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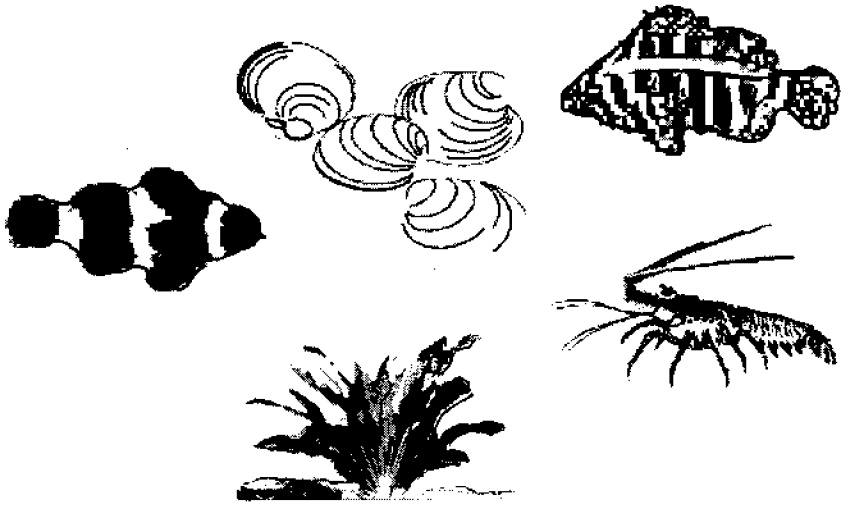
FLORIDA MARINE AQUACULTURE RESEARCH AND EXTENSION ISSUES — INCLUDING THE FLORIDA SEA GRANT LONG RANGE PLAN

by

William Seaman and Charles Adams



Sea Grant
Florida

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FLORIDA MARINE AQUACULTURE RESEARCH AND EXTENSION ISSUES, INCLUDING THE FLORIDA SEA GRANT LONG- RANGE PLAN

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I. INTRODUCTION

This document is one of seven prepared by the Florida Sea Grant College Program to guide its long-range coastal research, extension, communications and education statewide and beyond in major subject areas concerning Florida. Here we present a situation statement for marine aquaculture in Florida, analyze key planning references, identify complementary efforts, and define priorities on a statewide basis as well as for Sea Grant in 1997-2002. This information was complete enough to use in the Sea Grant statewide call for proposals in 1997, and revised slightly for this report.

A. Purpose

The information in this plan is to guide faculty across Florida, who will propose and actually conduct coastal aquaculture projects in the coming years, and to inform industry, agency, policy and civic interests who will collaborate with them or receive the results of Sea Grant efforts. It also identifies needed resources for attaining program goals. We seek to answer the question: What can and can't Sea Grant do to make sustainable marine aquaculture successful in Florida?

B. Sea Grant Perspective

Florida Sea Grant (FSG) provides a vehicle for university faculty and students to (1) conduct research and development in aquaculture issues of importance to Florida and the U.S. and (2) extend and apply scientific findings to sustaining or creating aquaculture opportunities. Conversely, Florida Sea Grant is not a regulatory, permitting or venture capital organization, although its multi-disciplinary faculty regularly collaborates with such interests. Sea Grant is not the only source of research support for marine aquaculture, so clearly it is necessary to coordinate planning with other interests.

Academic Role

Florida Sea Grant is the only statewide university-based program of coastal research, education and extension in Florida. It emphasizes the development of students, particularly at the graduate research level. In a given year it sponsors 15-20 faculty research projects in several fields, such as biotechnology, engineering, seafood technology, etc. Of these, at most a few are focused in aquaculture, although related studies on seafood product quality, environmental conditions, and biotechnology also make a contribution. Complementary efforts by extension faculty transfer information to the small marine culture industry. The modest scope of FSG efforts reflects the youth and limited extent of Florida marine aquaculture.

Past Record

FSG research on aquaculture of saltwater plants, invertebrates and fishes primarily has been opportunistic, and funded on the basis of individual projects (as opposed to thematic groupings of projects). Recent topics have included seagrass nursery practices, economics of hard clam culture, culture of ornamental (aquarium) shrimp and tropical fishes, and physiology of shrimp and fishes. Since 1972 aquaculture research has been funded by FSG both as 19 larger multi-year Annual Projects and 22 shorter Program Development (pilot) studies. Also, FSG extension agents in local areas regularly have provided advice and some demonstrations (e.g., "backyard aquaculture," blue crab shedding), while the state specialists in economics and seafood technology have led workshops on financial feasibility and product quality, for example. One of the most effective publications produced by FSG discusses economic considerations for potential aquaculture investors, as a guide to understanding risks in this emerging area.

Besides the traditional academic outputs of contributions to the scientific literature and completed master's and doctoral research theses, outcomes of FSG aquaculture projects include serving as the "R&D" arm for coastal plant nursery operators, developing technology for cultivation of angel wing clams as a new seafood product, and assisting homeowners and small businesses to improve fish production practices.

To augment the relatively modest Sea Grant "core program" budget that has been fairly constant in recent years, external funding has been sought. Most notably, State of Florida support for development by an interagency team of softshell blue crab production opportunities has offered FSG a means to serve aquaculture interests statewide.

