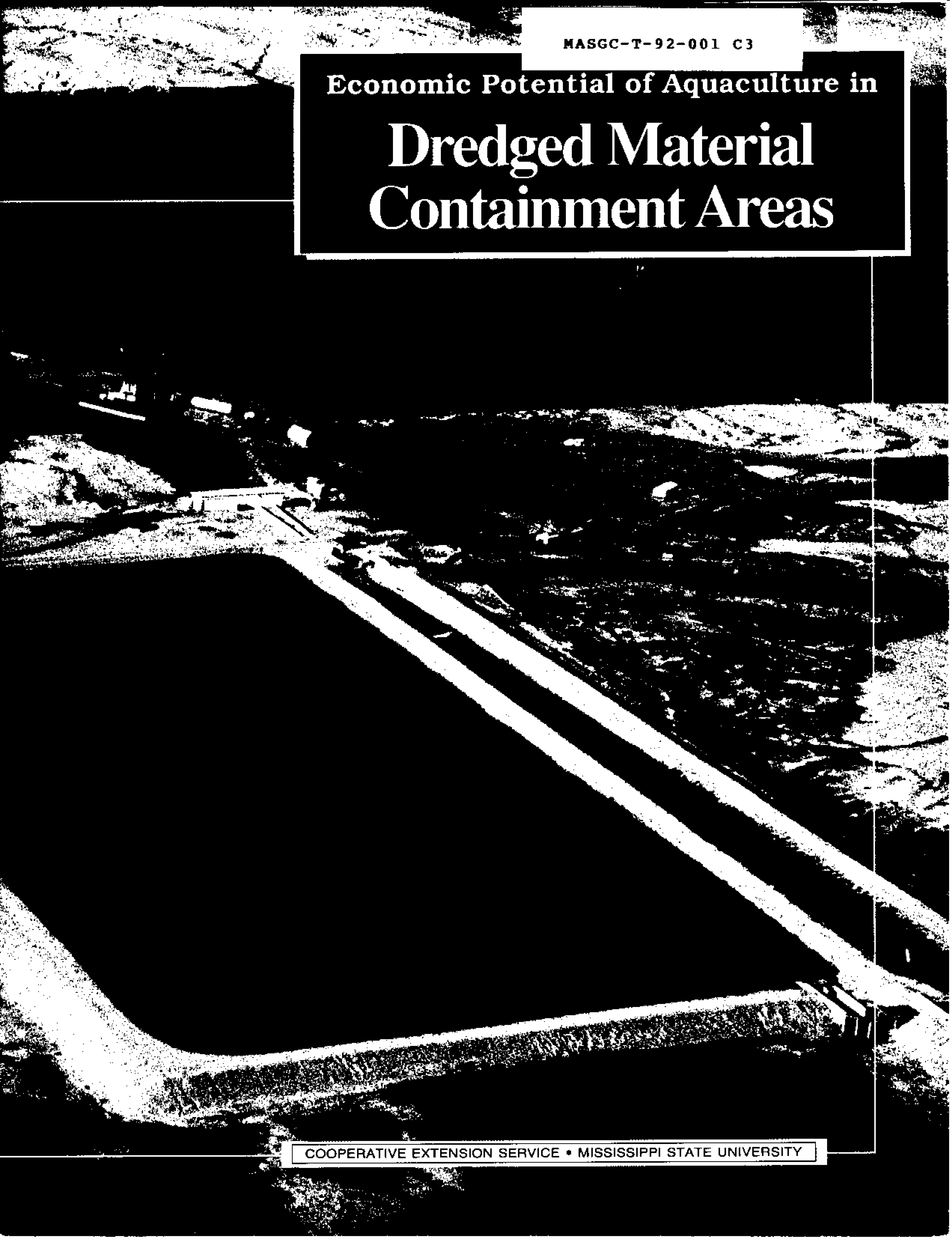
Economic Potential of Aquaculture in Dredged Material Containment Areas



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Economic Potential of Aquaculture in Dredged Material Containment Areas

Kenneth J. Roberts
Marine Resource Economist
Louisiana Cooperative Extension Service
Louisiana State University
Baton Rouge, Louisiana

David G. Marschall
Environmental Specialist
C-K Associates, Inc.
Baton Rouge, Louisiana

Jurij Homziak
Marine Resources Specialist
Mississippi Cooperative Extension Service
Biloxi, Mississippi

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Economic Potential of Aquaculture in Dredged Material Containment Areas

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Introduction and Background

U.S. Army Corps of Engineers Channel Maintenance

Maintenance of harbors and navigation channels is an ongoing task that is vital to the economic well-being of the country. It is also an undertaking of considerable size. The U.S Army Corps of Engineers maintains more than 400 ports and more than 25,000 miles of coastal and inland waterways. For a variety of reasons related to their physical characteristics and locations, many harbors and navigation channels silt up and require maintenance dredging to be kept open. Estimates of the amount of sediment dredged by the Corps of Engineers range from 300 million cubic yards to 450 million cubic yards annually.

Disposal of this material is, in many parts of the country, a constant and increasingly difficult problem. Options for disposal of this vast quantity of dredged material include open-water disposal, unconfined land disposal alongside the channel, confined land disposal in leveed containment areas, or some combination of these methods that results in creation or enhancement of habitat. Some Corps of Engineers districts are pursuing the latter option by building islands for shorebirds or for creating marsh. Open-water disposal and unconfined disposal are increasingly more difficult because of water quality concerns.

Disposal in dredged material containment areas (DMCA's) is now the option that suits the needs of many dredging projects of the Corps of Engineers. DMCA's can range in size from a few acres to more than 1,000 acres. They typically consist of a ring levee of from 5 to as much as 50 feet in height with a control structure to allow regulation of the interior water level. DMCA's may be divided by interior levees into cells allowing sequential filling or increased residence time for water to lose its sediment load. Placement of material in a particular DMCA depends on the needs of the Corps of Engineers district and is influenced by such factors as the rate of shoaling, the type of material (whether sand, silt, or clay) or the proximity of other disposal areas. A maintenance dredging operation can last from a few weeks to more than a year and may need to be repeated from every 3 years to once every 10 or 15 years. For these reasons, the active life of a DMCA might be as long as 50 years making it possible for a site to be used for other purposes much of the time. Most DMCA's are located on private property and, because benefits of channel maintenance indirectly accrue to local communities or users, the acquisition of easements for disposal is the responsibility of the project sponsor.

Project sponsors may be port and waterway districts, municipalities, state or county agencies, or navigation districts. Local sponsors work in partnership with their Corps of Engineers district to identify disposal sites in advance of the need to dredge.

On the national level, an estimated 7,000 acres of new DMCA's are needed annually. In many parts of the country, finding and acquiring suitable sites is difficult. Landowners may demand too high a price for their property or may be reluctant to have it used for what they perceive as waste disposal.

Origins of the Containment Area Aquaculture Program

To help overcome some of the difficulties of site acquisition, the Corps of Engineers has worked to identify ways by which the landowner can use the acreage for activities that produce income but do not interfere with periodic disposal of dredged material. Such activities are known as beneficial uses. Research by the Corps of Engineers identified aquaculture as a potential beneficial use of containment areas. By designing and operating a DMCA for both material placement and aquaculture, benefits could be realized by the landowner, the aquaculture industry, local port and waterway authorities, and the Corps of Engineers.

For the concept to be adopted and applied as a tool for the acquisition of new sites for DMCA's, the technical and economic feasibility of DMCA aquaculture had to be demonstrated. Demonstrating technical and economic feasibility was the principal objective of the Containment Area Aquaculture Program (CAAP).

