agriculture-National Institute of Food and Agriculture should take steps in the very near future to strongly recommend that a succession plan be developed for each RAC by tasking a specific committee that includes one or more representatives of the host institution, the current director, and at least one representative from the Board of Directors, Industry Advisory Council, and Technical Committee, as appointed by the current RAC Director. The succession plan should preferably include provisions for the incoming director to overlap for at least one complete program planning and funding cycle with the current Director to ensure a smooth transition. The succession plan should ensure stability of RAC administration for those RACs that have been performing well by focusing on retaining the current administrative office and staff and filling the Director position at the current host institution.

Table 40 lists additional suggestions for the National Institute of Food and Agriculture related to succession planning for the RACs.

Increase engagement of U.S. Department of Agriculture-National Institute of Food and Agriculture with host institutions and with the RACs

The U.S. Department of Agriculture-National Institute of Food and Agriculture needs to increase engagement with host institutions to reaffirm the critical role of U.S. Department of Agriculture support for the RACs, the Directors, and the administrative staff. The deans of the colleges under which the RACs function are key individuals for continued, essential support for the RACs, as is the upper administration of each host institution. An annual meeting with the deans should be organized by the National Institute of Food and Agriculture national program leader to update the deans on notable successes and accomplishments, challenges, and future opportunities. Notable successes should be shared.

The National Institute of Food and Agriculture's strong support for the RACs is critical to continuous and future support from the host institution.

Such engagement would include increasing awareness of how aquaculture fits into the overall administrative programs at the host institution, both the academic programs and support from aquaculture farms for the host institution.

The National Institute of Food and Agriculture and center Directors should use the National Coordinating Council forum to identify mutually agreeable actions. The National Institute of Food and Agriculture should collaborate with the RACs on defining the effective role of Extension personnel in RAC projects. The National Institute of Food and Agriculture needs to be engaged in annual program planning meetings and other meetings of the RACs to improve understanding of the opportunities and challenges of each RAC. Table 41 lists additional suggestions for the National Institute of Food and Agriculture related to increasing engagement of the National Institute of Food and Agriculture with individual RACs, host institutions, and RAC committees (Boards of Directors, Industry Advisory Council, Technical Committee).

Streamline project development and implementation process

The contracting and funding processes should be streamlined to reduce the time from problem identification to initiation of the research and Extension activities. This would include streamlining the proposal review process as well as reporting. Many of the projects funded by the RACs address fairly short-term and immediate needs of aquaculture farmers. Thus, getting projects started as early as possible will decrease the time to solutions to problems faced by aquaculture farmers.

An onboarding process should be developed that includes an orientation for new Industry Advisory Council and Technical Committee members on RAC procedures and specific expectations and responsibilities for each new member. It is critical to ensure that all economically important species groups within a region are represented and supported by their RAC, with their interests balanced with the major species groups in the region. Project oversight should be continued through monitoring progress of projects. Evaluation systems need to be put in place to track adoption and impacts over time from RAC-funded projects. Brief surveys of farmers during annual association meetings can be used to document adoption of new practices by farmers as one component of an ongoing evaluation system. Table 42 lists additional suggestions related to improving operational effectiveness of the RAC program.

Farmer placing hybrid catfish eggs into hatching jar.
Credit: SRAC

Address dilemma related to allowing Facilities & Administration/Indirect Costs in the RAC program.

The current authorization language of the RAC program prohibits universities from charging overhead, often referred to as either “Facilities & Administration” or “Indirect Costs.” The review team explicitly asked interviewees their views on whether the prohibition on paying overhead should be changed. Responses from interviewees clearly revealed that there are strongly opposing views on this issue across the various groups interviewed. Universities clearly prefer to receive overhead costs.

Seaweed farmer harvesting sugar kelp. Credit: Maine Aquaculture Association

In initial interviews with RAC Directors, less than half mentioned the lack of overhead as an issue at their institution, but over the course of the review, more Directors began to mention it, likely reflecting pressure from their institutions to receive payment for overhead. Of the members of Boards of Directors, 30% said that the lack of overhead was an issue, another 20% said that it was an issue of upper administration but that their university would continue to support the RAC despite the lack of overhead, but the other 50% of Board members did not mention overhead as an issue.

Farmers (Industry Advisory Council members and those not directly involved in the RACs) were strongly opposed to paying overhead. The host institution's support for the RAC is that of office space for the Director and an administrative person, not for research facilities. Universities that participate in research projects clearly need access to university research facilities, but not necessarily those of the host institutions. Farmers support funding going directly to the research and Extension projects, not into general university accounts.

Members of the Technical Committees interviewed were also not supportive of overhead payments. No Technical Committee member interviewed could identify a specific researcher or Extension person who was prevented from submitting a proposal or who declined to submit a proposal because of the lack of overhead payment. Many Technical Committee interviewees did mention that their universities wanted overhead payments to be made, but Technical Committee members feared that paying overhead would reduce the funding available to do the work that the project required. An especially strong concern was that overhead payments would be made allowable but without an increase in overall funding. In that case, the amount of funding available for projects would be reduced further from the already very low current levels.

The strong opposing viewpoints within the RAC community (host institutions, Boards of Directors, Industry Advisory Councils, and Technical Committees) on this issue is a conflict that RACs should begin to address. Meetings need to be scheduled within each RAC committee and across the committees to discuss strategies for arriving at a resolution that is acceptable to all. It is not in the interest of the RACs for farmers, scientists, and universities to have differing positions on this issue. Table 43 lists additional suggestions related to the dilemma of indirect cost (overhead) payments to universities.

CONCLUSION AND FUTURE OUTLOOK

The future of the RACs and the fulfillment of their bold mission depend on increased funding and the commitment and desire of aquaculture research and Extension personnel to solve real-world industry needs.

The RACs were created in 1987 as an innovative model to mobilize research and Extension expertise to enhance viable and profitable U.S. aquaculture production for the benefit of consumers, farmers, service industries, and the American economy. The RAC model explicitly addresses the substantial variation in aquatic species, farming practices, and research and Extension needs across geographic regions of the U.S. by creating five regional centers charged with addressing the priority needs of aquaculture farmers in each region.

The RAC model is unique among federal programs. It may be the only federally-funded program that is driven by farmers to annually respond to priority needs. The RAC structure is based on grassroots participation and engagement of farmers at every stage of project development, from the initial identification of priority needs, to project monitoring and implementation through to project completion. The strong commitment of each RAC to the support and development of commercial aquaculture in each region is an important factor that has contributed to fulfilling the RAC mission.

The success of the RAC model in generating strong impacts on farms has been further enhanced by its requirement for the formation of collaborative, interdisciplinary, and multistate teams that explicitly include researchers, Extension personnel, and farmers. Problems faced by aquaculture farmers rarely are simple, one-dimensional problems, and the identification of effective and feasible solutions requires teams composed of individuals with diverse skill sets and perspectives.

> The RAC program exemplifies an early pioneering version of the public-private partnership concept that has become popular in recent years.

Individuals interviewed by the review team mentioned that the RAC is one of the best programs ever conceived in the country related to the way it jointly engages farmers, researchers, and Extension personnel in efforts targeted towards solving farmer problems and moving U.S. aquaculture farming forward. The RAC program exemplifies an early pioneering version of the "public-private partnership" concept that has become popular in recent years.

The structure of the RACs is an important factor that has contributed to its ability to fulfill its mission. The RAC committee structure and the operational processes of identifying aquaculture farm priorities, review and discussion among farmers, researchers, and Extension personnel are mechanisms that build teamwork and capacity through networking and collaboration among researchers, Extension personnel, and farmers within the region.

The RAC model has implemented a degree of ongoing scientific and stakeholder scrutiny and oversight that is unparalleled in other grant programs. The direct involvement of farmers, the project reporting requirements, annual evaluations, and consequences for under-performing projects impose a level of scrutiny unlike that of other grant programs.

The diverse characteristics of projects funded by the RACs are exemplified by the portfolio of projects funded. Projects have addressed the needs of more than 70 species of aquatic animals and plants (including all major aquaculture species) and integrated efforts across more than 45 subject matter areas and academic disciplines to solve problems of aquaculture farmers. The RAC effort included an estimated 1,283 participants at 170 distinct institutions that included 1862 and 1890 land-grant universities, non-land grant universities, state and federal agencies, farmers, and non-governmental organizations.

Strong, widespread support for continuation and strengthening of the RAC program was evident throughout the review. Farmer testimonials praised the unique aspects of the program that made it unlike any other federal aquaculture program in the U.S. in that it empowered direct farmer participation and representation to solve priority needs of aquaculture farmers.

Developing production methods for Koran angelfish, a novel ornamental species. Credit: University of Florida

Farmer harvesting clams in Willapa Bay, Washington. Credit: Jada Pearson

> Individuals interviewed by the review team mentioned that the RAC is one of the best programs ever conceived in the country related to the way it jointly engages farmers, researchers, and Extension personnel in efforts targeted towards solving farmer problems and moving U.S. aquaculture farming forward.

Those interviewed by the review team listed many RAC-funded projects that farmers considered to have been impactful to U.S. aquaculture. The examples included impacts to major sectors of U.S. aquaculture but also to the development of new species sectors as a result of RAC-funded projects that made breakthroughs in culture methods to close life cycles and develop successful farming practices for new species. The review team selected a few examples of impactful projects and developed estimates of the return on investment and the economic contributions and impacts for these examples.

The estimated returns on the investment were found to be very high in these examples with substantial (ranging from millions to billions of dollars of total economic impact and thousands of jobs) impacts to the U.S. economy. This exercise, although limited to a few examples, underscores the value of the RAC model and explains the strong support that was expressed throughout the review.

The strong impacts on the economy occurred despite the very limited funding for the RAC program. A key finding of the review was that the RAC program is dramatically underfunded. There was universal agreement that the RAC program needs to be continued but with increased funding. Most also strongly voiced the need for more RAC support to advance aquaculture in the U.S. through increased funding. With more resources the program could be even more effective than it has been.

The RAC program has fallen behind other federal aquaculture programs despite its unique and critical role in advancing U.S. aquaculture. With the annual loss of purchasing power from inflation and increasing costs of research and salaries, the trajectory of continued level funding will eventually become unsustainable. Action is needed now to reverse the trend and increase investment in the RAC program.

A renewed interest in aquaculture has become evident across the U.S. This increased interest is reflected in farming new species, in the role of aquaculture in food security, in developing a more climate-resilient nation, and to support rural economies in the U.S. Expansion of the highly effective RAC program would address high priority administration issues related to rural economies, jobs, resilience, education, and food security.

The future of the RACs and the fulfillment of their bold mission depend on increased funding and the commitment and desire of aquaculture research and Extension personnel to solve real-world aquaculture farm needs. The challenges and opportunities are ever-present for aquaculture advances in the U.S., and the RACs have demonstrated their value in each region. Recommendations and suggestions presented in this review are intended to further strengthen the effectiveness, value, and impact of the RACs into the future.