C. Methods

A recent spate of documents concerning Florida and U.S. aquaculture provided a strong foundation for preparing this plan. Having access to them eliminated the step of exhaustively (re) surveying various business, agency and academic interests to identify needs. Rather, analysis of this material by FSG staff provided an initial needs assessment. Information about national aquaculture issues came from documents by the National Research Council (3), the Federal interagency Joint Subcommittee on Aquaculture (6), and the National Sea Grant College Program (7). Florida issues are described by the Florida Aquaculture Review Council (5), the Committee on Agriculture and Consumer Services of the Florida House of Representatives (2), and the newly released Florida State Aquaculture Plan (1).

To complement published background material, Florida Sea Grant convened an invited group of experts to discuss marine aquaculture needs. University faculty were drawn from the respondents to a statewide survey conducted by FSG early in 1996. Representatives of industry and key state agencies also participated. A central part of the meeting was based on entry of information about needs, opportunities and issues into a table listing both major

"commodities" (e.g., plants, various animals) and informational needs. In other words, persons were invited to the October 24, 1996 planning meeting on the basis of in-depth knowledge and experience with one or more of the following groups: plants, ornamental aquarium invertebrates and fishes, bivalve mollusks, decapod crustaceans, marine bait, and food and gamefish. Each invitee was sent a worksheet to record information to bring to the meeting. The completed table is discussed in a following section. Meeting participants are listed in Appendix One.

II. STATUS OF FLORIDA MARINE AQUACULTURE

This section summarizes Florida aquaculture issues, needs and opportunities. In comparison to aquaculture elsewhere in the United States, commercial aquaculture in Florida is dominated by tropical fish culture with very little success evident in the culture of food species. The recent development of a viable hard clam culture industry is a notable exception. Further, in contrast with aquaculture elsewhere in the world, including innovative approaches such as net ranching and cage culture and practices such as rope culture of bivalves,Florida's aquaculture industry has been restricted by geographic, climatic, and regulatory constraints to typically employ the more traditional pond and closed system aquaculture techniques. In sum, Florida marine aquaculture may be characterized as a diverse melding of a number of candidate species of which only a very few have provided the level of success seen elsewhere in the U.S. for commercial aquaculture.

A. Diversity of Activities

The Florida aquaculture industry is characterized by a wide variety of production technologies and cultured species. However, only a small portion are marine. For the combined fresh and saltwater sectors, Florida has over 500 active aquacultural growers, utilizing about 4,000 water-surface acres, whose aggregate 1995 farm-gate sales were estimated to be $79 million. This value represents an approximate 50 percent nominal increase in sales over the last five years. Of this, less than $10 million is marine-oriented. Although the production of food species has experienced some recent growth, over 80 percent of the total statewide sales value is associated with non-food tropical fish, aquatic plants, alligator hides, and sport and game fish. The remaining sales value is accounted for by the production of food species, such as catfish, alligators, tilapia, and shellfish. In particular, the culture of molluscan shellfish has shown the greatest increase in sales for a food species, with hard clams being the individual mollusk species with the most promise (i.e., there are 200 growers, using about 1000 acres). Many other species exhibit either short or long-term potential for commercial culture, as described in the 1996 Florida Aquaculture Plan (1).

Although commercial aquaculture in Florida has experienced modest growth in recent years, the full potential for the state's industry has yet to be realized. Projected industry growth has not been attained. Recent research efforts suggest that numerous barriers to

entry for new growers and expansion of current growers exist, including economic, regulatory, and technical issues. Research, extension, and education efforts need to be directed toward these problematic issues to allow the industry to better compete within the environment of existing input and product markets.

B. Agency, Industry and Academic Roles

A number of state agencies and educational/research institutions are associated with assisting the development of commercial aquaculture in Florida. The Florida Department of Environmental Protection issues a number of permits and licenses for commercial aquaculture in Florida, and also conducts research and hatchery operations. The Department of Agriculture and Consumer Services provides generic and product-specific marketing services for aquaculture and seafood products, and is the legislatively designated lead agency. The Game and Freshwater Fish Commission oversees stock enhancement activities and the tagging of certain cultured freshwater species that enter the seafood market channels. The various Water Management Districts provide regulated access to groundwater supplies. The Department of Labor and Employment has provided funding for several aquacultural training programs. A variety of aquacultural-related research, extension, and education programs are provided via private universities, institutions of the State University System, and the Florida Sea Grant College Program. The industry itself provides opportunities for information exchange via the Florida Aquaculture Association, etc.

The legislatively mandated Aquaculture Interagency Coordinating Committee provides a focused forum for the various state agencies, academia and industry to discuss existing problems, legislative initiatives, and funding opportunities associated with the further development of commercial aquaculture in Florida. A subjective index of effort or interest within the organizations identified in the Florida Aquaculture Plan (1) as having "priorities" is given in Table 1.

III. PRIORITIES FOR SUSTAINABLE AQUACULTURE

The scope of this discussion is based on the definition by the Food and Agriculture Organization of the United Nations of aquaculture as

> "the farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated..."

as adopted by the U.S. National Research Council (3). We take a multi-disciplinary view that includes not only the biological expertise that has dominated much of the research and development in this field but also economics, law, engineering and other academic skills. The context for this plan is that it draws from the recent documents referenced.