The Environmental Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES) conducted the Dredged Material Research Program (DMRP) from 1973 through 1978. One of the specific goals of the DMRP was to "develop and test concepts for using disposal sites for productive purposes and consider the use of dredged material as a natural resource" (Saucier et al. 1978). Two work units funded under the DMRP that addressed productive uses were: *The Investigation of Mariculture as an Alternative Use of Dredged Material Containment Areas* and *The Demonstration of Marine Shrimp Culture in an Active Dredged Material Containment Area.* Important results of these two work units included: 400 species of plants and animals were identified as potential culture organisms in DMCA's; small-scale studies with shrimp grown in dredged sediments showed no biological limitations to mariculture; and, shrimp raised in a 20-acre containment area cell without supplemental feedings grew at a rate comparable to wild shrimp. These positive findings, and the increasing difficulty in securing disposal sites, led the Corps of Engineers to look more closely at aquaculture.

The Containment Area Aquaculture Program was thus created to examine fully the beneficial-use concept of aquaculture with emphasis on more economical and environmentally compatible site acquisition. The CAAP had two major activities: a field demonstration of aquaculture in a DMCA on a commercial scale, and the exchange of information on DMCA aquaculture to districts, local sponsors, and the interested public.

The focus of this report is an introduction to aquacultural economics as it pertains to dredged material containment areas. The report is intended to introduce the reader to such topics as economic concepts and aquaculture business planning. The report concludes with a section providing sources of additional information that a reader can use to pursue more detailed data on a particular species.

The CAAP Demonstration Project

Purposes

After nearly a decade of deliberation concerning the potential use of DMCA's for aquaculture, a large commercial-scale demonstration project was established between Brownsville and Port Isabel, Texas late in 1986. The site encompassed approximately 230 acres on the eastern side of the Brownsville Ship Channel. The demonstration project had multiple purposes, including:

- Determination of design specifications and construction methods that would allow multiple use of DMCA's for both aquaculture and dredged material disposal;
- Development of management strategies that would allow aquaculture operations and material disposal to coexist;
- Documentation of construction and production costs that would allow an objective evaluation of economic success to be made; and
- Compilation of the economic and technical information generated by the demonstration.

Construction and Management

In 1986, modifications for aquaculture were made to two large containment areas, Disposal Area (DA) A of 104 acres, and Disposal Area B of 116 acres.

A 4-acre nursery pond was built in Disposal Area A, adjacent to the water intake structures. Changes made to the existing DMCA's included raising the perimeter levees to a minimum of 6 feet above the pond bottom, widening the levee crown widths to between 12 and 15 feet, leveling the pond bottoms, excavating interior drainage ways, and installing an in-levee water control/harvest structure.

For shrimp farm management, the Corps of Engineers contracted with MariQuest, Inc., a California-based full-service mariculture consulting and development company. A Texas mariculture consulting firm, the Cultured Seafood Group, took over management responsibilities in the last year of operations. The project was in operation from 1986 to fall 1989. The project was under the overall supervision of the WES CAAP managers with on-site coordination and construction supervision of the Galveston District through the Brownsville Area Office. The Brownsville Navigation District, an independent political entity of the State of Texas, was the dredging sponsor and landowner.

Production

A two-stage production cycle was used. Postlarvae were first stocked and reared in the nursery pond. The juveniles were transferred to the main ponds for growout. Table 1 describes project stocking and production. Two crops of white shrimp, *Penaeus vannamei*, were raised in Pond A in 1987. The first crop was harvested in September 1987, and produced 106,037 pounds of whole shrimp with 75% survival. The second crop was harvested in December 1987, and produced 48,425 pounds with 56% survival. The two 1987 crops received semi-intensive management, the most important aspect of which was daily feed of between 1.5% and 3% of body weight. The total Pond A yield of 154,062 pounds represented a respectable 1,485 pounds per acre for 1987.

Table 1. CAAP Demonstration Project Stocking and Production Record

	1987		1988		1989	
	CROP 1 POND A	CROP 2 POND A	CROP 3 POND A	CROP 4 POND B	CROP 5 NURSERY & POND B	CROP 6 POND A
SPECIES:	*P. vannamei*	*P. vannamei*	*P. vannamei* *P. stylirostris*	*P. vannamei* *P. stylirostris*	*P. pennicilatus*	*P. vannamei* *P. stylirostris*
Stocking Month	March	July	April	March, April	Sept., Nov.	May, June, July
Harvest Month	September	December	November	November	February	October
Time in Pond–Weeks	24	22	28	31	16-24	15-21
Days Above 24 Degrees Celsius	132	106	170	130	N.A.	111
Days Above 36 PPT Salinity	103	67	142	122	N.A.	109
Stocking Rate–Postlarvae/Acre	40,000	40,000	22,000	42,000	N.A.	47,600
Survival	74%	56%	3.4%	50.6%	0%	23%
Management	Semi-intensive	Semi-intensive	Extensive	Semi-intensive	Semi-intensive	Semi-intensive
Feeding–% Body Wt/Day	1 1/2 - 3	1 1/2 - 3	None	1 1/2 - 3	5	1 1/2 - 3
Feed Conversion Ratio	1.5:1	0.68:1	N.A.	1.77:1	Unknown	2.45:1
Yield–Whole Shrimp, Lb	106,037	48,425	4,504	70,460	0	31,206
Yield–Whole Shrimp, Lb/Acre	1,020	466	43	607	0	286
Yield–Tails Only, Lb	66,175	29,055	2,785	44,390	0	18,724
Yield–Tails Only, Lb/Acre	636	279*	27	383	0	180
Majority Size	36-50 Tails	51-80 Tails	16-35 Whole	41-70 Whole	0	51-80 Tails

* peeled and undeveined weight

In 1988, three crops were attempted in order to demonstrate alternative production scenarios. One shrimp crop was attempted in each pond during the normal production season (March-November). In addition, a third, cool-weather shrimp crop was included. Pond B was stocked at the same rate as the 1987 crops and also received semi-intensive management after having received dredged material the previous summer. This trial was intended to demonstrate the compatibility of aquaculture production with material disposal. Production of a mix of *P. vannamei* and *P. stylirostris* totaled 70,459 pounds, or 607 pounds per acre.

Pond A was stocked with the same two species, but shrimp were not fed, i.e., they received extensive management. Extensive production methods are less costly and may allow more small enterprises to undertake DMCA aquaculture ventures. Growth of the shrimp appeared to be satisfactory. However, survival was limited to only 3.4% because of due to predation by sea trout which had entered as postlarvae when the intake predator filter failed.

The third alternative was the stocking of a cool-water-tolerant species, *P. penicillatus*, during the winter of 1988-89. This trial was to evaluate the potential of growing winter shrimp crops to produce three harvests per year. The effort was a failure. These shrimp were much less cold tolerant than had been reported and all were killed by unusually cold temperatures during February 1989.

One crop was stocked in 1989. This was also a mix of *P. vannamei* and *P. stylirostris*, but a worldwide shortage of postlarvae prevented timely stocking and resulted in poor survival and growth. Final production was 31,206 pounds of small shrimp, or approximately 300 pounds per acre.

Once harvested, shrimp were transported to a processor where they were graded, deheaded, packed, and frozen. Smaller shrimp were sold in the peeled, undeveined (PUD) product form. Shrimp were then kept in cold storage, where they were sold from inventory at the discretion of MariQuest based upon prevailing shrimp market prices. Revenue from shrimp sales was returned to the U.S. Treasury.