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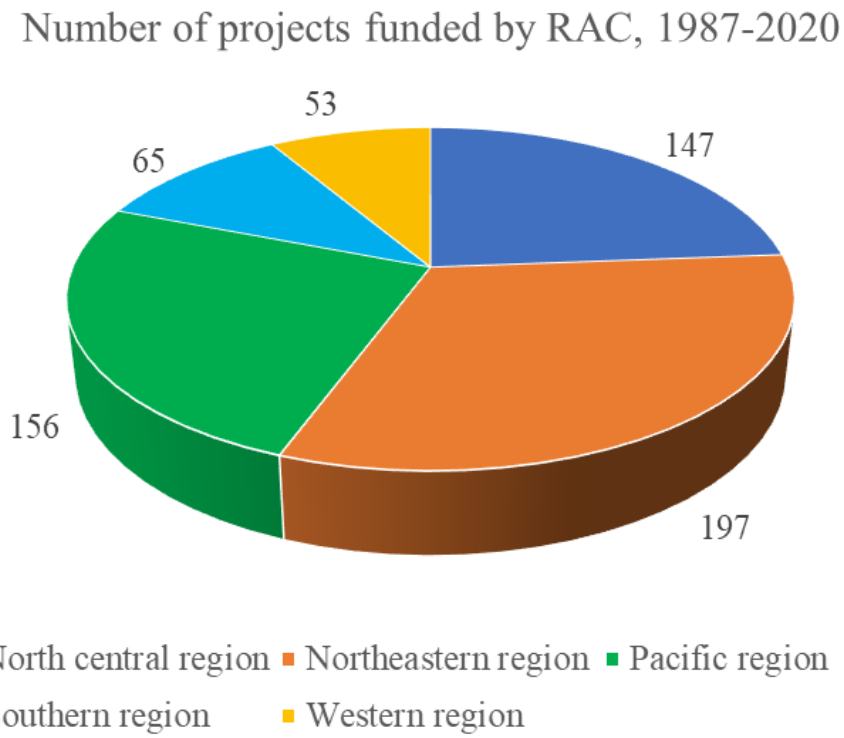
Section Image Credits

Table of Contacts - Farmer in trout raceway. Credit: Keri Rouse
Figures and Tables (pages 4 and 5)- Floating fish feeder on pond. Credit: Keri Rouse
Tables (pages 6 and 7) - Oyster seed in floating upweller system. Credit: National Aquaculture Association
Executive Summary - Kampachi swimming in a net pen. Credit: CTSA
Introduction - Catfish feed research. Credit: SRAC
Methods - Farmer incubating eggs in hatchery. Credit: Keri Rouse
Finding - Farmers holding sturgeon in tank. Credit: Ken Beer, The Fishery, Inc.
Results - Oyster farmer on boat. Credit: Keri Rouse
Conclusions and Future Outlook - Farmers with catfish in seine net. Credit: Les Torrans

FIGURES

Figure 1. RAC investments by number of projects (1a) and number of participants (1b).

a)



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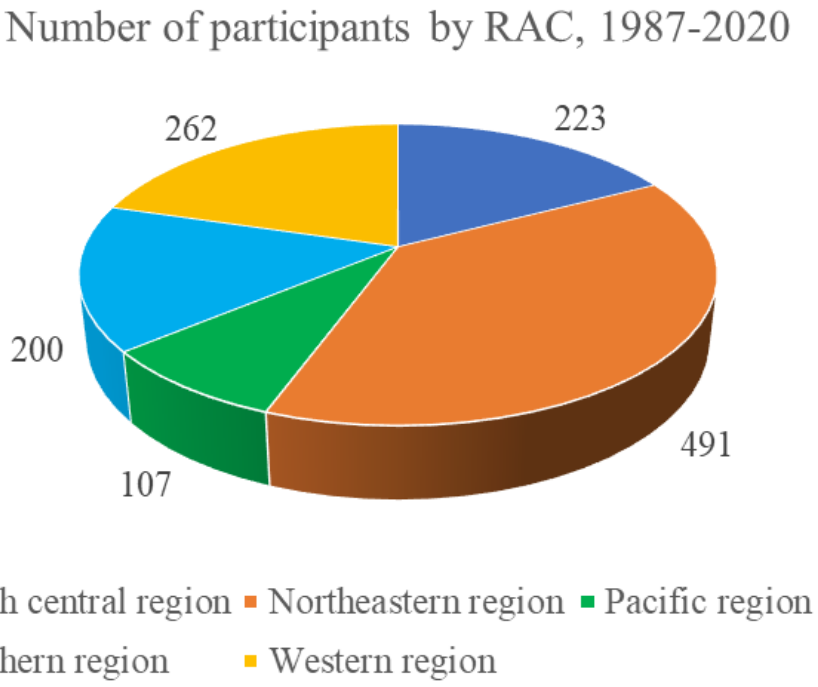
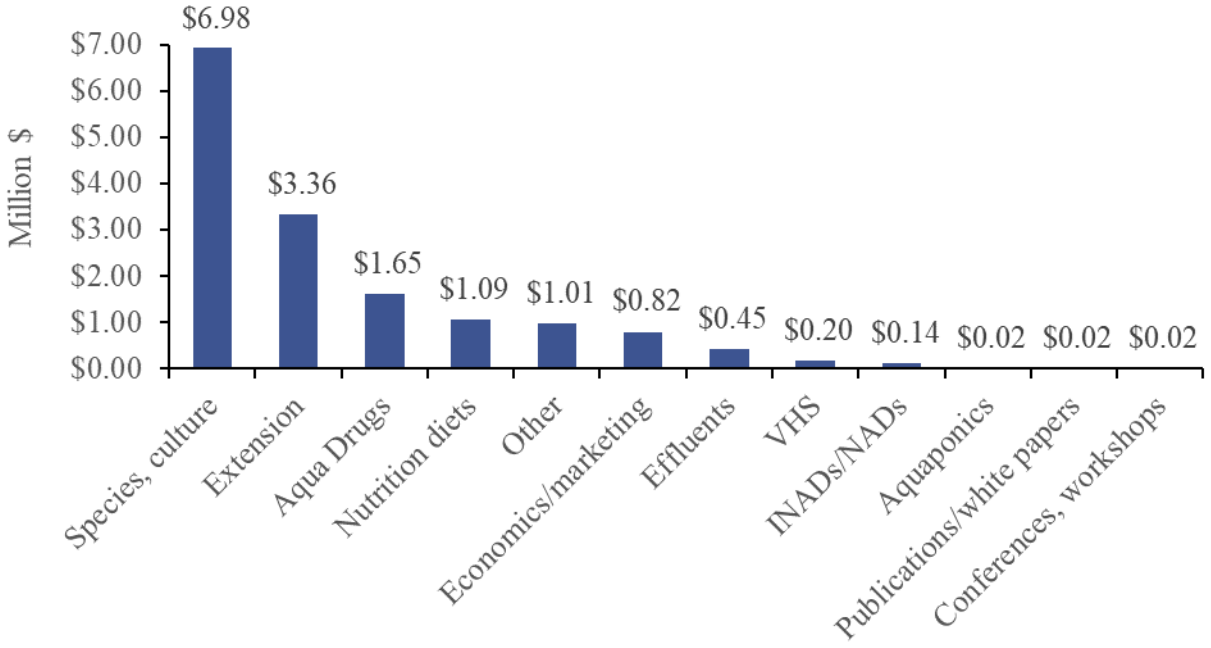


Figure 2. Projects funded by subject matter by RAC, 1987-2020.

a) North central regional center



b) Northeastern regional center

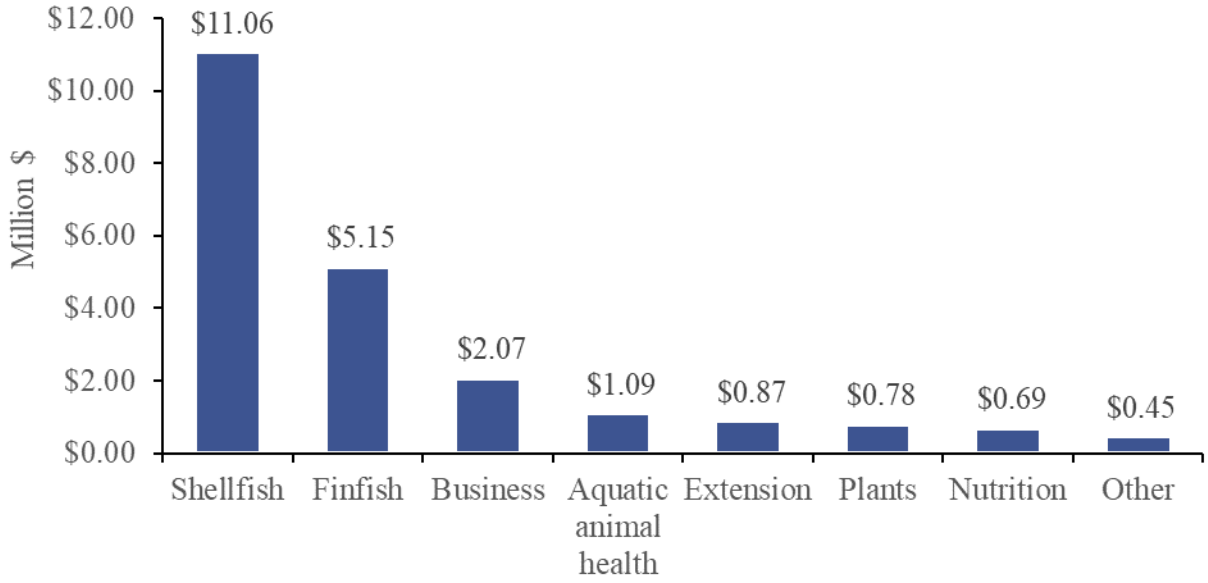


Figure 2. Projects funded by subject matter by RAC, 1987-2020. (continued)

c) Pacific regional center

d) Southern regional center

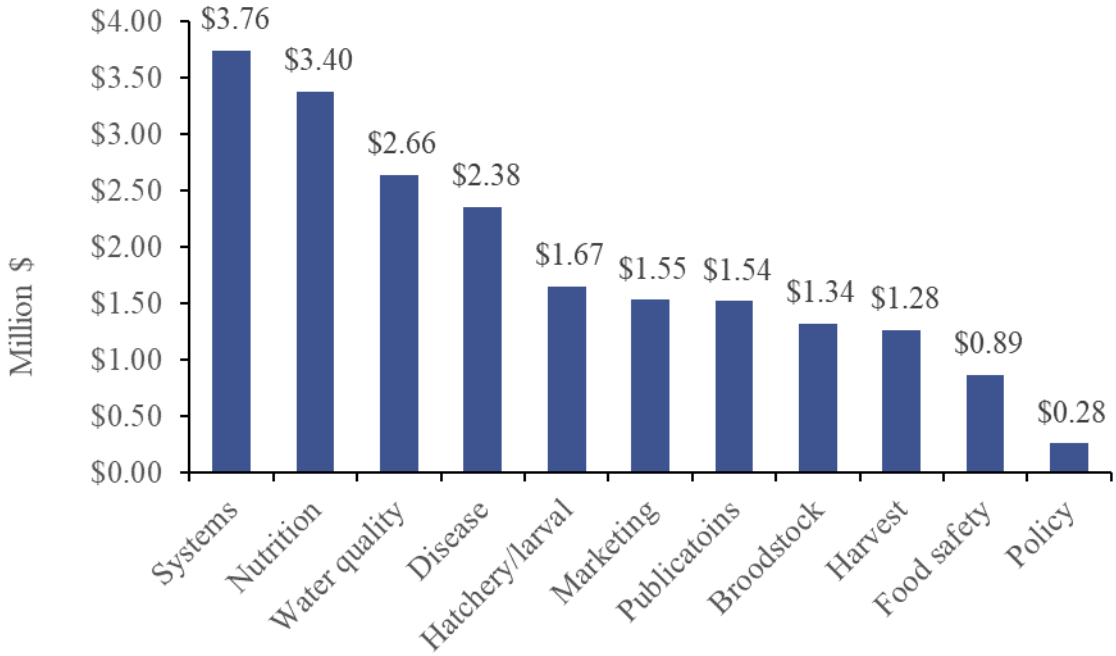
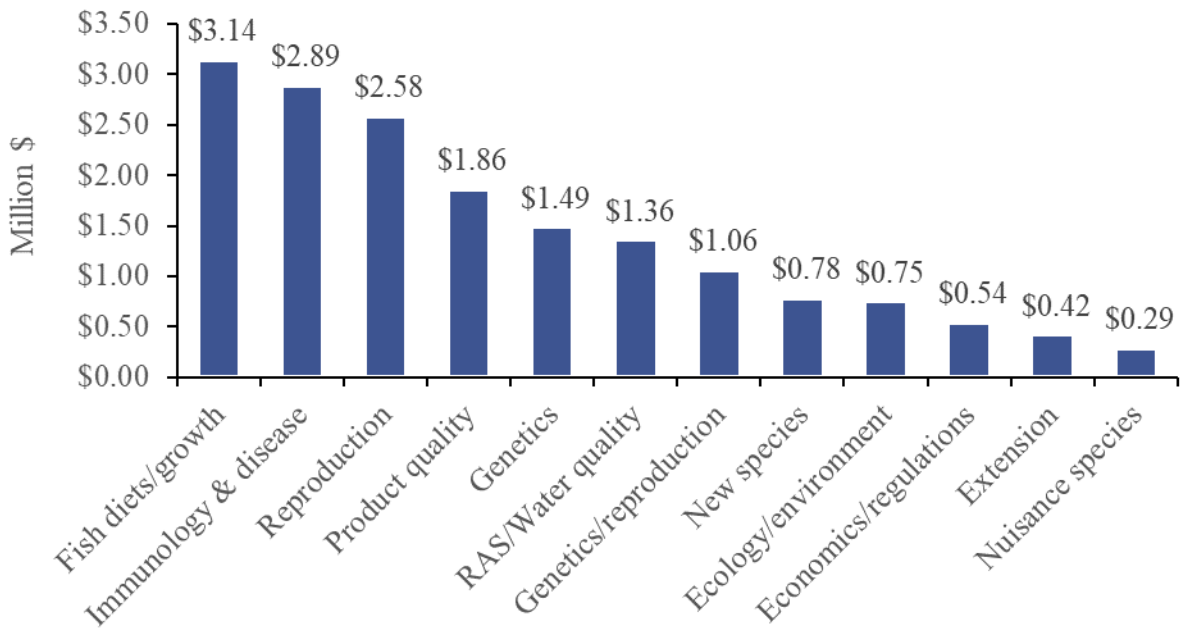


Figure 2. Projects funded by subject matter by RAC, 1987-2020. (continued)

e) Western regional center



TABLES

Table 1. States, territories, and countries that have been involved in at least one RAC project, 1987-2020.