Table 1. Presence and involvement of state agency, university and non-profit independent laboratory organizations in Florida aquaculture. (Note: Information based on 1996 Florida Aquaculture Plan [Reference 1], as identified in a list of research and development priorities compiled by the Florida Aquaculture Review Council. Three categories of priorities [i.e., "general," "freshwater," "marine"] are arbitrarily set for this analysis only. Number of priorities does not necessarily equate to effort or budget level, and is used as a subjective index of interest.)

	Focus and Number of Short - and Long - Term Priorities		
Organization	General	Freshwater	Marine
Florida Aquaculture Review Council	6	2	6
Florida Agricultural and Mechanical University	3	3	1
Bureau of Seafood and Aquaculture, Florida Department of Agriculture and Consumer Services	5	2	5
Florida Department of Environmental Protection, Marine Research Institute	-	-	29
Florida Game and Fresh Water Fish Commission	-	10	-
Florida Power Corporation Mariculture Center	7	-	3
Florida Sea Grant College Program	-	-	14
Florida State University	3	-	5
Harbor Branch Oceanographic Institution	2	-	15
Mote Marine Laboratory	3	-	13
University of Florida Institute of Food and Agricultural Sciences	8	7	15
University of Miami Experimental Hatchery	1	-	7
University of South Florida	-	-	1

A. Goal

The goal of Florida Sea Grant for marine aquaculture is -- in the context of a five-year planning horizon -- to enhance the sustainable productivity of existing commercial activity and assist industry in achieving the production of additional selected ocean and coastal species with the fewest constraints and highest economic potential.

To do this a combination of research, extension, education and communication efforts are required. Each of the sections below draws from the "matrix" of issues, needs and opportunities (Table 2) compiled by the statewide advisory panel (Appendix One) described previously.

Note to Reader: The following long section on "Overall Florida Issues" is a comprehensive summary of the issues given in Table 2, which reflect needs and opportunities on a statewide basis and appropriate to the various industry, agency and academic interests in Florida. Then, in the subsequent shorter section, "Priorities for Florida Sea Grant," topics appropriate as possible Sea Grant projects are identified.

B. Overall Florida Issues

No single document can capture all the issues, needs and opportunities connected with marine aquaculture in Florida. Based on all the priorities recorded in the survey of the Florida Aquaculture Review Council (5) of 12 organizations (Table 1), no single entity could conduct or sponsor work to address all items listed.

Table 2 in this report represents a collection of priority issues identified by one or more individual experts and discussed among their peers, and then reviewed in aggregate by additional experts. It is not specific to Florida Sea Grant, but is intended as a guide for the full spectrum of saltwater aquaculture interests in Florida. In concert with the Florida Aquaculture Plan (1) and other materials, it establishes a framework for research, extension/outreach and related activities by organizations with a mission of fostering sustainable aquaculture in Florida. Our intent is that future working groups could use this information for planning and actions.

(A.) Accounts of Individual Commodities

The keywords in the "cells" of Table 2 are explained in the following accounts. Obviously, no one priority is exclusive to Florida Sea Grant; multiple interests typically will have roles to play (e.g., research, marketing, and so forth). Florida Sea Grant does not intend to conduct its work in isolation, so that prospective investigators will need to foster inter-organizational cooperation.

Use of the term "commodity" is consistent with agriculture and its reference to such groups as citrus, vegetables, etc.

TABLE 2. FLORIDA MARINE AQUACULTURE PRIORITIES: RESEARCH, EXTENSION, TECHNOL
OF ORGANISMS. (Note: Information is based on contributions from invited industry, agency and academic experts, as of th
C O

SUBJECT AREA	1 Salt-tolerant Plants	2. Aquatic Plants	3.Ornamental Organisms	4. Oysters	5. Clams	6. Scallops
LIFE HISTORY	////////////	////////////	////////////	////////////	////////////	////////////
A. Reproduction	Seedlings Needed	Root Propagation	Close Life Cycles, Larviculture	Seed Supply	Seed Availability, Broodstock	Seed Supply
B. Genetics	Monitoring Contamination		Broodstock Management	Hybridization, Triploids		
C. Physiology						
D. Nutrition			Diets	Micro-Diets	Micro-Diets	
E. Health/disease			Diagnosis, Prevention, Treatment	Immunization, Disease Resistance		
ECONOMICS	////////////	////////////	////////////	////////////	////////////	////////
F. Financial Feasibility	Feasibility Analysis	Feasibility Analysis	Economic Feasibility Analysis	Feasibility of Culture Tech., Relaying & Depuration, Irradiation		Feasibility (Small-Scale)
G. Marketing	Describe Market	Describe Market	Describe Market	Value Added Products, Consumer Education	Seasonal Harvest, Market Expansion	Market Analysis
PRODUCTION	////////////	////////////	////////////	////////////	////////////	////////////
H. Production Technologies		Seagrass Commercial Propogation	Intensive Culture Techniques, Land-Based Systems	Upland Production, Seed Availability		Growout
I. Water/waste	Constructed Wetlands	Grassilaria Culture				
J. Product Quality, Processing				Alternative Products, Safety Concerns, Education	Shelflife Storage	
REGULATIONS AND POLICY:	////////////	////////////	////////////	////////////	////////////	////////
K. Environmental Impacts			Document Natural Colonization	Bacteria Sources	Environmental Enhancement	
L. Siting			Appropriate Locations	Contaminants	Quality	Location
M. OTHER		Seagrass Replacement	Conservation of Wild Species			