DMCA Economics Analyses

What did the project demonstrate? One of the stated purposes of the field demonstration in Brownsville was the "documentation of construction and production costs that would allow an objective evaluation of economic success to be made." A true appraisal of "economic success," however, was not possible. The demonstration project differed significantly from a true commercial venture by undertaking large-scale experiments with different species, stocking densities, feed rates, and marketing strategies. It differed also by being a federal government activity managed by a private company with associated administrative and management burdens. For these reasons, true economic success is not as relevant as are the costs of construction and production.

Construction Costs

An important aspect of the demonstration project was the opportunity to determine the costs of pond construction and installation of a water control/harvest structure. Both a diked disposal area and an aquaculture facility require perimeter levees and a water control structure. Because the use of these structures will be shared, costs of construction will also be shared. These important startup costs need to be examined from the viewpoint of the aquaculturist as well as from the viewpoint of the Corps of Engineers district.

The Galveston District Operations Division manages maintenance dredging in the Brownsville Ship Channel. District personnel calculated the costs to the district of converting the two existing DMCA's, DA 4A and DA 4B, to aquaculture ponds. These costs are summarized in Table 2.

DA 4A became the 104-acre Pond A. It was converted between March and May 1986. Work required moving 56,800 cubic yards of material to construct 9,566 linear feet of perimeter levee. In addition, 2,000 feet of ditch to facilitate draining required moving 15,700 cubic yards of material. Material moving costs and the installation of an in-levee water control/harvest structure amounted to $203,149. An additional $40,000 in costs were attributed to engineering, design, inspection, and administration. Had the district not been meeting the needs of a shrimp farmer, these costs were estimated to have been $85,000 and $15,000, respectively.

DA 4B became the 116-area Pond B. Conversion took place between March 1987 and June 1987, and required moving 82,358 cubic yards of material to construct 12,000 linear feet of levee. District costs for construction were $90,055, and for engineering, design, inspection, and administration were $18,000.

Table 2. Summary of Galveston District Costs with and without CAAP Demonstration Project.

Cost Category	Costs Incurred with Demonstration Project		Estimated Costs without Demonstration Project	
	DA4A	DA4B	DA4A	DA4B
Engineering, Design, Administration	$40,000	$18,000	$15,000	$16,000 0
Construction	$203,14 9	$90,055	$85,000	$82,000 0
Pond Cost Totals	$243,14 9	$108,00 5	$100,00 0	$98,000 0
Project Cost Totals	$351,204		$198,000	

Estimates of these costs without the shrimp farm were $82,000 and $16,000, respectively.

The levee construction costs for DA 4B were considerably less than for DA 4A on a cubic-yard basis because the DA 4B costs were part of a larger dredging contract. They represented approximately one-fourth of the total amount of levee work required under a $1.2 million contract. Levee costs for DA 4A were contracted separately, thus the higher cost. The lower cost scenario is the more likely one to be encountered in a commercial DMCA aquaculture venture. Site selection, facility design, and construction would normally take place in coordination with the local Corps of Engineers district, tying construction of the facility to a larger dredging project. These estimates of costs are project specific and should only be viewed as an example of the range of costs that may be encountered.

Production Costs

Table 1 provides a record of production data for the demonstration project. Production operations in the 1987 crop year were the closest to actual commercial practices and will be used for comparing and evaluating production and production costs.

On a physical yield basis, the two harvests from Pond A in 1987 produced 154,462 pounds of whole shrimp. This represents a yield of 1,485 pounds per acre. Because 75% of the shrimp consumed in the United States are imported, comparison to foreign aquaculture operations is relevant. R. Rosenberry reports in the September/October 1990 issue of *Aquaculture Magazine* that the average yield for farmed shrimp from Mexico is 765 pounds per acre, from Ecuador 593 pounds per acre, and from the Western Hemisphere 2,654 pounds per acre.

Texas A&M researchers Hollin and Griffin (1985) used a yield of approximately 950 pounds per acre of whole shrimp in analyzing a hypothetical Texas farm of 20 ponds of 25 acres each with one harvest per year. For a 20-acre impoundment in South Carolina, Pomeroy (1990) used a yield of 250 pounds per acre of whole shrimp. It is apparent from these figures, and the demonstration project yield of 1,485 pounds per acre, that containment area aquaculture has the potential for at least limited success.

Mainland United States shrimp aquaculture occurs principally in south Texas and in South Carolina. Shrimp research data from these two states are available in the aquaculture literature, and provide comparative data for yields as well as production costs.

From the previously cited references for Texas and South Carolina, selected production costs from the demonstration project are compared in Table 3 to similar costs for producing farm-raised shrimp from

Table 3. Comparison of CAAP Demonstration Project to Hypothetical U.S. Shrimp Aquaculture Facilities.

	Containment Area Aquaculture Program Demonstration Project (Actual Values)		South Carolina Ricefield Impoundment[1] (Theoretical Values)		Texas Shrimp Mariculture Facility[2] (Theoretical Values)	
Pond Size	One 104-acre pond		One 20-acre pond		Twenty 25-acre ponds	
Number of Crops	2		1		2	
Total Yield (tails)	95,230 lb		3,150 lb		761,115 lb	
Per Acre Yield	915 lb		158 lb		1,522 lb	
	Total Cost	Per Pound Cost	Total Cost	Per Pound Cost	Total Cost	Per Pound Cost
Feed Cost	$47,961	$.50	$2,063	$.66	$351,554	$.46
Labor Cost (includes harvest)	$48,949	$.51	$2,460	$.78	$115,360	$.15
Fuel Cost	$7,619	$.08	$300	$.10	$10,300	$.01
Postlarvae Cost	$81,130	$.85	$2,000	$.63	$618,000	$.81

[1] Pomeroy, Robert S. "Estimated Costs of Marine Shrimp in One, 20-acre Existing Ricefield Impoundment, South Carolina, 1990." Fifty percent survival of postlarvae stocked at 10,000 per acre directly into growout pond. Harvest includes ice and boxes.

[2] Hollin, Dewayne, and Wade Griffin. "Preliminary Economics of Shrimp Mariculture in Texas" *In* Texas Shrimp Farming Workshop, Texas A&M University, 1985. Fifty percent survival of postlarvae stocked at 40,000 per acre into nursery ponds.

hypothetical aquaculture operations in these two states. The South Carolina example is based on the experience of shrimp farmers and researchers using existing ricefield impoundments for shrimp ponds. Due to the more northerly latitude, South Carolina aquaculturists attempt only one crop per year. All of the per-pound production costs from the demonstration project used for comparison are reasonably close to those theoretical values used for South Carolina by Pomeroy (1990).

The Texas example represents a large "agribusiness" shrimp farm of more than 500 acres, and provides contrast with the smaller South Carolina pond of 20 acres. With the exception of fuel costs, the labor, postlarvae, and feed costs incurred at the containment area site agree well with the theoretical costs chosen by Texas researchers Hollin and Griffin (1985). While this model assumes two crops per year, other studies have suggested that one crop per year may pose less risk of loss to cold weather (Sadeh et al. 1986).

Some of the difficulties of comparing harvest and production costs for U.S. aquaculture arise because there are relatively few companies producing cultured shrimp, and there is no domestic reporting system that provides a reservoir of data. Moreover, the data that are available reflect the trends in U.S. shrimp farming towards smaller ponds of 5 to 20 acres each, and higher intensity management of more densely stocked animals. The expectation is that with smaller ponds, closer management is possible. The demonstration project ponds were considerably larger than those used for comparison of harvest figures. The respectable yield of 1,485 pounds per acre may attest to the skills of the demonstration project managers, but the large pond size makes comparisons to figures from research literature less direct.