Alabama	Kansas	Northern Mariana Islands
Alaska	Kentucky	Ohio
American Samoa	Louisiana	Oklahoma
Arizona	Maine	Oregon
Arkansas	Republic of Marshall Islands	Outside region[a]
California	Maryland	Republic of Palau
Canada	Massachusetts	Pennsylvania
Colorado	Michigan	Rhode Island
Connecticut	Minnesota	South Carolina
Delaware	Mississippi	South Dakota
Federated States of Micronesia	Missouri	Tennessee
Florida	Montana	Texas
Georgia	Nebraska	Vermont
Guam	New Hampshire	U.S. Virgin Islands
Hawai'i	New Jersey	Virginia
Idaho	New Mexico	Washington
Illinois	New York	West Virginia
Indiana	New Zealand	
Iowa	North Dakota	

[a]Not specified.

Table 2. Individuals interviewed in the review of the RAC program; representation by RAC, geographic area, species, and expertise/discipline.

Interviewee	Regional center	State/territory	Species	Expertise/discipline
Directors				
Joseph Morris	north central	Iowa	baitfish, walleye, sunfish	ecology, fisheries management
Reginal Harrell	northeastern	Maryland	hybrid striped bass	fisheries, wildlife science, ecology
Cheng-Sheng Lee	Pacific	Hawai'i	milkfish, grey mullet	reproduction/early life history
Jimmy Avery	southern	Mississippi	catfish, crawfish	Extension
Graham Young	western	Washington	salmon	reproductive biology of fish
BOD				
Paul Brown	north central	Indiana	hybrid striped bass, tilapia, trout	nutrition
Jay Harmon	north central	Iowa	swine	agriculture engineer
Puneet Srivastava	northeastern	Maryland	water resources	water resources
Richard Rhodes	northeastern	Rhode Island	sheep	reproductive endocrinology
Nicholas Comerford	Pacific	Hawai'i	forests	soil science
anonymous	Pacific	anonymous	anonymous	anonymous
Keith Coble	southern	Mississippi	agriculture	risk management
Steve Lommel	southern	North Carolina	plants	plant scientist; virologist
Walter Dickhoff	western	Washington	salmonids	reproductive biology
Jeri Bartholomew	western	Oregon	wild Pacific salmon	parasitology
IAC				
Bill Lynch	north central	Ohio	yellow perch	Extension/fisheries management
Dan Vogler	north central	Michigan	trout	aquaculture
Dan Ward	northeastern	Massachusetts	oysters, bay scallops	aquaculture
Brian Gennaco	northeastern	New Hampshire	oysters	aquaculture
John Corbin	Pacific	Hawai'i	general aquaculture	state dept. agriculture
Ron Weidenbach	Pacific	Hawai'i	tilapia	aquaculture
Townsend Kyser	southern	Alabama	catfish	aquaculture
Marty Tanner	southern	Florida	ornamentals	aquaculture
Ken Beer	western	California	sturgeon, largemouth bass, tilapia	aquaculture
Jackie Zimmerman	western	Idaho	trout	feeds/therapeutants/supplier

Table 2. Individuals interviewed in the review of the RAC program; representation by RAC, geographic area, species, and expertise/discipline. (continued)

Interviewee	Regional center	State/territory	Species	Expertise/discipline
Non-IAC[a]				
Margaret Cleveland	north central	Missouri	ornamentals	online marketing
Dave Gollon	north central	Wisconsin	baitfish	aquaculture
Adam Hater	north central	Ohio	sportfish	aquaculture
Stacey Sisk	north central	Illinois	largemouth bass	aquaculture
Aurora Burgess	northeastern	Maine	seaweed	aquaculture
Charlie Conklin	northeastern	Pennsylvania	trout	aquaculture
Brittany Peachey	northeastern	New York	trout	aquaculture
Mike Rice	northeastern	Pennsylvania	ornamentals	aquaculture
Steve Arce	Pacific	Hawai'i	shrimp	breeding
Tom Bowling	Pacific	Hawai'i	ornamentals	hatchery
Neil Sims	Pacific	Hawai'i	kampachi	aquaculture
Jim Wyban	Pacific	Hawai'i	shrimp	genetics
Jim Ekstrom	southern	Texas	hybrid striped bass, redfish	aquaculture
J.B. Hanks	southern	Louisiana	crawfish	aquaculture
anonymous	southern	anonymous	anonymous	anonymous
Margie Saul	southern	Arkansas	baitfish	aquaculture
Tim Rapine	southern	Virginia	oysters	aquaculture
Bill Dewey	western	Washington	shellfish	aquaculture
Craig Elliott	western	California	blue catfish	aquaculture
Bill Engler	western	California	catfish, tilapia	aquaculture
Jeff Hetrick	western	Alaska	shellfish	aquaculture
Linda Lemmon	western	Idaho	trout, sturgeon	aquaculture
Kathleen Nisbet/Muncy	western	Washington	shellfish	aquaculture

[a] Farmers in this category were selected to represent states and species groups that had not been represented in the Industry Advisory Council group, but included some individuals who had served on the Industry Advisory Council in the past and two who were serving at the time of the interviews.

Table 2. Individuals interviewed in the review of the RAC program; representation by RAC, geographic area, species, and expertise/discipline. (continued)

Interviewee	Regional center	State/territory	Species	Expertise/discipline
TC-Research				
Simone Valle de Souza	north central	Michigan	aquaculture	economics
Paul Brown	north central	Indiana	trout, tilapia, bass, yellow perch	nutrition
Elizabeth Fairchild	northeastern	New Hampshire	marine finfish	aquaculture; fisheries ecol. & mgmt.
Daphne Munroe	northeastern	New Jersey	shellfish	shellfish ecology
Harry Ako	Pacific	Hawai'i	moi, mahi mahi, Chinese catfish	agricultural biochemistry
Alan Emerson	Pacific	Hawai'i	snapper, grouper, lobster	NOAA coordinator/ management
Delbert Gatlin	southern	Texas	redfish, tilapia	nutrition
Brian Bosworth	southern	Mississippi	catfish	breeding
Wendy Sealey	western	Montana	trout	nutrition
Brian Small	western	Idaho	trout	physiology
TC-Extension				
anonymous	anonymous	anonymous	anonymous	anonymous
anonymous	anonymous	anonymous	anonymous	anonymous
Dennis McIntosh	northeastern	Delaware	general aquaculture	water quality
Don Webster	northeastern	Maryland	shellfish	aquaculture
Bradley Kai Fox	Pacific	Hawai'i	seriola, milkfish, ornamentals	tilapia physiology
Kelley Anderson Tagarino	Pacific	American Samoa	tilapia, aquaponics	Extension
Michael Schwarz	southern	Virginia	finfish, crustaceans, shellfish	aquaculture
Craig Watson	southern	Florida	aquaculture	Extension
Kevin Fitzsimmons	western	Arizona	tilapia, shrimp, seaweed	phycology/Extension
Jackson Gross	western	California	abalone, seaweed, trout	reproductive ecologist
Other				
Sebastian Belle	northeastern	Maine	salmon	economics
Bob (Skid) Rheault	northeastern	Rhode Island	shellfish	aquaculture
Neal Anderson	southern	Arkansas	baitfish	aquaculture
Mike Freeze	southern	Arkansas	hybrid striped bass, grass carp	aquaculture
Amy Stone	southern	Florida	supplier	supplier
Katie Harris	western	California	trout	aquaculture
Don Kent	western	California	marine finfish	aquaculture
Jim Parsons	western	Washington	salmon, shellfish, sablefish	aquaculture
Jeffrey Silverstein	USDA-ARS	Washington, D.C.	general aquaculture	physiology

Table 3. Number of entities funded in each Regional Aquaculture Center by type of entity, state, and country, 1987-2020.

Metric	North central	Northeastern	Pacific	Southern	Western	Total by row[a]
Entities funded[b] (no.)	44	58	28	41	17	188 (170)
Universities (no.)	31	31	20	38	14	134 (108)
1862[c] (no.)	21[b]	13	10	19	10	73 (50)
1890[d] (no.)	2	2	0	2	0	6 (5)
Non-LGU[e]	8	14	4	16	3	45 (42)
Other universities (<1% funding)	n.a.	n.a.	n.a.	n.a.	1	1 (1)
Agencies (no.)	4	6	10	3	1	24 (24)
Producers (no.)	3	3	0	0	1	7 (7)
Private companies (no.)	3	15	0	0	0	18 (18)
NGO	2	2	2	0	1	7 (7)
Foundations	n.a.	1[c]	n.a.	n.a.	n.a.	1 (1)
Community college	n.a.	1	2	1	n.a.	4 (4)
HBCU[f]	n.a.	1	n.a.	n.a.	n.a.	1 (1)
Within or outside region						
Inside region (no.)	37	54	21	32	16	160
Outside region (no.)	7	4	7	9	1	28
States/territories in region (no.)	12	12	7	15	12	58
Funded in region (no.)	12	12	7	14	9	54
Funded outside region (no.)	7	5	unspecified	10	2	24
Other countries funded	2	0	unspecified	0	1	3

[a] Values in parentheses are those excluding those funded by more than one RAC.
[b] Different campuses in same university system were counted as separate entities.
[c] Land-grant universities created by the Morrill Act of 1862.
[d] Land-grant universities created by the Morrill Act of 1890.
[e] Non-land-grant university.
[f] Historically Black College and University.

Table 4. Number of projects and participants by Regional Aquaculture Center, 1987-2020.

Regional center	Number of projects[a]	Number of participants[b]
North central	147	223
Northeastern	197	491
Pacific	156	107
Southern	65	200
Western	53	262
Total	**618**	**1283**

[a]Number of projects vary among RACs due to differences in size and length of projects per RAC.
[b]Participants include scientists, Extension personnel, farmer advisors, aquaculture farmers, non-funded collaborators, and others.

Table 5. North central regional center spending[a] by institution, 1987-2020.

Institution	Amount ($)	Category
Michigan State University	2,315,671	1862[b]
Southern Illinois University-Carbondale	2,174,053	non-LGU[c]
The Ohio State University	2,072,561	1862
Purdue University	1,798,065	1862
University of Wisconsin-Madison	1,341,034	1862
Iowa State University	1,104,191	non-LGU
University of Wisconsin-Milwaukee	1,081,903	1862
University of Wisconsin-Stevens Point	617,233	1862
University of Minnesota-Duluth	506,797	1862
USGS Upper Midwest Environmental Sciences Center	476,684	agency
University of Missouri-Columbia	421,869	1862
University of Nebraska-Lincoln	327,598	1862
Virginia Tech	171,414	1862
Center for Food Integrity	166,000	NGO
North Dakota State University	149,224	1862
Lincoln University	128,975	1890[d]
Lake Superior State University	113,546	non-LGU
Illinois State University	97,822	1862
National Aquaculture Association	85,000	NGO

[a] Host institution spending includes both administrative costs and awards funded to research and Extension personnel at the host institution.
[b]Land-grant universities created by the Morrill Act of 1862.
[c]non-land-grant university.
[d]Land-grant universities created by the Morrill Act of 1890.