OGY TRANSFER AND COMMUNICATIONS OPPORTUNITIES, ISSUES AND NEEDS FOR MAJOR GROUPS
e fourth quarter of 1996. Only the highest priority "boxes" are completed: See text for discussion: Empty spaces indicate lower priority.)
M M O D I T Y

7. Softshell Blue Crabs	8. Shrimp	9. Bait Shrimp	10. Baitfish	11. Food Finfish	12. Sportfish	13.Other
////////////	////////////	////////////	////////////	////////////	////////////	////////////
	Seed Stock Production		Spawning, Maturation, Larval Development	Spawning, Maturation, Larval Development	Ovulation Induction	Offshore Tech., Cage Culture
	Broodstock		Stock Selection	Genetic Conservation	Genetic Conservation	Genetic Conservation Stock Enhancement
Molting Triggers	Freshwater Growth					
	Micro-Diets	Micro-Diets	Diets	Formulated Diets	Formulated Diets	
	Vectors, Pathogen-Free Stocks			Drug Screening, Diagnosis, Drug Development, Probiotics	Drug Screening, Diagnosis, Drug Development, Probiotics	
////////////	////////////	////////	////////////	////////////	////////////	////////
Small-Scale Feasibility	Economic Feasibility	Profitability, Economic Analysis	Profitability, Feasibility	Pilot-Scale Demonstration of Economic. Feasibility		
Demand Assessment	Live Markets, Alternative Markets	Size/ Scope, Wild Competition, Market Access, Pricing Markets	Size/Scope, Species, Competition with Existing Markets	National & International Markets		
////////////	////////////	////////////	////////////	////////////	////////////	////////
Control Molting, Integration of Facilities	Re-Circulation, System Costs	Intensive Systems	Systems Design	Offshore Techniques, ID Low Cost, High Density Systems	Larviculture	
Discharge	Quality Access	Discharge	Discharge	Waste Utility, Discharge	Cost Effectiveness	
				Taste Difference by Product Methods		
///// //////	////////////	//////// ////	////////////	////////////	////////	//////
Waste Water Discharge	Discharge Efluent, Water Quality Constraints			Discharge Water, Re-use Systems to Minimize Water Useage	Discharge Water, Re-use Systems to Minimize Water Useage	
	Available Sites					
		Identify Species	Idenitfy Species	Identify Species	Identify Species	

1. Salt-tolerant Plants

Terrestrial vegetation such as sea oats for dune restoration is in demand and the nursery industry is responding by seeking methods to enhance propagation, growth, and survival. Issues include:

1A. Reliable supplies of plant seedlings are needed.

1B. In view of concern for the possible impact on population genetics from long-distance transplanting, a 1997 statewide workshop of national significance addressed the perceived issues, prior to new research in this field.

1F,G. Description and analysis of the market potential generally and also for individual salt-tolerant species would help quantify demand for these organisms and thereby define the potential impact of biological research on plant supply. Financial feasibility studies would be useful to industry planning.

1I. The role of salt-tolerant plants in construction of wetlands on terrestrial habitats, possibly to receive effluent for processing, may be of interest if explored with appropriate user/manager groups.

2. Aquatic Plants

Inter-tidal and submerged aquatic vegetation is part of critical habitats for coastal fishery species and is used in ecosystem restoration (e.g., salt marshes, mangrove forests). Issues include:

2A. The propagation of plants from root tissue would increase the affordable supply of stock.

2F,G. Description and analysis of market potential, and analysis of financial feasibility will help businesses decide on which plants to grow.

2H,I. Development of commercial propagation techniques, and the potential for use of submerged plant species in waste treatment, may expand markets.

2M. Culture of sea grasses for planting/restoring seagrass beds, as well as for mitigration purposes, would enhance the viability of this process.

3. Ornamental Aquarium Organisms

Plants, invertebrates and fishes all are part of the Florida aquarium production and wholesale industry, the state's largest aquaculture sector which presently is dominated by freshwater species but offers potential for saltwater organisms. The culture of ornamental fish is the single most important component of the commercial aquaculture industry in Florida. Although the majority of species cultured are freshwater, there exists a notable demand for marine species, including finfish and numerous invertebrates. Also, sizable demand exists for octocorals and other encrusting marine organisms in the marine aquaria trade industry. A moratorium on the harvesting of live rock in Florida waters and closure of harvest in federal waters creates an opportunity for development of a viable culture technology. Issues include:

3A,B. Closure of the life cycle for numerous desired fish species, including larviculture and broodstock management, needs to be achieved.

3D. Nutrition of saltwater fishes and invertebrates may be enhanced by development of formulated diets.

3E. Diagnosis, treatment and prevention of diseases in saltwater aquarium fishes are needed.

3F. The economic feasibility of live rock and fish culture needs to be assessed. What species are the most profitable and at what scale of operation? Baseline economic analysis needed.

3G. What is the size and nature of the state, national, and international markets for aquarium species and live rock?

3H. The most appropriate live rock culture techniques need to be determined. What are the best types of rocks to use? What forms of intensive closed system culture methods are appropriate? What in-tank culture methods are appropriate? What is optimal culture material, depth, current, proximity of natural live rock, latitude, bottom conditions, containment/protection systems, etc.? Will artificial cultch materials work?