The two 1987 crops of the demonstration project illustrate an advantage to starting postlarvae in a nursery pond. With the head start, time in the growout pond can be shortened, and if the climate allows, two crops can be produced in a single year improving returns to the operation. This two-crop advantage must be weighed against the alternative of keeping a crop in a pond longer and harvesting larger shrimp which sell for a higher price. In addition, two crops require that the costs of harvesting be incurred twice.

The Brownsville shrimp farm thus demonstrated that aquaculture in a DMCA is quite feasible, based on both yield and production costs. The broader value of the CAAP demonstration project is in the new information generated that will guide future aquaculture ventures in DMCA's.

Summary of Economic Benefits

The demonstration revealed a significant value to lowered startup or entry costs. Containment levee cost estimates by the Galveston District were $1,600 and $900 per acre for Pond A and Pond B, respectively. When compared to aquaculture literature, these values appear high. The demonstration project ponds were 100+ acres each but were compared to cost data from the literature for smaller ponds near 20 acres each. Engineering, surveying, design, and permitting work, if performed by the CE, could be worth $400 per acre. For the demonstration project, the combined capital savings were estimated to be $271,000. The annual drain on cash flow of the estimated $271,000 startup capital needs would have been $63,000 (Roberts et al. 1990).

The major potential investment-reducing incentive to using a DMCA is the pond construction cost. Parker (1988) identified coastal pond construction costs of $1,000 per acre in Texas. Another well-documented levee cost in the aquaculture literature is that related to catfish farms. Keenum (1988) provides an estimate for catfish pond construction of $840 per acre. This estimate was based on a system of eight ponds of 17 acres each. Soils of coastal areas and the remoteness of sites could make DMCA projects more costly. However, the large pond size should make construction costs lower on a per-acre basis. Use of a pond construction value to prospective culturists of $800 per acre for DMCA culture appears reasonable.

There is also value to reducing investment capital needs for engineering, design, surveying, and permitting. To the extent that the Corps of Engineers district or the ports and waterway district provides these services, an additional value of $400 per acre could occur. Using estimates of investment needs from the aquaculture literature, a combined value for pond engineering, design, surveying, permitting, and construction of $1,200 per acre can be justified.

For the approximately 230-acre CAAP demonstration project, this amounts to $271,000. The reduction of investment capital needs may be as important to increasing lender support as it is to lowering break-even costs since capital availability is a well-known constraint in the aquaculture industry. In an industry known for scarcity of funds available from financial institutions, this capital savings is both real and valuable. Investors characteristically provide a high share of an aquaculture project's startup capital because most projects lack full institutional support. Not only could the lowered immediate demand on cash outflow increase chances for company success, but a DMCA aquaculture venture would be available to a wider number of prospective companies. This is an outlook that will be of value not just to large containment areas like those at the demonstration project, but to smaller sites suited to more intensive operations or part-time operators.

Development of Economics Computer Model

Once the demonstration project was established and produced real-world data, specific start-up costs and crop returns were identified and quantified. These demonstration results were then used in formulating a computer model that allows a user to "test" the economic feasibility of raising various animals in DMCA's of different sizes (Roberts et al. 1990).

The primary objective of the DMCA model is to provide a spreadsheet template with the features necessary to input specific data, perform "what if" scenarios, and obtain calculated results which will enable the user to make sound economic and marketing decisions which must be considered prior to starting an aquaculture business.

Specific requirements of the model were to:

- be useful to both CE district personnel and the landowners who are not experts at either dredging or aquaculture;
- be flexible to analyze selected variables that may be peculiar to certain species in different parts of the country;
- allow separation of expenditures of the aquaculturist and the CE district; and
- be PC-compatible, portable, and designed for the novice PC user to operate with a minimum amount of computer knowledge.

After reviewing several existing aquaculture economics models, a special model for DMCA aquaculture was developed and tested with live data to identify specific startup investments, variable and fixed costs, and potential crop returns over a specified period of time. The final analysis of the computer model provides the aquaculturist with differences in annual expenses, net income/loss, and cash balance figures with and without financial assistance from the CE district.

The DMCA model is a combination of six worksheets developed with Lotus 1-2-3, a spreadsheet software product of the Lotus Corporation. The worksheets accept and calculate data for

1) Construction Costs,
2) Initial Investment Costs,
3) Annual Variable Costs,
4) Annual Fixed Costs,
5) Annual Sales Summary, and
6) Annual Income Statement and Annual Cash Balance Statement.

The spreadsheet format will accept initial input, perform required calculations, and update figures from Page 1 to Page 6. Once the worksheets are filled in, individual or multiple parameters can be changed and the results of these changes can be viewed immediately. This is a significant advantage of the spreadsheet format. However, the six worksheets are designed so that they can be used without the computer performing all of the calculations.

Worksheets have been developed that require the user to input a number of cost figures. These figures may have to be estimates, as in the length of a pond levee, or they may require some research into typical values either from aquaculture literature or experts. Examples of these are the cost of fingerlings or the number of pounds of a species that may be harvested per acre.

Although the worksheets require considerable input, they are structured to assist the potential aquaculturist in initiating a thorough pre-project evaluation. Standard financial analysis concepts are incorporated to prompt the user to consider the full range of factors and to appreciate their relationships.

The computer model was used to test the feasibility of rearing either crawfish, catfish, hybrid striped bass, or clams in a DMCA. The results of these tests can be reviewed in literature available from the U.S. Army Corps of Engineers, Waterways Experiment Station in Vicksburg, Mississippi. A copy of the computer model is also available. The six worksheets are shown in the Appendix.

The Construction Costs Worksheet (Worksheet Page 1 of 6) performs initial calculations on levee costs. The specifications for levees in aquaculture may vary considerably by species. In addition, the size of a DMCA will likely determine the length of levee that must be built. The worksheet separates those costs that would be incurred by the CE district from those that would be incurred by the aquaculturist. It is expected that each will bear some costs related to obtaining the necessary local, state, or federal permits and authorizations.

The Initial Investment Costs Worksheet (Worksheet Page 2 of 6) identifies many standard items that must be purchased prior to startup of an aquaculture project. Page 2 ends with a total of all investment costs, including sums carried from Page 1.

The Annual Variable Costs Worksheet (Worksheet Page 3 of 6) identifies those costs that fluctuate yearly based on production of a crop. Like other farming activities, many aquaculture businesses borrow a portion of their operating funds either for a fixed number of years or based on a production cycle with the principal due following harvest. The interest on this loan is a variable cost that is accounted for with other variable costs. (Principal repayment is accounted for on Worksheet Page 6.)

The Annual Fixed Cost Worksheet (Worksheet Page 4 of 6) identifies those costs that must be paid regardless of harvest success or failure. The aquaculturist's annual costs are separated from the savings that result from having the CE build levees, install water control structures, and provide other assistance with making the site ready.

Depreciation costs are normally calculated in several ways depending upon the nature of the depreciable item. For simplicity, this worksheet treats all depreciation the same (that is, levee improvements are the same as vehicles), ignores salvage value, and results in an annual cost-recovery figure that is an average based on a single number of years of amortization. It should be noted, based on the experience of the CAAP demonstration project, that depreciation should be accelerated because of the high probability that a DMCA is in a remote and relatively harsh environment.

The Annual Sales Summary Worksheet (Worksheet Page 5 of 6) makes straightforward calculations of harvest. It allows for two crops in a year, which is feasible for shrimp.

The final worksheet (Worksheet Page 6 of 6) provides two forms of financial summary: an **Annual Income Statement** and an **Annual Cash Balance Statement.** The former considers the depreciation of capital investment expenses as an expense (as a fixed cost). This figure is added when considering the cash balance, which reflects the actual flow of cash.