Table 5. North central regional center spending[a] by institution, 1987-2020. (continued)

Institution	Amount ($)	Category
Freshwater Fish Farms of Ohio	80,050	producer
University of Illinois Urbana-Champaign	77,798	non-LGU
USGS Northern Rocky Mountain Science Center	76,500	agency
Aqui-S New Zealand	60,000	private
Pittsburg State, Kansas	53,000	non-LGU
University of Wisconsin Extension	52,560	1862
Kansas State	45,199	1862
South Dakota State	28,200	1862
Illinois Natural History Survey	22,725	agency
University of Wisconsin-Superior Sea Grant Institute	22,000	1862
Illinois-Indiana Sea Grant Purdue University	15,602	1862
Bay Port Aquaculture	13,834	producer
Transferee Laboratory, CANTEST Ltd.	12,100	private
Paragon Aquaculture	10,536	producer
University of South Dakota	8,500	non-LGU
University of Illinois, Illinois-Indiana Sea Grant	7,000	non-LGU
Mississippi State University	5,000	1862
University of Arizona	4,500	1862
University of Maryland	3,700	1862
University of Arkansas at Pine Bluff	3,005	1890
Aquaculture Bioengineering Corp.	2,500	private
Minnesota Dept. of Agriculture	2,400	agency
N.A. Fish Farmers Coop	2,400	producer
Auburn University	950	1862
Notre Dame University	323	non-LGU
Total institutions in region (number)		37
Total institutions outside region (number)		7
Total 1862 universities (number)		21
Total 1890 universities (number)		2
Total non-LGU (number)		8
Total private company (number)		3
Total producer (number)		4
Total agency (number)		4
Total NGO (number)		2
Total entities (number)		**44**

Table 6. Northeastern regional center spending[a] by institution, 1987-2020.

Institution	Amount ($)	Category
University of Rhode Island	2,468,815	1862[b]
University of Maine	2,342,267	1862
Rutgers University	2,117,043	1862
University of Maryland	2,041,793	1862
Marine Biological Laboratory	1,734,764	private
University of New Hampshire	1,434,137	1862
University of Connecticut	1,421,847	1862
Roger Williams University	1,056,193	non-LGU[c]
University of Delaware	790,128	1862
Cornell University	686,613	1862
Stony Brook University New York	670,125	non-LGU
Delaware State University	602,286	1890[d]
NRAC-Massachusetts	547,500	non-LGU
Maine Aquaculture Innovation Center	320,509	foundation
New Jersey Medical School	296,190	non-LGU
Martha's Vineyard Shellfish Group	269,749	NGO[e]
Tesla Laboratories, Inc	250,000	private
USDA ARS	219,832	agency
Ward Aquaculture Farms Massachusetts	218,084	producer
Pennsylvania State University	200,000	1862
USDA APHIS	189,732	agency
Aquatechnics, LLC, CT	178,694	private
University of Southern Maine	156,900	non-LGU
Center of Marine Biotechnology, University of Maryland	138,500	1862
Portsmouth SCUBA	117,000	private
University of Pennsylvania	109,954	non-LGU
SUNY - Brockport	108,994	non-LGU
Maine Cultured Mussels, Inc.	108,000	producer
Salem State College	101,659	non-LGU
NOAA	100,000	agency
Biological Services, Inc.	90,000	private
West Virginia University	89,981	1862

[a] Host institution spending includes both administrative costs and awards funded to research and Extension personnel at the host institution.
[b]Land-grant universities created by the Morrill Act of 1862.
[c]Non-land-grant university.
[d]Land-grant universities created by the Morrill Act of 1890.
[e]Non-governmental organization.

Table 6. Northeastern regional center spending[a] by institution, 1987-2020. (continued)

Institution	Amount ($)	Category
Micro Technologies, Inc.	89,920	private
University of Massachusetts	84,307	non-LGU
Massachusetts Maritime Academy	83,799	non-LGU
Research Foundation, State University of New York	69,965	non-LGU
Sacred Heart University	63,925	non-LGU
University of Maryland Eastern Shores	62,240	1890
NGO	60,000	NGO
Atlantic Cape Community College	50,000	community college
Berkshire Technology Group Inc., Massachusetts	49,720	private
Duquesne Light Company	48,000	private
C&J Associates	46,150	private
E. J. Richardson Associates	36,000	private
Mott Media, Inc.	34,504	private
Michigan State University	27,000	1862
Cheyney University of Pennsylvania	19,901	HBCU[f]
National Marine Fisheries Service	19,500	agency
Bellwether Consulting, Inc.	17,350	private
Greaves Dairy Equipment	12,000	private
University of New England	11,000	non-LGU
Massachusetts Department of Food and Agriculture	10,000	agency
Coastal Plantations International	9,500	private
Rhode Island Commission on Aquaculture	5,000	agency
University of Arizona	4,500	1862
Tufts University	3,945	non-LGU
Spinney Creek Shellfish, Inc.	3,460	producer
Bigelow Laboratory for Ocean Studies	2,849	private
Total institutions in region (number)		**54**
Total institutions outside region (number)		4
Total 1862 universities (number)		13
Total 1890 universities (number)		2
Total HBCUs (number)		1
Total non-LGU (number)		14
Total NGO		2
Total producers (number)		3
Total private, non-farm companies (number)		15
Total foundations (number)		1
Total community colleges (number)		1
Total agencies (number)		6
Total entities		**58**

[f]Historically Black College and University

Table 7. Pacific regional center spending[a] by institution, 1987-2020.

Institution	Amount ($)	Category
Oceanic Institute	6,831,254	agency
University of Hawai'i at Manoa	3,659,677	1862[b]
College of Micronesia	1,839,401	non-LGU[c]
University of Hawai'i, Sea Grant College Program	1,571,660	1862
University of Hawai'i at Hilo	1,121,348	1862
Hawai'i Sate Aquaculture Development Program	1,000,747	agency
University of Arizona	973,104	1862
University of Guam	506,269	non-LGU
Guam Department of Commerce	494,109	agency
Palau Community College	459,492	community college
Rongelap Atoll Local Government	442,236	agency
University of Hawai'i, Hawai'i Institute of Marine Biology	428,041	1862
Northern Marianas College	190,550	non-LGU
American Samoa Dept. of Marine & Wildlife Resources	110,300	agency
Pacific American Foundation	100,000	NGO[d]
College of the Marshall Islands	92,156	non-LGU
Palau Aquaculture Cooperative Association	45,000	producer
Pohnpei State Maine Resources	41,464	agency
Michigan State University	40,000	1862
Private Industry Council, Marshall Islands	34,321	NGO
CNMI[e] Department of Land and Natural Resources	30,500	agency
Bureau of Marine Resources	14,832	agency
University of Florida	12,000	1862
American Samoa Community College	11,994	community college
University of California	11,000	1862
University of Maryland	8,949	1862
North central regional center	5,000	agency
University of Arkansas	3,005	1862
Total institutions in region (number)		**21**
Total institutions outside region (number)		7
Total 1862 universities (number)		10
Total non-LGU (number)		4
Total agencies (number)		10
Total community college (number)		2
Total NGO		2
Total entities (number)		**28**

[a] Host institution spending includes both administrative costs and awards funded to research and Extension personnel at the host institution.
[b]Land-grant universities created by the Morrill Act of 1862.; [c]Non-land-grant university.; [d]Non-governmental organization.
[e]Commonwealth of the Northern Mariana Islands (U.S. Commonwealth).

Table 8. Southern regional center spending[a] by institution, 1987-2020.

Institution	Amount ($)	Category
Mississippi State University	3,694,934	1862[b]
Auburn University	3,037,154	1862
Texas A&M University	2,720,027	1862
University of Arkansas at Pine Bluff	2,587,002	1890[c]
Louisiana State University	2,145,127	1862
University of Florida	1,189,115	1862
USDA	748,356	agency
NC State University	745,331	1862
University of Georgia	633,425	1862
Clemson University	440,541	non-LGU[d]
Virginia Tech	422,663	1862
University of Memphis	221,978	non-LGU
University of Tennessee	178,097	1862
University of California at Davis	173,065	1862
University of Mississippi	147,956	non-LGU
Louisiana Tech University	125,000	non-LGU
Kentucky State University	111,019	1890
SC Dept of Natural Resources	84,427	agency
Waddell Mariculture Center	79,301	non-LGU
Texas State University	65,837	non-LGU
College of Charleston	39,973	non-LGU
Texas Tech University	39,478	non-LGU
Southern Illinois University	30,000	non-LGU
University of Southern Mississippi	28,205	non-LGU
East Carolina University	24,994	non-LGU
University of Missouri	24,951	1862
Montana State University	22,050	1862
South Carolina Sea Grant	18,790	agency
Michigan State University	10,518	1862
University of SW Louisiana	9,150	non-LGU
University of Arkansas	8,005	1862
OSU Research Foundation	5,000	1862
Purdue University	4,996	1862

[a] Host institution spending includes both administrative costs and awards funded to research and Extension personnel at the host institution.
[b]Land-grant universities created by the Morrill Act of 1862.
[c]Land-grant universities created by the Morrill Act of 1890.
[d]Non-land-grant university.

Table 8. Southern regional center spending[a] by institution, 1987-2020. (continued)

Institution	Amount ($)	Category
University of Maryland	4,700	1862
University of Arizona	4,500	1862
University of Texas	3,998	non-LGU
University of the Virgin Islands	2,072	non-LGU
Gadsden State Community College	2,000	community college
University of North Carolina	2,000	non-LGU
Tennessee Tech University	1,890	non-LGU
Oklahoma State University	800	1862
Total institutions in region (number)		**32**
Total institutions outside region (number)		9
Total 1862 universities (number)		19
Total 1890 universities (number)		2
Total non-LGU (number)		16
Total agencies (number)		3
Total community colleges (number)		1
Total entities (number)		**41**

[a] Host institution spending includes both administrative costs and awards funded to research and Extension personnel at the host institution.

Table 9. Western regional center spending[a] by institution, 1987-2020.

Institution	Amount ($)	Category
University of California at Davis	3,716,000	1862[b]
University of Washington	3,274,000	non-LGU[c]
University of Idaho	2,529,000	1862
Oregon State University	2,471,000	1862
Washington State University	1,267,000	1862
State and federal	676,000	agency
Colorado State University	671,000	1862
Not-for-profit	496,000	NGO[d]
University of Arizona	444,000	1862
University of Alaska	388,000	1862
Montana State University	345,000	1862
Other universities (< 1%)	313,000	n.a.
Virginia Tech University	202,000	1862
University of Southern California	172,000	non-LGU
Industry	116,000	producer
New Mexico State University	105,000	1862
University of California at San Diego	99,000	non-LGU
Total institutions in region (number)		**16**
Total institutions outside region (number)		1
Total 1862 universities (number)		10
Total non-LGU (number)		3
Total agencies (number)		1
Total producers (number)		1
Total NGOs (number)		1
Total “n.a.” (number)		1
Total entities		**17**

[a] Host institution spending includes both administrative costs and awards funded to research and Extension personnel at the host institution.
[b]Land-grant universities created by the Morrill Act of 1862.
[c]Non-land-grant university.
[d]Non-governmental organization.

Table 10. Funding of species in each Regional Aquaculture Center as compared to the state's rank in importance in region by sales ($), 1987-2020.

	Top species funded by respective Regional Aquaculture Center				
Metric	**#1**	**#2**	**#3**	**#4**	**#5**
North central regional center	Yellow perch	Sunfish	Walleye	Hybrid striped bass	Salmonids
Share of funding	14%	9%	7%	6%	4%
Industry market share in region	3%	Could not calculate		0%	32%
Northeastern regional center	Shellfish	Finfish			
Share of funding[a]	44%	23%			
Industry market share in region	77%	23%			
Pacific regional center	Marine finfish	Ornamentals	Shrimp	Tilapia	Giant clams
Share of funding	18%	12%	11%	7%	5%
Industry market share in region[b]	5%	3%	34%	5%[c]	0%
Southern regional center	Catfish	Baitfish	Ornamentals	Crawfish	Hybrid striped bass
Share of funding	50%	10%	6%	4.8%	4.6%
Industry market share in region[d]	36%	6%	7%	0%	3%
Western regional center	Trout/ salmonids	Sturgeon	Oysters	Other freshwater	Marine finfish
Share of funding	50%	20%	19%	4%	3%
Industry market share in region	26%	3%	35%	8%	0%

[a]Data provided had a category of "shellfish" that represented 11% of all funding as well as categories of "oysters" and "clams;" all shellfish was summed. The "finfish" category accounted for 8% of all funding, but no projects were listed for "trout", that accounts for 18% of all aquaculture sales in the Northeastern region. Ornamentals account for 3% of all sales in the region. The majority of projects funded in the region that identified the species were of marine, not freshwater finfish species.

[b]Algae 39% market share.

[c]Value for total freshwater finfish, of which most is assumed to be tilapia.

[d]Oysters were 23% of sales in 2018 Census, clams 12% of sales, red drum 5%, sportfish 4.5%. Crawfish very likely had much greater sales, but most data were suppressed in the Census for confidentiality reasons.

Table 11. North central regional funding by species, 1987-2020.