3K,L. The most appropriate sites for live rock culture need to be identified. This should be done in the context of the existing regulatory policy at both the state and federal level. The candidate species complement associated with alternatives site should be described. The feasibility of upland culture needs to be assessed. Need to better understand the natural colonization of live rock species.

3M. The conservation aspects of harvest of wild fish species need to be considered in management.

4. Oysters

The culture of diploid and triploid oysters in approved waters represents an alternative source of product for a market characterized by seasonal availability and quality/safety concerns. Issues include:

4A. A consistent supply of seed is needed. Seed production methods need to be refined to better provide seed to prospective culturists.

4B. Research is needed to assess the technical feasibility of utilizing hybridization or ploidy in the domestic culture of Crassostrea virginica in Florida. Although found to be successful in temperate regions of the nation, will it be successful in subtropical settings? (May provide for improved product availability and quality, as well as disease resistance. To what extent will these actually occur?)

4D. Development of a micro-diet would be particularly useful for the hatchery and nursery phase of the culture process.

4E. Development of a method to immunize or create a disease resistance would not only enhance the technical feasibility of oyster culture, but also provide opportunities to increase quality and safety assurance by consumers.

4F. Need to examine the economic feasibility of oyster culture. What are the financial characteristics of oyster culture and how is this related to culture methodology? Is relaying a viable option to culture in Florida?

4G. What are the alternatives for value-added processing for oysters? (Frozen product, alternative cooked product, depuration, irradiation. What are the market opportunities and constraints for each?) Need to overcome poor market image. Alternative product forms need to be investigated.

4H. Examine the technical feasibility of upland culture methods. How can the availability of seed be enhanced by upland culture methods?

4J. Need to continue research in methods to identify and control bacterial and viral contamination of shellstock product. This will have a high payoff in terms of consumer confidence. Successes should be communicated to the consuming public via effective educational and promotion activities.

4K. Sources of bacteria and viral contamination should be identified. There is a need to better understand the vectors of these contaminants and how they can be controlled.

4L. The constraints imposed by contaminants on suitable culture sites need to be assessed.

5. Clams

The culture of hard clams is the fastest growing food-species segment of the Florida aquaculture industry. Cultured hard clams possess characteristics distinct from wild-caught clams. Issues include:

5A. Work needs to be done on broodstock selection, to provide for a domesticated strain for culture purposes. This would enhance the quality of seed available for growout. Those characteristics required for high density culture could be incorporated into the resulting broodstock. Seed availability is also a concern.

5D. Development of a micro-diet would be particularly useful for the hatchery and nursery phase of the culture process.

5G. Examine the advantages of seasonal harvests, so that bacterial contamination could be minimized and higher market prices could be acquired. Work also needs to be done on expanding the market for cultured clams within Florida. Awareness of the availability of cultured clams needs to be increased among seafood purveyors in Florida so as to expand the in-state market.

5J. Research needs to be conducted into the appropriate methods to increase shelflife of cultured clams, particularly during the summer months. Alternative methods may include wet storage, dry storage, tempering, etc. The economics of these alternative methods, including scale economies, need to be better understood. Are IQF and vacuum packaging techniques appropriate for clams?

5K. How do filter-feeding organisms, such as molluscan shellfish, provide for enhanced water quality? How can these benefits be translated into information useful for aquaculture promotion efforts?

5L. Where are the most appropriate culture sites in Florida for hard clams? What areas have appropriate food sources, water quality conditions, no pre-existing populations of molluscan shellfish, and a favorable outlook for good water quality into the foreseeable future?

6. Scallops

A market for whole bay scallops has developed in the mid-Atlantic region of the U.S. The market potential for whole bay scallops in Florida is unknown, as are the most efficient culture techniques. Issues include:

6A. A consistent supply of seed is needed. Seed production methods need to be refined to better provide seed to prospective culturists.

6F. The economic feasibility of all phases of production in Florida needs to be examined. The financial characteristics of the hatchery, nursery, and growout phases need to be assessed. In terms of growout, what method is most profitable (lantern nets, soft bags, trays, etc.)?

6G. The market potential for alternative product forms needs to determined. In particular, what is the market potential for whole and half-shell scallops? How should this product be positioned in the existing market for scallop products? What are the seasonal and geographic characteristics of this market?

6H. The technical feasibility of alternative growout methods needs to be assessed. How does the appropriateness of each method change in relation to culture site? What are the inherent risks associated with each production method? Refine existing methods used elsewhere for Florida conditions.

6L. Given the current regulations, concerning water column use, where can scallop culture be practically undertaken?

7. Softshell Blue Crab

Soft crabs are a traditional Florida product, the supply of which has historically been constrained by availability of peeler crabs. Interest in soft crab has increased recently as a possible alternative source of income for small-scale operations. Issues include:

7C,H. Research needs to be directed toward better understanding the effectiveness of methods to trigger or synchronize molting in blue crab. This will help alleviate the problem of peeler availability and reduce labor requirements. The use of hormones and photoperiod manipulation are methods that need to be better understood. In addition, methods to delay hardening following the molting process are needed. Are low-calcium shedding systems feasible? Also, is the integration of shedding systems with clam culture viable?

7F. The economic feasibility of small-scale soft crab shedding operations needs to be assessed. What is the profit potential of a small-scale system? What are the peeler requirements of such systems in order to maximize profits?