In an income statement, the repayment of loan principals is not reflected, whereas in a cash balance statement, this outlay of cash is shown. The payment of loan principals is calculated in the same manner as was depreciation. In the early years of loan repayment, there is a greater percentage of interest payment and less principal payment.

For simplicity of calculation, the computer model treats repayment of principal as an average yearly outlay.

The final calculation of the model is the value of having the CE build levees, install control structures, perhaps put in an access road, and contribute such preconstruction costs as chemical testing of sediments, assistance with permits, and other site evaluation costs that, though difficult to quantify, would have to be borne by an aquaculturist beginning without the CE.

Date

CONTAINMENT AREA AQUACULTURE PROGRAM

ECONOMICS AND MARKETING WORKSHEET

Species

CONSTRUCTION COSTS

DIRT VOLUME per LINEAR FOOT CALCULATION

A = TOP Width	______	Ft.	<-Insert
B = BASE Width	______	Ft.	B = (S1+S2) x H + A
H = HEIGHT	______	Ft.	<-Insert
S1 = INNER SLOPE	______	Ft.	<-Insert
S2 = OUTER SLOPE	______	Ft.	<-Insert

DIRT VOLUME AND COST CALCULATIONS

VOLUME = ______ CU. FT. per LINEAR FT. (A + B)/2 x H

LENGTH = ______ LINEAR FT. <-Insert

TOTAL VOLUME = ______ CU. YD. (VOLUME x LENGTH / 27)

DIRT MOVING COST: ______ PER CU. YD. <-Insert

USCOE'S CONSTRUCTION COSTS

A. LEVEE (Dirt Moving) COST	______	(Dirt Moving Cost x Total Volume)
B. WATER CONTROL STRUCTURE(S)	______	<-Insert
C. ACCESS ROAD	______	<-Insert
D. PRECONSTRUCTION COSTS (permits, tests, etc.)	______	<-Insert

USCOE'S Total Construction Costs (A, B, C, D) ______

AQUACULTURIST'S CONSTRUCTION COSTS

E: POND IMPROVEMENTS (seeding, shaping, etc.)	______	<-Insert
F. SITE IMPROVEMENTS & UTILITIES (piers, pilings, septic system, electricity, water, etc.)	______	<-Insert
G. PRECONSTRUCTION COSTS (permits, tests, etc.)	______	<-Insert
H. CONSTRUCTION SUPERVISION	______	<-Insert

Aquaculturist's Total Construction Costs (E, F, G, H) ______

USCOE & AQUACULTURIST'S TOTAL CONSTRUCTION COSTS ______

U.S. ARMY CORPS OF ENGINEERS
CONTAINMENT AREA AQUACULTURE PROGRAM
ECONOMICS AND MARKETING WORKSHEET

Date

Species

INITIAL INVESTMENT COSTS

EQUIPMENT COSTS

AERATOR & SCREEN	________	<-- Insert
BOAT & MOTOR	________	<-- Insert
BUILDING (Feed Storage)	________	<-- Insert
BUILDING (Office/Service)	________	<-- Insert
CHEMICALS	________	<-- Insert
COOLERS	________	<-- Insert
FEED BINS	________	<-- Insert
FEEDERS	________	<-- Insert
FLOATS	________	<-- Insert
GENERATORS	________	<-- Insert
HARVEST BASKETS	________	<-- Insert
HARVEST MACHINE	________	<-- Insert
MESH BAGS	________	<-- Insert
MOWER	________	<-- Insert
NETS	________	<-- Insert
NIGHT LIGHTS	________	<-- Insert
PUMP SHED	________	<-- Insert
TRAILER	________	<-- Insert
TRAPS	________	<-- Insert
VALVES	________	<-- Insert
VEHICLES	________	<-- Insert
WATER PIPE	________	<-- Insert
WELL & PUMPS	________	<-- Insert
WET SUIT / SCUBA	________	<-- Insert
OTHER: Miscellaneous	________	<-- Insert
OTHER: ________	________	<-- Insert
OTHER: ________	________	<-- Insert
OTHER: ________	________	<-- Insert
TOTAL EQUIPMENT COST	________	

INITIAL INVESTMENT COSTS SUMMARY

Aquaculturist's Investment Costs
Total Equipment Costs
Total Construction Costs (Page 1): ________
Total Investment Costs ________

USCOE'S Investment Costs
Total Construction Costs (Page 1) ________

Total Aquaculturist's & USCOE'S Initial Investment Costs ________

U.S. ARMY CORPS OF ENGINEERS
CONTAINMENT AREA AQUACULTURE PROGRAM
ECONOMICS AND MARKETING WORKSHEET

Date

<u>Species</u>

ANNUAL VARIABLE COSTS

VARIABLE PRODUCTION COSTS

BAIT	____________	<-Insert
CHEMICALS	____________	<-Insert
FEED	____________	<-Insert
FERTILIZER	____________	<-Insert
FINGERLINGS / POSTLARVAE	____________	<-Insert
FUEL	____________	<-Insert
HARVESTING	____________	<-Insert
HAULING	____________	<-Insert
HIRED LABOR & PAYROLL TAX	____________	<-Insert
ICE	____________	<-Insert
MANAGER	____________	<-Insert
PROCESSING	____________	<-Insert
REPAIRS & MAINTENANCE	____________	<-Insert
SACKS	____________	<-Insert
SEED	____________	<-Insert
SUPPLIES	____________	<-Insert
TRANSPORTATION	____________	<-Insert
UTILITIES (Electricity, Telephone, Etc.)	____________	<-Insert
OTHER: ________________	____________	<-Insert
OTHER: ________________	____________	<-Insert
OTHER: ________________	____________	<-Insert
OTHER: ________________	____________	<-Insert
A. SUB-TOTAL VARIABLE COSTS	____________	

OPERATING LOAN COSTS

B. % of Variable Costs Borrowed	____________	<-Insert
C. Total Amount of Operating Loan	____________	(A x B)
D. Term of Operating Loan (Years)	____________	<-Insert
E. Annual Operating Loan Payment	____________	(C / D)
F. % of Interest on Operating Loan	____________	<-Insert
G. Interest Paid on Operating Loan	____________	(E x F)
H. TOTAL VARIABLE COSTS	____________	(A + E)

Date

Species

ANNUAL FIXED COSTS

AQUACULTURIST'S EXPENDITURES / DEPRECIATION

A.	Total Investment Costs	________	(From Page 2)
B.	Amortization Schedule (Years)	________	<--Insert
C.	Annual Investment Depreciation	________	(A / B)
D.	% of Initial Investment Borrowed	________	<--Insert
E.	Amount of Investment Loan	________	(A x D)
F.	Term of Loan (Years)	________	<--Insert
G.	Annual Principal Payment	________	(E / F)
H.	% of Interest on Investment Loan	________	<--Insert
I.	Interest Paid on Investment Loan	________	(E x H)
J.	Annual Insurance Premiums	________	<--Insert
K.	Salaried Employees and Payroll Taxes	________	<--Insert
L.	Miscellaneous	________	<--Insert
M.	Other ________	________	<--Insert
	TOTAL FIXED COSTS	________	(C+I+J+K)

AQUACULTURIST'S FIXED COSTS SAVINGS

(Based on Value of USCOE'S Contribution to Total Construction Costs)