Species	Amount ($)	% of total
All[a]	8,485,710	53.8
Yellow perch/nutrition diets and all yellow perch	2,260,217	14.3
Sunfish	1,342,154	8.5
Walleye	1,153,048	7.3
Hybrid striped bass	975,710	6.2
Salmonids	637,742	4.0
Largemouth bass	325,000	2.1
Tilapia	268,791	1.7
Baitfish	261,973	1.7
Crayfish	49,677	0.3
Total	**15,760,022**	**100**

[a]All includes projects that impact either all or at least multiple species.

Table 12. Northeastern regional center funding by species, 1987-2020.

Species	Amount ($)	% of total
All[a]	5,390,716	24.3
Shellfish	2,538,155	11.4
Eastern oyster	2,175,373	9.8
Clams	2,040,492	9.2
Finfish	1,758,468	7.9
Oyster	1,360,309	6.1
Striped bass & hybrid	929,416	4.2
Salmon	798,550	3.6
Lumpfish	599,798	2.7
Green sea urchin	543,584	2.4
Mussels	539,951	2.4
Seaweed	459,403	2.1
Scallops	429,500	1.9
Ornamentals	382,481	1.7
Polychaete	347,715	1.6
Razor clam	346,565	1.6
Black sea bass	291,266	1.3
Cod	253,612	1.1
Flounder	201,296	0.9
Tautog	198,084	0.9
Baitfish	145,457	0.7
Smelt	126,208	0.6
Halibut	123,986	0.6
Marine finfish	57,936	0.3
European oyster	57,366	0.3
Crayfish	56,123	0.3
Shrimp	42,552	0.2
Total	**22,194,362**	**100**

[a]All includes projects that either impact all or at least multiple species.

Table 13. Pacific regional center funding by species, 1987-2020.

Species	Amount ($)	% of total
All[a]	4,539,782	22.6
Shrimp	2,224,905	11.1
Moi	2,064,228	10.3
Marine ornamental	1,460,120	7.3
Tilapia	1,325,933	6.6
Giant clam	1,004,655	5.0
Freshwater ornamentals	924,943	4.6
Pearl oysters	670,831	3.3
Bivalve	520,912	2.6
Coral grouper	442,256	2.2
Amberjack	434,400	2.2
Sponge	393,841	2.0
Macroalgae	390,665	1.9
Rabbitfish	356,342	1.8
Copepod/rotifer	299,876	1.5
Freshwater foodfish	295,576	1.5
Crab	283,018	1.4
Sea Cucumber	263,271	1.3
Opihi	262,839	1.3
Abalone	248,840	1.2
Marine finfish	164,788	0.8
Milkfish	153,810	0.8
Microalgae	117,969	0.6
Mullet	88,700	0.4
Opakapaka	78,000	0.4
Coral grouper	59,644	0.3
Feed related	1,008,266	5.0
Total	**20,078,410**	**100**

[a]All includes projects that impact either all or at least multiple species.

Table 14. Southern regional center funding by species, 1987-2020.

Species	Amount ($)	% of total
Catfish	10,422,000	50.2
All[a]	4,118,000	19.9
Freshwater baitfish	1,610,000	7.8
Ornamentals	1,173,000	5.7
Crawfish	997,000	4.8
Hybrid striped bass	950,000	4.6
Marine baitfish	400,000	1.9
Tilapia	350,000	1.7
Shellfish	330,000	1.6
Trout	251,000	1.2
Goldfish	142,000	0.7
Total	**20,743,000**	**100**

[a]All includes projects that either impact all or at least multiple species.

Table 15. Western regional center funding by species, 1987-2020.

Species	Amount ($)	% of total
Trout/salmonids	8,712,000	50.0
White sturgeon	3,494,000	20.0
Pacific oysters	3,354,000	19.2
Other freshwater fish	744,000	4.3
Marine finfish	541,000	3.1
Other shellfish	355,000	2.0
Tilapia	228,000	1.3
Total	**17,428,000**	**100**

Table 16. Funding by state as compared to the state's rank in importance in region by sales ($) and by number of aquaculture farms, 1987-2020.

	Top states/countries funded by each Regional Aquaculture Center				
Metric	**#1**	**#2**	**#3**	**#4**	**#5**
North central regional center					
Rank by center funding	Wisconsin	Michigan	Illinois	Ohio	Indiana
Rank by 2018 sales ($)[a]	3	8	4	2	7
Rank by 2018 farms (no.)[b]	1	2	3	1	6
Market share (%)[c], sales	15%	7%	10%	16%	8%
Northeastern regional center					
Rank by center funding	Rhode Island	Maine	Massachusetts	New Jersey	Maryland
Rank by 2018 sales ($)[d]	8	1	2	7	3
Rank by 2018 farms (no.)[e]	8	2	1	4	6
Market share (%), sales	3%	41%	16%	4%	16%
Pacific regional center					
Rank by center funding	Hawai'i	Federated States of Micronesia	Guam	Republic of the Marshall Islands	Republic of Palau
Rank by 2019[f]	1	5	2	4	3
Rank by 2018 farms (no.)	1	Data not available			
Market share (%)[g], sales	100%				
Southern regional center					
Rank by center funding	Mississippi	Alabama	Texas	Arkansas	Louisiana
Rank by 2018 sales ($)[h]	1	4	7	6	2
Rank by 2018 farms (no.)[i]	4	6	7	8	1
Market share (%)[j], sales	26%	12%	8%	8%	17%
Western regional center					
Rank by WRAC funding	Washington	California	Oregon	Idaho	Montana
Rank by 2018 sales ($)[k]	1	2	4	3	11
Rank by 2018 farms (no.)[l]	1	2	3	4	10
Market share (%), sales	52%	27%	6%	11%	D

[a]Missouri is #1 in terms of sales in the North Central Region, Minnesota is #5, and Iowa #6.
[b]Nebraska and Minnesota are #4 and #5, respectively, in terms of number of farms.
[c]Missouri has 18% of market share of sales in the North Central Region, and Iowa and Minnesota each have 9%.
[d]Number 4 in sales in the Northeastern region is Connecticut, #5 is New York and #6 is Pennsylvania.
[e]By number of farms, #3 is Pennsylvania and #5 is New York.
[f]FishStatJ database, FAO (2021).
[g]The only sales values listed in the Census of Aquaculture are for Hawai'i in this region. By volume listed in FishStatJ, the major species raised in the Pacific Islands are, in descending order: milkfish, shrimp, spinefoot (rabbitfish), and giant clam, at < 100,000 lb/yr each.
[h]Virginia is #3 in terms of sales in the Southern Region and Florida is #5.
[i]Florida is #2 in terms of number of farms in the Southern Region, Virginia is #3, and North Carolina is #5.
[j]Virginia has 14% of market share of sales in the Southern Region, and Florida has 9%.
[k]Montana developed federal laboratories on fish health and fish technology centers despite not having much commercial production in the state. Colorado is #5 in aquaculture sales in the Western region, but has less research capacity in aquaculture.
[l]By number of farms, Alaska is #5.

Table 17. North central regional spending by state, 1987-2020.

State	Funding Amount ($)	% of total funding
Wisconsin	3,601,950	22.85
Michigan	2,478,068	15.72
Illinois	2,379,398	15.10
Ohio	2,152,611	13.66
Indiana	1,813,990	11.51
Iowa	1,104,191	7.01
Missouri	716,844	4.55
Minnesota	476,680	3.02
Nebraska	327,598	2.08
Virginia	256,414	1.63
North Dakota	151,624	0.96
Kansas	98,199	0.62
Montana	76,500	0.49
New Zealand	60,000	0.38
South Dakota	36,700	0.23
Canada	12,100	0.08
Mississippi	5,000	0.03
Arizona	4,500	0.03
Maryland	3,700	0.02
Arkansas	3,005	0.02
Alabama	950	0.01
Total funding	**15,760,022**	**100**
Total states funded in region (number)		12
Total states funded outside region (number)		7
Total other countries funded (number)		2
Total states, territories, countries funded (number)		**21**

Table 18. Northeastern regional center spending by state, 1987-2020.

State	Funding Amount ($)	% of total funding
Rhode Island	3,530,008	15.97
Maine	3,387,388	15.33
Massachusetts	3,001,868	13.58
New Jersey	2,586,733	11.70
Maryland	2,262,033	10.23
Connecticut	1,868,974	8.46
New Hampshire	1,551,137	7.02
New York	1,535,697	6.95
Delaware	1,392,414	6.30
Pennsylvania	329,855	1.49
Virginia	250,000	1.13
Colorado	145,732	0.66
West Virginia	137,981	0.62
Michigan	61,504	0.28
Ohio	44,000	0.20
Vermont	12,000	0.05
Arizona	4,500	0.02
Total funding	**22,101,824**	**100**
Total states funded in region (number)		12
Total states funded outside region (number)		5
Total entities funded (number)		**17**

Table 19. Pacific regional center spending by state/country/territory, 1987-2020.

State	Funding amount ($)	% of total funding
Hawai'i	12,908,002	65.44
Federated States of Micronesia	1,539,530	7.80
Guam	1,218,607	6.18
Republic of the Marshall Islands	1,155,858	5.86
Republic of Palau	965,618	4.90
Commonwealth of the Northern Mariana Islands	595,668	3.02
American Samoa	291,336	1.48
Outside region	1,050,887	5.33
Total funding	**19,725,506**	**100**
Total states funded in region (number)		1
Total other entities funded in region (number)		6
Total entities funded outside the region (number)		1
Total entities funded (number)		**8**

Table 20. Southern regional center spending by state, 1987-2020.

State	Funding amount ($)	% of total funding
Mississippi	4,517,609	22.67
Alabama	3,039,154	15.25
Texas	2,829,340	14.20
Arkansas	2,667,733	13.39
Louisiana	2,281,277	11.45
Florida	1,196,114	6.00
North Carolina	838,991	4.21
South Carolina	663,042	3.33
Georgia	633,425	3.18
Virginia	426,663	2.14
Tennessee	401,965	2.02
California	173,065	0.87
Kentucky	112,019	0.56
Illinois	30,000	0.15
Maine	27,999	0.14
Missouri	24,951	0.13
Montana	22,050	0.11
Michigan	10,518	0.05
Maryland	9,814	0.05
Indiana	6,996	0.04
Ohio	5,000	0.03
Arizona	4,500	0.02
Virgin Islands	2,072	0.01
Oklahoma	800	0.004
Total funding	**19,925,097**	**100**
Total states funded in region (number)		14
Total states funded outside region (number)		10
Total states funded (number)		**24**

Table 21. Western regional center spending by state, 1987-2020.

State	Funding amount ($)	% of total funding
Washington	4,924,000	27.82
California	4,744,000	26.81
Oregon	2,698,000	15.24
Idaho	2,606,000	14.72
Montana	835,000	4.72
Colorado	671,000	3.79
Arizona	444,000	2.51
Alaska	388,000	2.19
Virginia	257,000	1.45
New Mexico	105,000	0.59
Arkansas	21,000	0.12
British Columbia	5,000	0.03
Total funding	**17,698,000**	**100**
Total states funded in region (number)		9
Total states funded outside region (number)		2
Total other countries (number)		1
Total entities funded (number)		**12**

Table 22. Research topics funded by Regional Aquaculture Center, percent of funding, 1987-2020.

	Regional center				
Research area	**North central**	**Northeastern**	**Pacific**	**Southern**	**Western**
Production methods/systems	44%	77%	16%	18%	8%
Nutrition/feeds	7%	3%	9%	16%	18%
Water quality/effluents	3%	-	-	13%	-
Disease/aquatic animal health	1%	5%	16%	11%	17%
Hatchery/larval rearing, feed	-	-	26%	8%	15%
Economics/Marketing/Business	5%	9%	4%	7%	3%
Publications/information	0.1%	-	9%	7%	-
Broodstock	-	-	-	6%	-
Harvest	-	-	-	6%	-
Food safety/product quality	-	-	-	4%	11%
Policy	-	-	-	1%	-
Extension	21%	4%	13%	-	2%
Aqua drugs/INADs/NADs	11%	-	-	-	-
Genetics/reproduction	-	-	4%	-	15%
New species	-	-	-	-	5%
Ecology/environmental impact	-	-	-	-	4%
Nuisance species	-	-	-	-	2%
Other	6%	2%	4%	3%	-

Table 23. North central regional funding by subject matter, 1987-2020.