7G. There is a need to better understand the market for softshell crab products. What are the seasonal changes in demand and does Florida possess a seasonal comparative advantage to other producing regions? How should small-scale producers best access the market and how should they position their product relative to the local and regional markets?

7I,K What are the problems associated with wastewater discharge from small-scale soft crab shedding operations? What are the nutrient loads associated with this discharge? What are the design requirements of a filtration system that can effectively reduce nutrient loading in wastewater coming from shedding systems?

8. Shrimp

Although the potential for the culture of penaeid shrimp for food use in Florida has been constrained by numerous technical and economic factors, refinements in culture techniques may warrant a closer look at table shrimp and larval culture opportunities. Issues include:

8A. Additional work needs to be done addressing seed stock production and maturation methods for native Florida species. This would allow for a more consistent source of post larvae for bait and table shrimp culture in Florida.

8B. Research concerning broodstock selection is needed to provide a broodstock with the growth rate, survival, food conversion ratio, etc -- characteristics that will enhance the feasibility of marine shrimp culture in Florida.

8C. A better understanding of the osmoregulatory mechanisms necessary to allow freshwater culture of marine shrimp is needed. Freshwater culture of marine shrimps would allow for inland, less expensive lands to be used in the culture process. In addition, costs associated with water acquisition could be reduced, enhancing the feasibility of the culture of food shrimp in Florida.

8D. The development of micro-encapsulated feeds and other cost-effective feeds is needed. Feeds that will increase growth rates and survival at the larval and early postlarval stages will increase the likelihood of commercial viability.

8E. A better understanding of the vectors associated with viral and bacterial diseases of candidate culture species is needed. Are pathogen-free stocks feasible?

8F. The financial characteristics associated with food shrimp culture in Florida should be better understood. How sensitive economic feasibility is to changes in the various costs of production should be investigated to provide a more definitive assessment of the likelihood of commercial success for food shrimp culture in Florida.

8G. Identification of alternative markets for cultured food shrimp in Florida may increase the likelihood for commercial success. Although the markets for existing product forms may not provide prices high enough to allow profits, products such as live shrimp may be a viable alternative. These markets need to be identified and the potential for alternative products assessed.

8H,I,J,K. Research needs to be directed toward designing an effective recirculating system, that reduces discharge nutrients and minimizes cost of construction and operation. Appropriately designed water re-use systems would allow for a more cost-effective upland production system for food shrimp.

8L. The sites best suited in Florida for shrimp culture need to be identified. This is true for both marine and freshwater culture systems.

9. Bait Shrimp

A growing nearshore, saltwater, recreational fishing industry has increased the demand for all forms of natural bait, including bait shrimp. The culture of indigenous shrimp species may be faced with a more favorable market environment and appropriate technical methods. Issues include:

9D. The development of micro-encapsulated feeds and other cost-effective feeds is needed. Feeds that will increase growth rates and survival at the larval and early postlarval stages will increase the likelihood of commercial viability.

9F. The financial characteristics associated with bait shrimp culture in Florida should be better understood. How sensitive economic feasibility is to changes in the various costs of production should be investigated to provide a more definitive assessment of the likelihood of commercial success for bait shrimp culture in Florida.

9G. The market potential for cultured bait shrimp needs to be better understood. The existing market for bait shrimp has been found to be difficult to penetrate. What are the attributes of cultured bait shrimp that may make it attractive to existing distributors and ease entry into the market (seasonality, consistent availability, consistent sizes, etc.). To what degree will wild caught bait shrimp compete?

9H. What are the most appropriate culture methods? Small-scale recirculating system technology needs to be refined for application to bait shrimp culture.

9I. Research needs to be directed toward designing an effective recirculating system, that reduces discharge nutrients and minimizes cost of construction and operation. Appropriately designed water re-use systems would allow for a more cost-effective upland production system for bait shrimp.

9M. What species are more conducive to the high density culture environment likely required for bait shrimp culture? Are the indigenous species, such as pink shrimp, the best species to use? What are the regulatory barriers that apply?

10. Baitfish

Marine baitfish species are in great demand by saltwater recreational and commercial fishermen. Regulatory restrictions have reduced the availability of some species that may be enhanced through culture. Issues include:

10A. Research needs to be conducted toward the sexual maturation and larval development characteristics of candidate species for baitfish culture. A better understanding of the reproductive physiology and larval development of these species is needed.

10B. Research concerning broodstock selection is needed to provide a broodstock with the growth rate, survival, food conversion ratio, etc., characteristics that will enhance the feasibility of marine baitfish culture in Florida.

10D. The development of micro-encapsulated feeds and other cost-effective feeds is needed. Feeds that will increase growth rates and survival at the larval and juvenile stages will increase the likelihood of commercial viability for marine baitfish culture.

10F. The economic feasibility of marine baitfish culture in Florida needs to be assessed. The scale economies of the culture process need to be measured. The potential costs and earnings of marine baitfish culture should be estimated to provide potential culturists with information to make an informed investment decision. The profitability associated with alternative culture candidate species should be estimated.

10G. The market potential for cultured marine baitfish needs to be better understood. The existing market for wild-caught, marine baitfish is not well understood. What are the attributes of cultured baitfish that may make it attractive to existing distributors and ease entry into the market (seasonality, consistent availability, consistent sizes, etc.)? To what degree will wild caught baitfish compete? To what degree will other

marine non-finfish baits compete with cultured marine baitfish? In what regions of the state are marine baitfish preferred, and thus more marketable? What is the seasonality of demand by region? What sizes are demanded, by species?