AA.	USCOE'S Total Construction Costs	________	(From Page 1)
BB.	Amortization Schedule (Years)	________	(B above)
CC.	Annual Investment Depreciation	________	(AA / BB)
DD.	% of Initial Investment Borrowed	________	(D above)
EE.	Total Amount of Investment Loan	________	(AA x DD)
FF.	Term of Loan (Years)	________	(F above)
GG.	Annual Principal Payment	________	(EE / FF)
HH.	% of Interest on Investment Loan	________	(H above)
II.	Interest Paid on Investment Loan	________	(EE x HH)
	AQUACULTURIST'S FIXED COSTS SAVINGS	________	(CC + II)

ANNUAL SALES SUMMARY

SPECIES: ____________________

UNIT: ____________________

HARVEST 1

TOTAL UNITS HARVESTED	____________	<-Insert
PRICE PER UNIT	____________	<-Insert
AMOUNT OF SALE	____________	(Units Harvested x Price per Unit)
NUMBER OF ACRES	____________	<-Insert
UNITS HARVESTED / PER ACRE	____________	(Total Units Harvested / No. of Acres)
AMOUNT OF SALE / PER ACRE	____________	(Total Sales / No. of Acres)

HARVEST 2

TOTAL UNITS HARVESTED	____________	<-Insert
PRICE PER UNIT	____________	<-Insert
AMOUNT OF SALE	____________	(Units Harvested x Price per Unit)
NUMBER OF ACRES	____________	<-Insert
UNITS HARVESTED / PER ACRE	____________	(Total Units Harvested / No. of Acres)
AMOUNT OF SALE / PER ACRE	____________	(Total Sales / No. of Acres)

TOTAL ANNUAL SALES	____________	(Harvests 1 & 2)

Date

Species

ANNUAL INCOME STATEMENT

		With USCOE		W/out USCOE
REVENUE				
Total Annual Sales				
EXPENSES				
A. Total Variable Costs (Pg. 3)				
B. Total Fixed Costs (Pg. 4)				
Total Expenses with USCOE				
C. USCOE FIXED COST SAVINGS (Pg. 4)				
Total Expenses w/out USCOE				
NET INCOME		(a)		(b)

ANNUAL CASH BALANCE STATEMENT

NET INCOME				
LOAN PRINCIPALS				
Operating Loan Payment (Pg. 3, E)				
Investment Loan Payment (Pg. 4, G)				
Total Loan Principals				
USCOE'S Investment Loan Payments (Pg. 4, EE) ulturist's Fixed Costs Savings)				
DEPRECIATION				
Aquaculturist's Investment (Pg. 4, C)				
USCOE Investment (Savings) (Pg. 4, CC)				
Total Depreciation				
CASH BALANCE (Net Income – Principals + Depreciation)		(c)		(d)

VALUE OF USCOE'S PARTICIPATION

ANNUAL NET INCOME DIFFERENCE	(a) – (b)
ANNUAL CASH BALANCE DIFFERENCE	(c) – (d)

Economic Potential of Selected Species

This section summarizes the result of DMCA aquaculture computer model assessment of the economic potential of different species. Details are provided in Roberts et al. (1990).

Four evaluations were conducted: catfish, crawfish, hybrid striped bass, and hard clams. Initially, each species was examined under three scenarios: "low/break even," "average," and "good." Crop values and harvest per acre values were taken from published information to create the "average" scenarios. Adjusting the input figures in the models produced the other two scenarios. Because all of the "average" scenarios resulted in positive net incomes and cash balances, "good" scenarios were not included in the analyses.

The analyses examine facilities in a range of DMCA sizes, but all are considered on a scale that could be managed by an owner/operator with part-time help. All returns are to the owner/operator, whose salary has not been included as a project expense. Yields used in the analyses are below reported averages to reflect the uncertainties of operating in DMCA's. Prices for harvested products are average to below average to reflect potentially higher transportation costs.

For catfish, the DMCA economics computer model evaluated a system of four 20-acre ponds, and assumed growth to market size of 1.25 pounds within one year. A yield of 3,500 pounds of whole catfish per acre was also assumed.

For crawfish, the model evaluated a system of two 20-acre ponds. Levee height was assumed to be only 3 feet, and yield was assumed to be 1,000 pounds of whole crawfish per acre.

A hard clam operation consisting of a single 40-acre pond was analyzed with the computer model. Assumptions included harvest in year two of one million clams (25,000 per acre) and sale at $0.17 each.

Finally, hybrid striped bass were examined because they represent an emerging culture species that may be well-suited to DMCA's. A two-pond system of 40 acres total with 2 years to harvest was assumed. At $2.50 per pound, a break-even yield was slightly below 2,000 pounds per acre.

Corps of Engineers participation in a project results in savings, reflected in the net income statement, and has an impact on the cash balance of the operation. The estimated effects of Corps of Engineers participation on each species by crop cycle are shown in Table 4. These are sample calculations for illustration only. These values must be estimated using project-specific data to obtain values representative of specific projects.

Table 4. Estimated Effects on Net Income and Cash Balances of Corps of Engineers Participation in Aquaculture Projects Producing Selected Species[1]

Species	Net Income	Cash Balance
Catfish	$27,000	$16,200
Crawfish	$4,700	$3,000
Clams	$12,000	$2,600
Hybrid Striped Bass	$34,000	$20,000

[1] See Roberts et al. (1990) for further details.

Aquaculture Business Planning

Planning an aquaculture business requires, among other things, a forecast of the future. This makes it difficult for the prospective aquaculturist or his investors to settle on the specifics of their business. However, only by careful financial analysis will the aquaculturist produce a plan with sufficient documentation to convince investors or lenders. Analysis forces the individual to identify weaknesses in what may have begun as a general idea. In fact, the very enthusiasm to take advantage of the gap between seafood supply and future demand can obscure the need for planning.

The prospective aquaculturist must put personal interests to the test of thorough evaluation in the business plan. Such plans require supporting information, logical organization, emphasis on marketing as well as production, and an array of financial statements.

An aquaculture business plan must be clear as to:

1. species to be cultured,
2. size of the operation,
3. use of broodstock or purchased "seed",
4. technology to be used,
5. time horizon of going from planning to construction to production,
6. yield and target size of fish or shellfish,
7. marketing channels,
8. site evaluation and permits.

This list of components should not be considered complete. However, these are the critical components that would serve both the aquaculturist and the lender and investor reviewing the material. The first seven items listed can be analyzed almost theoretically because results and answers are not specific to a particular location. The final item requires a different level of planning and will not be completely settled until much work is done.

Each component of the business plan will be explained in more detail:

1. Species: An aquaculture business plan must demonstrate knowledge about a selected species. It should provide the results of your research into why the species is a good candidate. The level of production nationally and in the region chosen for the business can document suitability. If little or no personal experience with the species can be shown, significant justification should be provided from international experience and research results. The basic information about the species to be farmed that should be included in the plan include: (1) temperature range for growth and spawning, (2) dissolved oxygen needs, (3) salinity range for both larvae and adults, (4) pH, (5) water hardness, and (6) levels of minerals such as calcium, chlorides, phosphorus, etc.

2. Size of Operation: The aquaculturist must have organized information on the anticipated size of the operation. A common mistake in business plans is the presentation of information on only a completely developed facility. The business plan should clearly communicate immediate and long-term investment and operating capital needs. A facility may only reach successful operations after passing through a few years of financial losses in regard to operating costs.

Initial facility size should fit into a time schedule that allows efficient use of available capital as the facility grows to full size. The interim period allows for the inevitable need for retrofitting original designs, accounting for delays, establishing the needed management and labor skills, and refining the technology used.