Subject matter	Amount ($)	% of total
Species production methods	6,981,060	44.3
Extension	3,362,223	21.3
Aqua Drugs	1,645,820	10.4
Nutrition diets	1,086,266	6.9
Other	1,008,806	6.4
Economics/marketing	819,256	5.2
Effluents	448,300	2.8
VHS	197,960	1.3
INADs/NADs	144,241	0.9
Aquaponics	24,596	0.2
Publications/white papers	22,494	0.1
Conferences, symposia, workshops	19,000	0.1
Total	**15,760,022**	**100**

Table 24. Northeastern regional center funding by subject matter, 1987-2020.

Subject matter	Amount ($)	% of total
Shellfish[a]	11,059,311	50
Finfish	5,146,625	23
Business	2,070,307	9
Aquatic animal health	1,088,184	5
Extension	871,892	4
Plants	777,722	4
Nutrition	689,027	3
Other	450,115	2
Total funding	**22,153,183**	**100**

[a]Combined with finfish, for the production methods/systems category.

Table 25. Pacific regional center funding by subject matter, 1987-2020.

Subject matter	Amount ($)	% of total
Hatchery	4,768,731	23.7
Disease	3,283,771	16.4
Farm technology	3,188,212	15.9
Extension	2,695,476	13.4
Feed development	1,729,644	8.6
Information	1,724,411	8.6
Genetics	795,656	4.0
Economics	755,132	3.8
Environment	604,814	3.0
Live feed	395,204	2.0
Development plan	139,358	0.7
Total funding	**20,080,409**	**100**

Table 26. Southern regional center funding by subject matter, 1987-2020.

Subject Matter	Amount ($)	% of total
Systems	3,763,000	18.1
Nutrition	3,399,000	16.4
Water quality	2,662,000	12.8
Disease	2,376,000	11.5
Hatchery/larval	1,671,000	8.1
Marketing	1,550,000	7.5
Publications	1,537,000	7.4
Broodstock	1,341,000	6.5
Harvest	1,283,000	6.2
Food safety	886,000	4.3
Policy	275,000	1.3
Total funding	**20,743,000**	**100**

Table 27. Western regional center funding by subject matter, 1987-2020.

Subject matter	$	% of total
Fish diets/growth	3,137,000	18.30
Immunology & disease	2,886,000	16.84
Reproduction	2,582,000	15.07
Product quality	1,862,000	10.86
Genetics	1,486,000	8.67
RAS/water quality	1,358,000	7.92
Genetics/reproduction	1,062,000	6.20
New species	777,000	4.53
Ecology/environmental impacts	748,000	4.36
Economics/regulations	537,000	3.13
Extension	419,000	2.44
Nuisance species	285,000	1.66
Total funding	**17,139,000**	**100**

Table 28. Responses from interviewees of whether the Regional Aquaculture Centers have fulfilled their mission.

		Yes		Maybe/ somewhat		No		Not sure/don't know	
	n[a]	no.	%	no.	%	no.	%	no.	%
Board of Directors	10	9	90%	1	10%	0	0	0	0
Industry Advisory Council	10	9	90%	1	10%	0	0	0	0
Non-Industry Advisory Council[b]	16	9	56%	4	25%	0	0	3	19%
Technical Committee-research	9	8	89%	0	0	0	0	1	11%
Technical Committee-Extension	10	7	70%	1	10%	1	10%	1	10%
Prominent national leaders	7	2	29%	4	57%	1	14%	0	0

[a]Number of respondents for each category of individuals interviewed in the review.
[b]Farmers in this category who had not been involved with the RACs were not asked this question. Responses were from those with some experience with the RACs.

Table 29. List of projects funded from 2014-2021 for each regional center.

North central regional center
Largemouth bass strains for rapid foodfish and other growth
5th regional aquaculture Extension specialist project
5th aquaculture regional Extension facilitator project
16th “base” Extension project
Metagenomic analysis of microbial populations in aquaponics systems: rapid response project
6th aquaculture regional Extension
17th “base” Extension project
Youth education in aquaculture (YEA)
Assessing the status of aquaculture associations in the north central region
Professional development training in the north central region
Field assessment of design and operation of midwestern aquaculture buildings
Educating a workforce: Matching skill needs of the aquaculture industry with U.S, career and technical education
Comprehensive outreach and training program to expand development of NCRAC aquaculture
Development of all-female yellow perch population with thermal manipulation, sperm selection, and genomic data analysis
A NCRAC-sea grant partnership for regional aquaculture Extension focused on marketing and consumer demand
Supporting and expanding aquaculture in the Midwest through Extension and outreach
Formulation and assessment of a new generation of starter diets for largemouth bass and yellow perch larvae”
Evaluation of alternative management techniques and systems to improve production of pond-reared yellow perch (*Perca flavescens*): modeling the U.S. catfish industry
Choice of seafood: an analysis of the north central region market for farm-raised seafood

Table 29. List of projects funded from 2014-2021 for each regional center. (continued)

Northeastern regional center
Improving hatchery techniques of lumpfish (C*yclopterus lumpus*) for cleaner fish to control sea lice in Atlantic salmon net pens
Regional comparison of off-bottom oyster cages as marine habitat in the Northeast
Novel anti-predator coatings for shellfish
Evaluation of natural astaxanthin by microalgae as a potential pigment source for Atlantic salmon (*Salmo salar*) feed
Sponsorship of the Northeast Aquaculture Conference and Exposition
Inventory of barriers in the northeast that limit the aquaculture industry
Hatchery and nursery technologies for the production of blue mussels
Identification of the cause of hemic neoplasia in *Mercenaria mercenaria* and development of management methods
Development of a phage-based diagnostic test for the rapid detection of pathogenic Vibrio species in bivalves
A novel approach to prevent super chill in Atlantic salmon
Impact assessment of NRAC funding on aquaculture in the Northeast
Safe feedstocks for bivalve aquaculture
Testing and application of novel probiotic bacteria for use in marine aquaculture
Development of novel, nontoxic solutions for biofouling control and predator exclusion in shellfish aquaculture
Sponsorship of the Northeast Aquaculture Conference and Exposition
Teleost spermatozoal transcriptomes: requisite foundation for functional genomics, sperm quality and male fertility
White worm, *Enchytraeu albidus*, production and marketing for live aquaculture feed

Table 29. List of projects funded from 2014-2021 for each regional center. (continued)

Pacific regional center
Aquaculture Information Service for Pacific Region
Development of locally made commercial feed for tilapia aquaculture in Hawai'i
Establishment of milkfish fry production in Palau to reduce dependency on imported fry
Establishing coral grouper production in Palau thru application of intensive copepod production technology
Increasing production and improving food safety for Hawai'i new bivalve industry
Development of marine finfish aquaculture, aquatic feeds and training in Marshall Islands for sustainability and food security
Utilization of locally available algae in culture of ezo abalone and opihi in Hawai'i
Potential of black soldier fly as feed ingredient to support Hawai'i aquaculture
Utilization of local agri-processing by-products to produce fungal protein for aquatic feed production
Assuring oyster seed supply for Hawai'i and West Coast
Integrated multi-trophic aquaculture of shrimp and sea cucumbers for nutrient recycling, sludge reduction, & additional revenue
Aquaculture of opihi
Improving rabbitfish seed production capacity in Palau
Improving nursery and grow out culture of mangrove crab by minimizing cannibalism and developing feed supplements
Development of cost-effective aquatic feeds using locally sourced ingredients
Francisella noatunesis incidence and genetic assessment of feral tilapia populations in Hawai'i
Testing the feasibility of open cage culture of grouper in Palau
Disease prevalence survey of wild mud crab populations in the U.S. affiliated Pacific Islands
Cost effective local aquatic feeds for carnivorous and omnivorous fish with varying physical characteristics
Aquaculture Workshop at Oceanic Institute for students of Waianae High School Aquaculture Program
Opihi aquaculture Years 5 &6, improving hatchery technology and production
Improving cost-effectiveness of producing local aquatic feed from papaya fruit wastes via innovative bioprocessing years 1 & 2
A shrimp disease diagnostic lab for Hawai'i
Culture of a local marine polychaete for the use as a shrimp maturation feed years 3 and 4
Diagnosing prevalent diseases of aquaculture animals in Hawai'i
What's in the gut. A metabarcoding approach to examining diet in first feeding larvae
Examination of parasitic infections in shrimp populations in Hawai'i and detection of pathogens in commonly used shrimp feeds

Table 29. List of projects funded from 2014-2021 for each regional center. (continued)

Southern regional center
Publications, videos and computer software
Collective action alternatives
De-sticking egg masses
Control of virulent Aeromonas
Split-pond aquaculture systems
Blue catfish germplasm
Probiotic and prebiotic supplements
New spawning aid
LAMP assay for Amyloodinium
Waterbird predation risk
Native freshwater ornamentals
Ovulation for hybrid catfish production
Off-bottom cultured oysters
Technology adoption
Protein and lipid in tilapia feeds
Probiotics in finfish hatcheries
Edwardsiella in ornamental fish
Policy analysis of Lacey Act
Year-round harvest of channel-blue hybrid catfish
Western regional center
Triploids, tetraploids, and successful metamorphosis in purple hinge rock scallops (*Crassadoma gigantea*)
If you feed them, will they grow? A dietary approach to improving the growth of juvenile cutthroat trout
The economic impact of regulations on shellfish and trout aquaculture growth in the Western U.S.
Determining causes, costs, and benefits of triploidization to improve sturgeon caviar production
Adapting aquaculture to changing water chemistry in the Pacific Northwest

Table 30. Southern regional center projects funded that included development of aeration and intensive production systems, and hybrid catfish, that resulted in a 59% increase in productivity from 2010-2020 in the U.S. catfish industry.

Years	Total $ spent	Title
Production technology		
1988-1990	$124,990	Performance of aeration systems for channel catfish, crawfish, and rainbow trout production
2004-2008	$935,726	Innovative technologies for commercial-scale aquaculture (PAS, IPRS, split ponds)
2012-2016	$292,891	Performance evaluation of intensive, pond-based culture systems for catfish production
2014-2017	$452,824	Split-pond aquaculture systems: design refinement for catfish production and evaluation for culture in other species
Hybrid Catfish		
2004-2008	$460,000	Improving reproductive efficiency to produce channel x blue hybrid catfish fry
2014-2017	$44,343	Improvement of blue catfish germplasm for hybrid catfish production
2015-2017	$275,232	Integrated approaches to reducing individual variability and providing year-round harvest of channel-blue hybrid catfish
2017-2019	$126,619	Repeatability of incidence and time of ovulation, fecundity, & fertility in channel catfish females induced to ovulate for production of hybrid catfish fry
Total	**$2,712,625**	

Table 31. Returns on investment and economic impacts of the adoption by the catfish industry of intensive production systems and the complementary hybrid catfish technology.

Metric	Value	Notes, formulas, assumptions
Return on Investment		
Return on Investment		ROI is a crude metric and the least accurate of those calculated
2010 to 2019, cumulative	16,152%	Net Return ÷ Cost of Investment.
Annualized	32.3%	[(Ending Value ÷ Beginning Value) ^ (1 ÷ Number of Years)] – 1.
Net Present Value[a]	$1,073,298,055	Used discount rate of 7.5%.
Internal Rate of Return	2039%	Does not account for reinvestment of positive cash flows
Modified Internal Rate of Return[b]	123%	MIRR is the most accurate calculation of return on the investment & accounts for reinvestment of positive cash flows.
Economic Impact[c]		
Total Economic Impact, 2011 to 2019	$2.97 billion	Cumulative, 2011 to 2019
Direct impact, 2011 to 2019	$1.72 billion	Cumulative, 2011 to 2019
Indirect impact, 2011 to 2019	$0.86 billion	Cumulative, 2011 to 2019
Induced impact, 2011 to 2019	$0.396 billion	Cumulative, 2011 to 2019
Total Employment Impact, 2011 to 2019	3,666	Increase in the additional jobs supported
Direct employment, 2011 to 2019	1,719	Increase in the additional jobs supported
Indirect employment, 2011 to 2019	1,226	Increase in the additional jobs supported
Induced employment, 2011 to 2019	721	Increase in the additional jobs supported
Total tax revenue, 2011 to 2019	$121 million	Cumulative, 2011 to 2019
Federal tax revenue, 2011 to 2019	$53 million	Cumulative, 2011 to 2019
State and local tax revenue, 2011 to 2019	$68 million	Cumulative, 2011 to 2019

[a]Discount rate = 7.5%.
[b]Reinvestment rate = 7.5%.
[c]Multipliers taken from Hegde et al. (2022b).

Table 32. Pacific regional center projects funded on bivalve production, 2006-2017.