10H. The technical feasibility of alternative production systems needs to be determined. Are raceways preferred to dug ponds? Which systems are preferable to what species? What are the economic characteristics of each system design? Are the various system design alternatives amenable to various regions of the state? What regulatory issues are associated with each alternative design?

10I. What are the problems associated with wastewater discharge from small-scale baitfish culture operations? What are the nutrient loads associated with this discharge? What are the design requirements of a filtration system that can effectively reduce nutrient loading in wastewater coming from these culture systems?

10M. What species are more conducive to the high density culture environment likely required for bait fish culture.? Are the indigenous species, such as finger mullet and Fundulus, the best species to use? What are the regulatory barriers that apply?

II. Food Finfish

A variety of marine foodfish species have received attention as culture candidates in Florida. Commercial feasibility of the culture process has been demonstrated for few, if any. A thorough examination of the culture requirements and production economics is needed to assess the true potential of these various species as viable culture candidates. Regulatory agencies have not addressed permitting of offshore technologies. Issues include:

11A. Work needs to be done addressing the spawning, larviculture, and maturation of most candidate species of marine food finfish. For most species, the ability to close the life cycle is not well understood if at all.

11B. The issue of genetic conservation and the distinctness of fishery stocks may become a concern as species are reared and released incidentally or in stock enhancement programs.

11D. Research into formulated diets is needed. Nutritional requirements of primary candidate species need to be clearly established. This is needed to ensure low cost/ high quality feeds available at a commercial scale.

11E. Work is needed on disease diagnosis, vaccination techniques, screening, probiotics, drug development, and prophylatic methods for various candidate species.

11F. The financial feasibility of foodfish culture needs to be established on a pilot-scale basis. The basic financial characteristics of the culture process are not understood for most of the candidate species of marine food finfish.

11G. A better understanding of the market opportunities and limitations for cultured, marine food finfish is needed. What are the price constraints of entering local markets for wild-caught species? Do niche markets exist? What product forms are required? Are live markets feasible and for what species? What opportunities exist in domestic versus international markets?

11H. Research is needed to address the most effective saltwater growout techniques. What opportunities exist for offshore culture? What are the economic characteristics of offshore culture systems?

11I,K. More research is needed to create cost-effective methods of utilizing waste products in any intensive culture systems that may be employed for candidate species. Research is needed to design cost-effective water reuse systems to allow for low cost / high density culture with minimal discharge.

11J. Do taste attributes change as the production method changes? To what extent will production method effect the quality characteristics of cultured marine finfish?

11M. Appropriate candidate species need to be identified. Are certain species more appropriately cultured for stock enhancement purposes, as opposed to closed system growout for food? Which species have the greatest potential for viable commercial culture in the near future?

12 Sportfish

The culture of marine finfish for stock enhancement purposes has received considerable attention in Florida. The state is currently engaged in stock enhancement programs for snook, but the potential for other species requires further attention. Issues include:

12A. Efficient and predictable methods to induce ovulation and spawning for seasonally spawning species are necessary for year-round production.

12B. The issue of genetic conservation and distinctness may become a concern as species are reared and released at sea from hatchery sources.

12D. Research into formulated diets is needed. Nutritional requirements of primary candidate species needs to be clearly established. This is needed to ensure low cost / high quality feeds available at a commercial scale.

12E. Work is needed on disease diagnosis, vaccination techniques, screening, probiotics, drug development, and prophylatic methods for various candidate species.

12H. Many species can be reared from first-feeding larvae. Other species may need intensive "head-starting". Research is needed to determine the appropriate larviculture methods.

12I,K. More research is needed to create cost-effective methods of utilizing waste products in any intensive culture systems that may be employed for candidate species. Research is needed to design cost-effective water reuse systems to allow for low cost / high density culture with minimal discharge.

12M. Approprite candidate species need to be identified. Are certain species more appropriately cultured for stock enhancement purposes, as opposed to closed system growout for food? Which species have the greatest potential for stock enhancement purposes in the near future?

13. Other

Potential may or may not exist for the commercially viable culture of other marine species in Florida, such as marine algae, sponges, rotifers, spiny lobster, and others. Issues include possibilities to explore the culture of other species, such as for the production of biomedicinals, or else mussels or various lobsters. The feasibility of offshore technology as well as recirculating systems will need investigation.

(B). Cross-cutting Issues

In addition to issues unique to each of the 13 commodities or species groups described in the preceding section A, the advisory group meeting repeatedly identified several needs for different groups. Whereas, disease-related issues are recognized for several groups and are of concern, the most immediate issues include:

•Nutrition -- The need for development of micro-encapsulated feeds for different life stages of organisms is a high priority.

•Technology -- Development of recirculating systems for culture and production is another priority.

•Economic and Market Analysis -- The need for data on the financial feasibility and market opportunities for various species is high, as a guide for deciding whether or not to pursue biological and engineering work.

C. Priorities for Florida Sea Grant, 1997 - 2002

Consistent with its academic strengths and goals, Florida Sea Grant selectively identified priorities for research, extension and communications within the array of issues described above. The 13 commodity groups (listed across Table 2) are placed in historical context in Table 3, in terms of recent FSG effort and planned or potential new activity. From that information, a more focused set of priorities is identified in Table 4, developed with reference to recent emphasis of Florida Sea Grant and the analysis of needs in Florida generally (Table 2).