Aquaculture businesses are often driven by technology rather than by the market. New and evolving technology attracts attention on its own. A business plan that includes financial projections on the basis of full-scale operations only may be too focused on technology and not on reality. Technology is evolving rapidly in aquaculture. It changes in ways that make the immediate commitment of capital to a full-scale operation a poor use of limited funds. Full scale should be approached with technological flexibility in mind.

An additional aspect of the facility's size is the degree of integration. A vertically-integrated firm would be a company involved in holding broodstock for production of fry, producing the mature crop, and processing the harvest. A business plan should include information on the extent of integration. Additional activities besides those necessary for crop production may contribute to cost reductions and may improve sale prices, but they also change the capital needs. The business plan must address the use of capital for the core production facilities and it must include a justification for use of capital for any subsidiary activities.

Finally, pond or tank size must be indicated in the plan so that the costs of construction, stocking rates, and yields can be evaluated.

3. Use of Broodstock or Purchased Seed: The business plan should indicate whether or not broodstock are to be maintained for "seed" production. The broodstock and seed choice should include a thorough budget analysis justifying the benefit of beginning with such an approach and identifying capital needs. This is often excluded or overlooked. An aquaculturist contemplating holding and using broodstock must be aware that this choice may result in a longer period to payback. This should be shown in the business plan.

4. Technology: The history of aquaculture development includes rapidly evolving approaches to solving problems and overcoming constraints. This occurs because of new knowledge about the species being cultured. Also, there is rapid progress in the development of support technologies dealing with structures, equipment, feeds, filters, and the like. As research support increases and companies identify expanding markets for products and services, the technology the aquaculturist is asking investors to support can be difficult to describe. A tendency is to overlook the need for specifics here and use general, dazzling descriptions of technology.

A business plan for aquaculture must be specific in describing technology. Is the technology used by others in the industry? How stable has it been? Does it produce yields in an acceptable range of low to high? Has the technology been used in this country on the selected species? Is the technology species-specific or is it useful for several species? Will the equipment and machinery be purchased from vendors or will it be fabricated by the aquaculturist? The less conventional the technology, the more documentation is necessary to support the choice.

It is at this point in the business plan that an explanation of the technical and management skills of personnel should be included. A technologically complex approach can only function to its greatest potential when good technical staff are part of the company.

5. Time Horizon: Most of the business planning should be completed by the time financial support is sought. Besides the business plan in total, there must be plans developed from an engineering, building-design, and construction perspective. By developing this material, an estimate of time to complete the facility construction can be made. This assists investors or lenders in determining the accuracy of projected capital flow needs.

At completion of construction, the needs for operating capital will increase. The plan should describe the production or growth period to harvest, providing a range of time necessary to grow the species to a target size. Both optimistic and conservative estimates are valuable because operating costs are a significant part of total costs. Explaining the amount and timing of capital needs is a characteristic of a good business plan.

6. Target Size: The difficulty of obtaining capital will be increased if the plan only vaguely describes the product. It is not enough to indicate that the project will be growing hybrid striped bass, shrimp, or any other species. A plan that details the target size of fish or shellfish at harvest conveys useful information to the reader. It informs the reader that a specific market will be served and that the aquaculturist has evaluated market needs.

As size and time in the pond system increase beyond a point, break-even costs per animal also can be expected to increase. Profitable operation depends on efficiency. Therefore a business plan should forecast not only a target size but should anticipate a range of sizes at harvest. Although there will be a target weight or size, variation can be expected. How will management handle the smaller animals? They could be sold at lower prices or held longer to allow more growth. However, a second harvest will be more costly per animal because of the lower numbers. The issue of animal size may become a means of differentiating one farm's production from a competitor's or from animals caught in the wild.

7. Marketing: In developing a business plan, it is not sufficient to focus only on the sale of an animal as if it were a commodity. The aquaculture product should have more to offer than the wild-caught product and can command a higher price. Wild-caught fish are usually priced only on size. Therefore it is essential that the prospective aquaculturist identify buyers who value freshness, reliability, uniformity, careful handling, and packaging. He must also determine if the harvest will be sold to retail outlets, to food service companies, or to wholesalers who serve commercial fishermen.

Lenders and investors expect detailed information on marketing. An aquaculture business planner is advised to meet early with wholesalers, food service buyers, local processors, or brokers to secure specific information and possibly to reach agreement on marketing relationships.

8. Site Evaluation and Permits: Evaluation of the preceding seven items is essential to a sound business plan but the aquaculturist must demonstrate how that plan will work at a specific site. No planner or reviewer can consider the business a reasonable risk until a site is proposed. Variables such as water quality and availability, residual chemicals in the soil, flood history, compatibility with adjacent land uses, permits for discharges, and even predatory birds can all influence the feasibility of a particular site. Does the site require modification to make it suitable? If so, at what expense? Can the aquaculturist obtain the necessary permits to operate at the site? Permits can be a major impediment to using a site, and the business plan must demonstrate the aquaculturist's knowledge of the types of permits and agencies with which be must coordinate site planning, the likely costs of preparing applications, the length of time necessary to obtain permits, and the limits on facility size or operation that may be part of permit conditions.

It is likely that this section of the business plan will have to be updated with an addendum to communicate to lenders and investors the status of permit applications.

Business plans for aquaculture in a dredged material containment area should be no different from plans for conventional aquaculture businesses. With a containment area, however, the local Corps of Engineers district may be able to assist with many of the site evaluation factors. For instance, assistance may be available with chemical testing of sediments or with permits for structures in navigable waterways. Working in partnership with the Corps of Engineers may reduce the expense and delays in obtaining Corps of Engineers permits.

These advantages should be highlighted by the aquaculturist in his business plan. In addition, a significant lowering of initial capital needs has a value that can be quantified in the business plan. When provided at the site, levees, water control structures, access roads, and water availability represent capital and, therefore, reduced costs. Startup of a system can certainly be faster in a DMCA, and the need for investment capital can be reduced because revenues will be received sooner.

The plan must also address any aspects of a containment area that are less than optimum. A site may be too remote for inexpensive power to be used. This may result in more extensive culture being attempted at a containment site. Another shortcoming of a DMCA could be that the ability to expand the site may be limited.

The aspiring containment area aquaculturist is advised to follow a good business plan outline that includes all of the items noted herein. Dredged material containment areas will be financially attractive in many situations. Planning will identify those situations and can result in positive economic benefits from otherwise idle property.

Sources of Additional Information

The DMCA computer model – the six worksheets – and the aquaculture business planning guide both make clear the need for research into all aspects of an aquaculture business venture. As much data as possible on the species to be grown, the machinery and equipment needed, and the costs involved should be collected in advance of borrowing or spending. A variety of sources should be consulted, and should include those providing financial, technical, and regulatory information.

Sources of aquaculture information that follow are provided to assist those planning to enter the field. "Getting Started in Aquaculture - Where to Get Help" in *Aquaculture Magazine* (November/December 1989, p. 63-66) is an excellent guide to where to get answers to technical and economic questions.

Anyone seriously considering a commercial DMCA aquaculture venture should obtain copies of the other Containment Area Aquaculture Program extension documents available from the local Sea Grant Program or Advisory Service Office in their area. Separate Technical Reports published by the Corps of Engineers Waterways Experimental Station detail site selection and evaluation, contaminant testing, design and construction, demonstration, operations, legal and regulatory environment, and economic and marketing analyses. Titles and document numbers can be obtained from the Program Manager, Containment Area Aquaculture Program, Environmental Laboratory, CE-WES-ER-C, U.S. Army Corps of Engineers Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 391806399.