Years	Total $ spent	Title
2006-2009	$73,424	Developing bivalve culture to diversify and position Hawai'i as a supplier of safe, premium, edible shellfish products, Years 1 and 2
2011	$71,182	Establishing bivalve farming in Hawai`i
2013	$83,306	Increasing production and improving food safety for Hawai`i's new bivalve industry
2014	$55,200	Assuring oyster seed supply for Hawai`i and the West Coast
2017	$93,000	Developing bivalve farming in Hawai'i, supplemental funding for Years 7 and 8
Total	**$376,112**	

Table 33. Returns on investment and economic impacts of adoption of oyster hatchery methods and development of oyster hatcheries in Hawai'i in response to ocean acidification to provide seed supply to Alaska, Washington, California, Oregon, and Hawai'i.

Metric	Value	Notes, formulas, assumptions
Return on Investment		
Return on Investment		Crude metric and the least accurate of those calculated
2006-2023 (1st half), cumulative	100,961%	Net Return ÷ Cost of Investment.
Annualized	2.3%	[(Ending Value ÷ Beginning Value) ^ (1 ÷ Number of Years)] – 1.
Net Present Value[a]	$214,847,586	Discount rate of 7.5%.
Internal Rate of Return	78%	Does not account for reinvestment of positive cash flows
Modified Internal Rate of Return[b]	57%	Most accurate calculation of return on the investment & accounts for reinvestment of positive cash flows.
Economic Impact, 2006 (2nd half) to 2023[c] (1st half)		
Total Economic Impact	$691 million	Cumulative, 2006 to 2023 (1st half)
Direct impact	$380 million	Cumulative, 2006 to 2023 (1st half)
Indirect impact	$143 million	Cumulative, 2006 to 2023 (1st half)
Induced impact	$168 million	Cumulative, 2006 to 2023 (1st half)
Total Employment Impact	10,156	Jobs supported by Hawai'i oyster seed
Direct employment	7,121	Jobs supported by Hawai'i oyster seed
Indirect employment	1,462	Jobs supported by Hawai'i oyster seed
Induced employment	1,574	Jobs supported by Hawai'i oyster seed

[a]Discount rate = 7.5%.
[b]Reinvestment rate = 7.5%.
[c]Multipliers taken from Northern Economics (2013).

Table 34. Western regional center projects funded on sturgeon and caviar production methods, 1993-2018.

Years	Total $ spent	Title
1993-1996	$322,300	Sturgeon broodstock development
1997-2001	$394,000	White sturgeon domestic broodstock management
2001-2002	$200,000	Enhancing breeding and health of sturgeon broodstock
2002-2006	$228,000	Maximizing quality and shelf-life of sturgeon caviar
2007-2011	$400,004	Determining ripeness in white sturgeon females to maximize yield and quality of caviar
2010-2014	$555,210	Environmental and endogenous factors affecting egg quality and caviar yield in farmed sturgeon
2015-2018	$412,263	Determining causes, costs, and benefits of triploidization to improve sturgeon caviar production
Total	**$2,511,777**	

Table 35. Returns on investment and economic impacts of adoption of sturgeon spawning and culture methods that resulted in development of a $114 (2023) million sturgeon and caviar industry in the U.S.

Metric	Value	Notes, formulas, assumptions
Return on Investment		
Return on Investment		Crude metric and the least accurate of those calculated
	4,394%	Net Return ÷ Cost of Investment.
Annualized	2.3%	[(Ending Value ÷ Beginning Value) ^ (1 ÷ Number of Years)] – 1.
Net Present Value[a]	$118 million	Discount rate of 7.5%.
Internal Rate of Return[b]	669%	Does not account for reinvestment of positive cash flows
Modified Internal Rate of Return	35%	Most accurate calculation of return on the investment & accounts for reinvestment of positive cash flows.
Economic Impact		
Total Economic Impact	517 million	
Direct impact[c]	114 million	
Indirect impact	264 million	
Induced impact	139 million	
Total Employment Impact	1,711	
Direct employment	53	Jobs supported
Indirect employment	973	Jobs supported
Induced employment	685	Jobs supported

[a]Discount rate = 7.5%.
[b]Reinvestment rate = 7.5%.
[c]The economic impact analysis completed was an original analysis completed as part of the review based on cost structures from previous surveys and sales information provided by U.S. sturgeon farmers.

Table 36. Expectations of host institutions of the Regional Aquaculture Centers.

The institution that hosts a Regional Aquaculture Center is expected to provide the following support:
Provide support for the leadership role of the Director in the region.
Provide broad programmatic leadership for regional research and Extension activities.
Evaluate the RAC Director.
Provide an administrator to chair the RAC's Board of Directors.
Encourage cooperative and collaborative research and Extension programs with regional application.
Utilize institutional mechanisms and linkages to implement RAC programs.
Coordinate with aquaculture programs of other federal agencies.
Serve as focal points for information exchange and provide research and Extension linkages at the regional level.
Ensure that regional research needs are identified and research needs are properly integrated and delivered to the stakeholders through Extension educational programs.
Release and distribute project funds and reimbursements for travel expenses in a timely manner.
Provide efficient and timely support from the Office of Sponsored Programs to ensure that project funding is disbursed as quickly as possible to principal investigators.
The host institution is expected to have and make available the expertise to create and support a modern effective home page for the RAC for posting all relevant information from publications, notices related to funded projects, and other information about aquaculture important to stakeholders.
The RAC host institution is expected to maintain a listserv to reach and inform stakeholders in a timely manner about RAC projects and activities.
Communications offices of the host institution are expected to include notices of RAC projects funded, results, and deliverables from projects that have ended in their social media posts and in other press and news releases.
The host institution is expected to provide office space and necessary furniture for the Director and the administrative staff of the RAC, including telephone, computers, electricity, and web services.

Table 37. Specific suggestions related to increased funding for the Regional Aquaculture Center program.

A comprehensive effort needs to be made by stakeholders and universities involved in the RAC program to increase annual funding. Additional funding would contribute to development of more, larger, or longer-duration projects, participation of more researchers, addressing long-term needs or other priorities not previously addressed, and increasing Extension capacity.
Through an Inter-RAC Task Force and with farmer stakeholders, develop a document that lays out a vision of what U.S. aquaculture could be: • Factors that limit development. • How success would be measured. • What would be required to achieve milestones. The vision should articulate the desired goals but also how to attain those goals. Metrics could include: • Job creation. • Imports substituted. • Other measures of economic impact. Investment in aquaculture would be assessed against the value to the economy and the potential importance of aquaculture to key national priorities (i.e., food security, homeland security, resiliency, economic strength).
Design and implement a coordinated plan to seek increased funding for the RAC program through engagement across regions and institutions, including: • Association of Public and Land-grant Universities • Individual institutions • The Boards of Directors • American Farm Bureau Federation • National Aquaculture Association • Other national and state aquaculture organizations
The National Institute of Food and Agriculture should support inclusion of the Regional Aquaculture Centers in the President's annual budget request to Congress to help ease the uncertainty of continued funding year to year.

Table 38. Specific suggestions related to improving communications in the Regional Aquaculture Center program.

Websites
Develop a consistent, user-friendly, and attractive design and template for modern, state-of-the-art websites for each RAC with universal categories of content. Improved websites should include: • Comprehensive information on the RACs • Real-time information on priority research topic areas • New projects approved • Priority topic areas not funded • Abstracts of all current projects • Annual accomplishment reports • Work plans • Project final reports • Publications (scientific and Extension) • Extension materials (fact sheets, infographics, videos, newsletters) • Farmer stories and experiences with RAC projects.
Links across RACs should be developed to make information from each RAC available to other RACs to expand knowledge and use of published materials. Contact information for members of the Board of Directors, industry advisory council, technical committee, and a page on how to get involved with the RAC should be included. Include a portal through which farmer needs can be posted.
Update the web page for the Regional Aquaculture Centers on the NIFA website to be more prominent and attractive with photos and the brief description of the program with links to each of the Centers to increase the visibility of the program among NIFA partners.
Encourage members of the Industry Advisory Council, Technical Committee-Research, and Technical Committee-Extension to link their professional websites and social media accounts to their respective RAC websites and social media accounts.
Encourage state and regional aquaculture associations, National Aquaculture Association, other national aquaculture organizations, and individual farms to link their websites and social media accounts with their respective RAC website.
Communication and Engagement
Identify and implement an effective strategy, including engaging with communication specialists who would be responsible for continuous and timely information outreach, notification, and dissemination to growers, grower associations, the general public, and other stakeholders, as well as among all RACs, Boards of Directors, Industry Advisory Councils and Technical Committees through websites, listservs (e.g., Aquacontacts mail group), directed email, and social media. The strategy would include consideration of the most effective communication strategies for all socio-demographic groups, including millennial and younger generations. Develop and post a calendar for announcements that is updated regularly.
Communicate to regulators and policymakers the relevant RAC research findings that provide information that can be beneficial to the development or revision of regulations, laws, and policies that impact aquaculture growers and development. The RACs can be a valuable source of information for development of rigorous, science-based policies. A key mechanism could be communications through the Subcommittee on Aquaculture at the federal level and key regulatory or resource agency personnel at the state level.
Consider developing filters for subscribers to listservs or newsletters that allow recipients to tailor information received from the RAC program to specific interests, particularly those of farmers.
Develop and maintain a current and comprehensive database of producers, production systems, and species with contact information for internal use within each RAC to ensure all farmers and farming sectors (including feed companies and other suppliers) receive RAC communications regarding solicitation of needs or project ideas, requests for proposals, research updates, newsletters, etc.

Table 38. Specific suggestions related to improving communications in the Regional Aquaculture Center program. (continued)

Communication and Engagement

Maintain a current directory of contacts that includes:
• Aquaculture producer associations (national, regional, and state)
• Extension personnel with aquaculture responsibilities
• State Farm Bureau aquaculture committees
• Researchers with active aquaculture programs
• Principal contacts with critical Agencies:
  • Federal Task Forces on Aquaculture
  • U.S. Department of Agriculture-Agricultural Research Service
  • U.S. Department of Agriculture-Animal and Plant Health Inspection Service
  • Food and Drug Administration
  • U.S. Environmental Protection Agency
  • U.S. Army Corps of Engineers
  • National Oceanic and Atmospheric Administration-Office of Aquaculture-National Sea Grant
  • The U.S. Aquaculture Society
  • State aquaculture coordinators.
Include specification of mechanisms, time frames, and individuals responsible for updating the contact lists at least annually.

Develop a schedule for periodic articles about specific RAC-funded projects to be sent to aquaculture trade magazines that focus on U.S. aquaculture. Task Extension personnel within each region with specific assignments for development of these articles.
Develop a schedule for drafting one-page postings of RAC projects and accomplishments to the National Aquaculture Association's "Friday at the Laboratory" series, targeting two postings from each RAC per year.
Work through the National Coordinating Council to revise and update the Publications Policy Guidelines for the RACs (National Coordinating Council, 1991) to account for new technologies, web features, social media platforms and communication partners. The revised policy should clearly address the top priority to effectively communicate and share information with farmers and other stakeholders about RAC projects and outputs in a timely manner. The policy should also include a distribution plan to broaden dissemination through farmer associations.
Maintain a current list of all aquaculture meetings and conferences, including state aquaculture association meetings, in each region, with principal contact information. Task a representative of the appropriate RAC to offer to give a presentation on the RAC in the region where the meeting will be held. RAC directors and/or the National Institute of Food and Agriculture are encouraged to attend national, regional, and state aquaculture meetings and conferences to report on RAC accomplishments and be ambassadors to educate and inform others of the unique structure and opportunities to be involved. RACs should continue to be key sponsors and supporters of regional aquaculture conferences, like the North Central Regional Aquaculture Conference and the Northeastern Aquaculture Conference & Exhibition.