For 1997 - 2002, Florida Sea Grant must concentrate its limited budget on issues that either are important to a cross-section of marine aquaculture producers (e.g., micro-encapsulated diet) or represent a significant limiting factor to an established or nearly functioning production sector (e.g., clams, aquarium species). See Table 4.

Building on Past Achievement

The left column of Table 3 summarizes recent Florida Sea Grant activity related to aquaculture of saltwater organisms. It is appropriate that at least some of this work lead to new or continued research, extension and communications, as listed in the right column of Table 3.

Priorities

The issues of highest priority for FSG in 1997-2002 are listed in Table 4. They fall into four themes:

- Overall public awareness of the role of aquaculture in seafood production and in ecosystem management.

- Research on cross-cutting issues that pertain to several groups of organisms.

- Research on individual species or groups that show the greatest potential for enhancement from involvement of academic resources.

- Demonstration and technology transfer of results from recent FSG projects.

Table 3. Florida Sea Grant role in aquaculture of marine species, both recent and potential.

Commodity:	Involvement of Florida Sea Grant	
Species or Group of Organisms	Recent, actual activity	Potential priority in next five years
1. Salt-tolerant Plants	• Extension to homeowners and industry, including leadership of "salt-tolerant vegetation panel" and publications • Research on sea oats and other species reproduction, growth, survival	• Continuation: Extension; research on sea oat genetics and microprogagation • New: National conference on genetic conservation issues, prior to new research
2. Aquatic Plants	• Extension concerning mangrove pruning • Research on ecology and genetics of wild seagrass populations, and seagrass nursery production practices	• Continuation: Extension on emergent vegetation • New: Extension of seagrass nursery techniques
3. Ornamental Organisms	• Extension: None • Research on ornamental shrimp and pilot culture facilities for fishes	• Continuation: None • New: Extension for ornamental shrimp production practices, with research support as necessary; research on promising new species and production technologies
4. Oysters	• Extension: Overall seafood product quality • Research: Health and product quality	• Continuation: Extension • No new research in individual core program projects; need integrated approach
5. Clams	• Extension on economic aspects of clam farming and seafood quality • Research: None	• Continuation: Extension • New: Research on feeds, harvest strategy, market expansion, product shellfish and siting/impact factors
6. Scallops	• Extension: None • Research: Production and marketing	• Continuation: Extension of validated practices, research on limits to production

Table 3. Continued.

Commodity:	Involvement of Florida Sea Grant	
Species or Group of Organisms	Recent, actual activity	Potential priority in next five years
7. Softshell Blue Crabs	• Extension: Demonstration of shedding practices • Research: None	• Continuation: Extension • No new research
8. Shrimp	• Extension: None • Research: None	• None
9. Bait Shrimp	• Extension: None • Research: None	• None
10. Baitfish	• Extension: None • Research: None	• None
11. Food Finfish	• Extension: None • Research: None	• Continuation: None • New: Identification of priority species and systems
12. Sportfish	• Extension: None • Research: None	• None
13. Other	• Extension: None • Research: None	• None

Table 4. Florida Sea Grant priorities for marine aquaculture in 1997 - 2002.

Issue, Need or Opportunity	Activity Considered for Support
Overall Public Awareness	1. Communication and education to describe how aquaculture in the wild conforms with ecosystem management practices, and generally the role of aquaculture in production of seafood.
Research on Cross-cutting Issues	2. Determination of financial feasibility and market characteristics for species of greatest technical potential.
	3. Development of micro-encapsulated diets for appropriate invertebrate and finfish species where diet/nutrition is a limiting factor. (Preference for regional/national approach.)
	4. Development of intensive recirculating systems for culture.
Research on Individual Species or Groups	5. Development of culture techniques (e.g., brood stock management, diet, health, systems) for invertebrate or fish species of reasonably demonstrated economic viability as ornamental/aquarium commodities.
	6. Enhancement of production practices for hard clams, pertaining to life history through to product quality.
	7. Identification of finfish production technology options and candidate species for culture of seafood items, for longer range program development.
Demonstration and Technology Transfer	8. Application of research findings from current and recent Sea Grant projects concerning sea oats, seagrasses, ornamental aquarium shrimp, scallops and other shellfish.

Review Criteria

Florida Sea Grant considers research on species with no immediate promise of commercial feasibility to be of lower priority for funding. In other words, some demonstration of economic potential is required in proposing candidate species or groups for research project funding. Further, the specific bottleneck in biology or technology must be described in writing a proposal. Beyond that the "standard" review criteria of Sea Grant (i.e., rationale, science, users, expected results, innovativeness, investigator credentials) apply.

Implementation

The priorities in the preceding section will be advertised in the 1997 advertisement of Florida Sea Grant project funding opportunities for fiscal years 1998 and beyond.

In addition, FSG will address program development opportunities such as reconvening attendees to the advisory group meeting to refine the list of priorities and address follow-up issues. Particularly, there are opportunities to hold workshops on technical issues (e.g., recirculating systems) and identification of candidate species for finfish culture.

Opportunities to secure extension position(s) in saltwater aquaculture need development.

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V. APPENDIX ONE

Invitees and participants (*) in 1996 Florida Sea Grant aquaculture long-range planning meeting.

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