Cooperative Extension Service

This source of technical information is federally-, state-, and locally-funded. Each county has an Extension Service office often listed in the white pages of the telephone book. The land-grant university in each state has Extension Service specialists located at the university. The National Sea Grant College Program funds Marine Advisory Services in coastal and Great Lakes states. This functions to complement Extension Services in aquaculture in these areas. Biological, veterinary, economics, engineering, and other specialists are available to answer information requests. These are excellent sources of publications, newsletters, conferences, and videotapes.

Agricultural Experiment Stations

Each land-grant university conducts research at experiment stations and in academic departments. Individual researchers may be able to provide "in-process" insight to specific projects. Relevant academic departments and projects can be identified by the university's director of the agricultural experiment stations. Larger universities may have a coordinator of aquaculture programs.

Regional Aquaculture Centers

A cooperative effort of the U.S. Department of Agriculture and universities has resulted in the formation of regional aquaculture centers. These are centers that fund research and extension programs at cooperating universities. Most information available from a center's office will reflect information generated by universities.

Northeastern Regional Aquaculture Center
Southeastern Massachusetts University
North Dartmouth, MS 02747
(508) 999-8157

Western Regional Aquaculture Center
School of Fisheries
College of Ocean and Fishery Sciences
University of Washington
Seattle, WA 98195
(206) 543-4290

Center for Tropical & Subtropical Aquaculture
The Oceanic Institute
Makapuu Point
Maimanalo, HI 96795
(808) 259-7951

North Central States Regional Aquaculture Center
Fisheries & Wildlife Department
13 Natural Resources Bldg.
Michigan State University
East Lansing, MI 48824
(517) 353-1962

Southern Regional Aquaculture Center
Delta Branch Experiment Station
P. O. Box 197
Stoneville, MS 38776
(601) 686-9311

National Aquaculture Information Center

Both practical and technical reference support is available. International literature is indexed and abstracted in a database called Aquatic Sciences and Fisheries Abstracts. *Aquaculture: A Guide to Federal Government Programs*, a 1991 publication identifying federal programs, is available from the Aquaculture Information Center. The Center is part of the U.S. Department of Agriculture's National Agricultural Library in Beltsville, Maryland. Most of its services are free.

The *Quick Bibliography Series* published by the Aquaculture Information Center (AIC) is an excellent sources of publications on practical aquaculture literature.

Aquaculture Information Center
U.S. Department of Agriculture
10301 Baltimore Boulevard, Room 304
Beltsville, MD 20705-2351
(301) 344-3704

Periodicals

There are many regularly published sources of information. Those listed below include magazine, journals, and newsletters. Due to the rapidly evolving aquaculture industry, no list can be complete. Cooperative Extension Service personnel should be able to assist in procuring newly developed periodicals.

Aquaculture Digest
9434 Kearny Mesa Road
San Diego, CA 92126
This is a monthly report on marine fish and shellfish farming that is available by subscription.

Aquaculture Magazine
P. O. Box 2329
Asheville, NC 28802
This a a bimonthly magazine of freshwater and marine aquaculture developments that is available by subscription.

Aquafarm Letter
Box 14260
Benjamin Franklin Station
Washington, DC 20044
This is a timely newsletter that covers regulatory and policy matters primarily focused on Washington, D.C. It is available by subscription.

Catfish News/Aquaculture News
Aquacom, Inc.
P. O. Box 4566
Jackson, MS 39296
This is a monthly publication covering aquaculture with emphasis on catfish but inclusive of most domestic freshwater development. It is available by subscription.

Fish Farmer
34 Amberly Drive
Woodham
Weybridge
Surrey, KT 153SL
England.
This is an international magazine. The "International File" supplement covers information on marketing, financial planning and technology.

Fishery Market News Report
National Marine Fisheries Service
World Trade Center
2 Canal Street, Suite 400-H
New Orleans, LA 70130-1206
This is a source of varied information on natural fisheries. It includes a monthly summary of marketing and price data on farm raised catfish. It is available by subscription.

Fisheries of the United States
Superintendent of Documents
Government Printing Office
Washington, DC 20402
This is an annual report inclusive of production, import, export, consumption and price statistics. It is prepared by the National Marine Fisheries Service.

INFOFISH
P. O. Box 10899
Kuala Lumpur, Malaysia 50728
This is a bimonthly publication inclusive of articles on overseas aquaculture and market development. It is available by subscription.

Journal of the World Aquaculture Society
World Aquaculture Society
Room 143, J.M. Parker Coliseum
Louisiana State University
Baton Rouge, LA 70803
This is a professional journal including scientific articles on all aspects of fish farming. It is available by subscription.

Salmonid Magazine
506 Ferry St.
Little Rock, AR 72202
This is a trade magazine with information and articles on the trout and salmon industries. It is published quarterly and is free to members of the U.S. Trout Farming Association.

Shrimp Notes
Shrimp World, Inc.
417 Eliza Street
New Orleans, LA 70114

This is a specialized newsletter that is a market news analysis covering domestic and international shrimp supply and marketing developments. It is available by subscription.

Water Farming Journal
3400 Neyrey Dr.
Metairie, LA 70002

This is a newspaper on current events in the aquaculture industry.

Other Publications and Sources of Information

Some excellent sources for financial planning are available from Cooperative Extension Service and Sea Grant Advisory Service Programs. Species-specific sources of financial information are often available. Ask for information on aquaculture and/or financial planning for agricultural enterprises.

Trade journals often carry useful financial planning information. The following selected articles are especially useful.

"Six Ways to Lose Money in Aquaculture." J. Lindbergh and K. Pryor. *Aquaculture Magazine* May/June 1984, p. 24-25.

"Preparing an Aquaculture Plan for the Lender." C. Collins. *Aquaculture Magazine* March/April 1991, p. 68-72.

"Primer on Aquaculture Finances." R.J. Rhodes. *Aquaculture Magazine.* A 4-part series from November/December 1983 to May/June 1984.

Literature Cited

Hollin, Dewayne, and Wade L. Griffin. 1985. Preliminary Economics of Shrimp Mariculture in Texas. George Chamberlain, Michael Haby, Russell Miget, (ed). Texas Shrimp Farming Workshop. Texas Agricultural Extension Service, Corpus Christi, TX.

Keenum, M.E., and J. E. Waldrop. 1988. Economic Analysis of Farm-Raised Catfish Production in Mississippi. Mississippi Agricultural and Forestry Experiment Station Tech. Bull. 155. Mississippi State University.

Parker, Jack C., and Wayne Hayenga. 1979. An Analysis of the Investment Considerations for Penaeid Shrimp Mariculture in Pond Systems. Texas A & M University, College Station, TX.

Pomeroy, Robert S. 1990. Estimated Costs of Marine Shrimp in One, 20-Acre Existing Ricefield Impoundment, South Carolina, 1990." Aquaculture Economics Fact Sheet. Department of Agricultural Economics, Clemson University, Clemson, SC.

Roberts, Kenneth J., David G. Marschall and Leona M. Burrell. 1990. The Economics and Marketing of Aquaculture in Dredged Material Containment Areas Technical Report (in preparation). U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

Rosenberry, Robert. 1990. *Aquaculture Magazine*, September/October, 1990. Asheville, NC.

Sadeh, Arye, Christopher Pardy, Wade Griffin and Addison Lawrence. 1986. Uncertainly Consideration Resulting from Temperature Variation on Growth of *Penaeus stylirostris* in Ponds. Texas Journal of Science, 38: 2.

Saucier, Roger T., Charles C. Calhoun, Jr., Robert Engler, Thomas R. Patin, and Hanley K. Smith. 1978. Executive Overview and Detailed Summary. Technical Report DS-78-22. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.