Table 38. Specific suggestions related to improving communications in the Regional Aquaculture Center program. (continued)

Communication and Engagement
Develop a mechanism for or be a catalyst to share un-funded farmer priorities with other aquaculture-related funding opportunities, such as the Aquaculture Special Research Grant program, Sustainable Agriculture Research and Education Program, Sea Grant, U.S. Department of Agriculture-Agriculture and Food Research Initiative, etc. for consideration in developing their requests for proposals or applications. These are leveraging opportunities to expand the program's impact and further help farmers.
Initiate and facilitate interaction between chairs of the Board of Directors, Industry Advisory Council, and Technical Committee across the RACs so that these leaders can learn more about other RACs, share experiences, answer questions, identify best practices, lessons learned, and identify areas of mutual interest.
Improving Visibility and Awareness of the RAC Program
Improve the visibility and awareness of the RAC program among key stakeholders. There is a need for more aggressive and strategic communication and outreach to the broader aquaculture and seafood communities. The RACs need to tell their stories and promote their centers. A broad-based, multi-platform communications effort is needed to support promotion and visibility. These can include regular "Communications from the Director," newsletters, press releases of highlights, major results summarized in annual accomplishment reports, and summaries of key contributions to aquaculture from all RACs. Send email notices of new information posted on each RAC website to all subscribers. U.S. Department of Agriculture-National Institute of Food and Agriculture should distribute press releases on the RACs in the NIFA Weekly Digest Bulletin and the Aquacontacts mail group. Press releases should be sent from host institution communications offices to state-wide media outlets.
Develop and implement a schedule and strategy to produce short farmer video testimonials of impactful projects or those that are especially timely and topical. Post the video testimonials on RAC websites and distribute announcements of availability of each via email listservs to principal contacts, and social media.
Convene a symposium where RAC research over the life of the program would be presented to show how the program has benefited U.S. aquaculture farmers.

Table 39. Specific suggestions related to addressing the loss of Extension capacity.

Update, post, and implement the "Extension Guidelines for Involvement in the Regional Aquaculture Centers" (National Coordinating Council, 1994).
In each region, form a committee that includes representatives from the Board of Directors, Industry Advisory Council, and Technical Committee to examine strategies to enhance Extension support in their region.
The National Institute of Food and Agriculture, RACs, and land-grant universities engage to address the continued loss of Extension capacity within the RACs.
Farmers and aquaculture associations advocate to university administrators for more aquaculture Extension positions.
Increase support for the shrinking aquaculture Extension community. This may include RACs hiring communications specialists to assist with publication and dissemination of Extension materials and/or increase funding for Extension personnel on RAC projects, including partial salary support.
Consider funding a regional Extension specialist in regions where the loss of Extension capacity is insufficient to provide necessary support. The position could monitor projects, collect data on economic impacts, help support regional research projects, and improve communications with farmers and companies in a region. Two RACs have previously supported Extension positions with these responsibilities.
Develop an Extension network within each RAC to enhance existing capacity. Suggested activities include organizing a regional aquaculture Extension conference (for example such as the Northeast Aquaculture Conference and Exhibition), communicating findings and results of on-going projects, new concerns on the horizon, new species under consideration, and supporting each other in training sessions. The RAC Extension networks should also jointly organize an "emerging issues" session annually at Aquaculture America, organized by Extension personnel in the RACs and sponsored by the RAC program.
Develop an online Extension module that describes the functional and integrated role of Extension in RAC projects and informs researchers of the requirement for deliverables and/or methods to effectively reach and educate farmers about their findings and results in a timely manner.

Table 40. Specific suggestions for the National Institute of Food and Agriculture related to succession planning for the Regional Aquaculture Centers.

The National Institute of Food and Agriculture should engage with host institutions now to ensure that the National Institute of Food and Agriculture is aware of any issues or concerns at any level within each RAC.
The National Institute of Food and Agriculture should work with each RAC now to recommend development of a succession plan by tasking a specific committee that includes one or more representatives of the host institution, the current Director, and at least one representative from the Board of Directors, Industry Advisory Council, and Technical Committee, as appointed by the current RAC Director.
The succession plan should include an overlap of at least one complete program planning and funding cycle between the current and in-coming director to ensure a smooth transition. The uniqueness of a RAC, especially the importance of the active engagement and interaction among farmers, researchers, and Extension personnel is best achieved with an adequate overlap of Directors.

Table 41. Specific suggestions for the National Institute of Food and Agriculture related to increasing engagement with individual Regional Aquaculture Centers, host institutions, and RAC committees (Boards of Directors, Industry Advisory Councils, Technical Committees)

The National Program Leader for Animal Health and Aquaculture in the National Institute of Food and Agriculture should have an adequate travel budget to attend an annual or biennial meeting for each RAC based on advice from the Director.
The National Institute of Food and Agriculture should collaborate with RACs on defining the effective role of Extension and outreach in RAC projects with common expectations and objectives that will benefit stakeholders from RAC projects. This includes updating and/or adhering to the "1994 Guidelines for Extension Involvement in the Regional Aquaculture Centers" (National Coordinating Council, 1994).
The National Institute of Food and Agriculture should work with the RACs to more actively measure and document the short- and medium-term benefits of projects following project completion.
The National Institute of Food and Agriculture should request that new RAC proposals address or align with the updated National Science and Technology Council National Strategic Plan for Aquaculture Research only when parts are relevant to identified regional farmer priorities. RACs can focus on different disciplinary sections of the Plan. However, this should not be a requirement for approval of RAC proposals. The RACs, as a federally funded program, should be recognized as important contributors to the implementation of the Plan. The visibility of the RACs as an important contributing partner in federal aquaculture science programs should be increased through reporting RAC accomplishments and contributions to the Plan.
The National Institute of Food and Agriculture upper management should be fully represented and engaged with the National Science and Technology Council Subcommittee on Aquaculture to support interagency initiatives and contribute to the National Institute of Food and Agriculture aquaculture program expertise and activities, in addition to those of the National Program Leader for Animal Health and Aquaculture.
The National Institute of Food and Agriculture and Center Directors should use the National Coordinating Council forum to identify mutually agreeable actions to engage other federal agencies with interests in aquaculture. Increase interaction with the National Aquaculture Association for a national perspective of interregional concerns and new opportunities.

Table 42. Specific suggestions related to improving operational effectiveness of the Regional Aquaculture Center program.

Streamlining
The RAC, through either the Board of Directors, the Executive Committee, an *ad hoc* committee, or another mechanism, should review the entire project development process from problem identification to initiation of research and Extension activities to identify where the greatest time lags occur. Develop strategies to implement projects more quickly and work with the appropriate entities (i.e., RAC administrative office, host institution Office of Sponsored Programs, and the National Institute of Food and Agriculture, based on determination of where the greatest time delays occur).
Convene an inter-RAC committee to develop a streamlined mechanism to identify reviewers for RAC project proposals. Develop a directory of research and Extension personnel and their respective expertise who have agreed to serve as reviewers for some number of RAC proposals each year.
Monitoring and Evaluation of Project Impacts
The Extension person on each RAC project is in the best position to assess if: 1. The project met its goals. 2. Whether there are results of sufficient value to farmers and growers to warrant development of Extension materials for dissemination to farmers and growers and, if so, were those completed. 3. Whether a follow-up project is needed. Provide a simple form to the Extension person on the project to complete and submit to the RAC administrative office as part of the project termination process.
Develop an ongoing project monitoring and evaluation system for all RACs. • Form a committee or team among several RACs that primarily includes Extension personnel. The key missing link to the ability to evaluate impacts of RAC projects is the lack of a mechanism to gather information on whether farms, feed mills, or other stakeholders have begun to use project results in their businesses, how many have benefitted from adoption of the results, and some general sense of what, if any, benefits have occurred from adoption. • Extension personnel could administer short surveys at local and regional meetings, training courses or field days to gather this information each year. Consideration should be given to providing funding (does not have to be full time), to task one Extension person per region to coordinate distribution of a short questionnaire at all major aquaculture conventions in the region each year (there likely are only three to four per region per year). • Information should be entered into a database available to the RAC administrative office to identify and track project results that are being adopted by farmers. Periodic review of the database will provide clarity as to when there has been sufficient adoption of RAC-influenced improvements to initiate a more formal assessment of benefits and impacts. Without basic data about what results have been adopted on which farms, and whether adoption has been widespread or limited to a few farms, it is a waste of money to contract someone to do “impact assessment.”

Table 42. Specific suggestions related to improving operational effectiveness of the Regional Aquaculture Center program. (continued)

Balancing Interests
Ensure that all economically important species groups within a region are represented and supported, with their interests "balanced" with the major species groups in the region through periodic re-assessment (possibly every four years) of the composition of the Industry Advisory Council in each RAC.
Identify priority need areas that are problem- or issue-based that allow for inclusion of multiple commodities to be more inclusive of smaller sectors of aquaculture in each region.
Ensure that committed, engaged, thoughtful individuals are selected for the Industry Advisory Council, Board of Directors, and Technical Committee, with a greater focus on the individuals than a prescriptive emphasis on formal term limits. Be open and inviting to new participants, but keep a mix of experienced and new individuals on committees, with a process that involves some degree of rotation among members.
Rebalance representation on Boards of Directors to reflect only institutions with active aquaculture programs and/or interest in aquaculture. It is not necessary to seek representation from all states in a region without interest or programs in aquaculture. The Board of Directors needs only to be functional in its duties and representative of the region. Smaller committees of engaged individuals can operate more expeditiously.
RAC Operations
Ensure that all RACs understand that they have the flexibility to search for appropriate expertise outside the region in cases where regional expertise is not available. RACs should not ignore priority needs because expertise is not available in the region or it is a non-traditional topic. RAC priorities should be farmer priorities, not constrained by capacity in the region.
Clarify and emphasize to Industry Advisory Council and Technical Committee members that on-farm trials, commercial farm verification trials, and Extension demonstrations are valid projects and may accelerate adoption of previous research findings.
Encourage early career researchers to participate in their respective RAC.

Table 42. Specific suggestions related to improving operational effectiveness of the Regional Aquaculture Center program. (continued)

RAC Administrative Policy and Procedures
In all RACs, allow the Industry Advisory Council to make the final determination in ranking project ideas/ topics and proposals that are submitted to the Board of Directors for approval.
Develop and initiate an orientation/onboarding process for all new committee members. • For Industry Advisory Council members, the orientation should focus on procedures and responsibilities to ensure that they know that they are expected to solicit project ideas from other farmers in their state/region and make those known in the project development process. • On-boarding should include a meeting with new Industry Advisory Council members with the chair/co-chair of the Industry Advisory Council to help them understand how the process works, to bring project ideas to their first meeting and be prepared to explain and advocate for those problems to be addressed. • For new research and Extension personnel, onboarding should include expectations for engagement in all RAC activities and the core requirements of applied research to address farmer needs and the requirement for Extension involvement in all projects. • The orientation process should emphasize and promote team-building among researchers, farmers, and Extension personnel serving on the various committees and those funded to participate on individual projects. • The orientation process should include specific requirements of proposal and reporting guidelines. • During orientation, researchers should be encouraged to reach out to Extension personnel or others familiar with aquaculture farms to schedule visits to farms in their region prior to the RAC annual meetings to improve understanding of the real-world conditions that result in the problems articulated by farmers. Such farm visits should be at the expense of the researchers, to interact directly with stakeholders and identify the research areas that would be of greatest benefit as they design their research programs.
Invite the chair of the Board of Directors or other Board of Directors members to observe Technical Committee and Industry Advisory Council meetings. Boards of Directors members that attend a Technical Committee/Industry Advisory Council meeting can gain an understanding of their function, be better informed about the overall operation of the RAC, and share perspectives or recommendations for the good of the program.
Consider holding some RAC meetings in different states where possible and organize visits to aquaculture farms and research facilities for all meeting participants, including the Board of Directors.
Require Industry Advisory Council approval when recommending mini-grants or rapid response projects to the Board of Directors.
Require nutrition or feed-related project ideas submitted to be accompanied by a letter from a feed mill that attests to its commercial feasibility.
Provide line-item budgeted funds for farmer partners to cover extra expenses or costs associated with cooperative research if required for success of the project.
Send the list of project ideas to be considered at each RAC annual meeting to all Industry Advisory Council and Technical Committee members in advance of the annual meeting.

Table 43. Suggestions related to addressing dilemma related to allowing Facilities & Administration/Indirect Costs in the Regional Aquaculture Center program.

Because of the current shortfall in RAC funding, indirect cost recovery allowance should not be instituted until there is a budget increase to a level above the extra cost of F&As (IDCs) to avoid further decreases to funding for projects.
Any allowable indirect cost rate should either be capped at 10% similar to other National Institute of Food and Agriculture regional center programs or be negotiable to a lower rate not to exceed 10% to not significantly impact funds directly used to support research and Extension projects that address farmer and grower needs.
The National Coordinating Council should assess the critical need and impact of allowing any indirect cost recovery to the RACs and formulate a consensus action plan.

NATIONAL Aquaculture ASSOCIATION

A REVIEW OF THE REGIONAL AQUACULTURE CENTER PROGRAM:

A UNIQUE, FARMER-DRIVEN PROGRAM ADVANCING U.S. AQUACULTURE

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