TEXAS AQUACULTURE

STATUS OF THE INDUSTRY

Review Draft
for
1990 Texas Aquaculture Conference
January 30-February 1, 1990
Corpus Christi, Texas

Texas Aquaculture Association

Texas Agricultural Extension Service

Texas A&M University Sea Grant College Program

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Edited
by
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Printed
by
Texas Water Commission
1700 North Congress Avenue
Austin, Texas 78711-3087

Sponsored
by
Texas Aquaculture Association
Texas Agricultural Extension Service
Texas A&M University Sea Grant College Program

FINANCIAL CONTRIBUTORS

Much of the educational cost of this conference was defrayed by contributions from aquaculture support groups. Their strong commitment to aquaculture in Texas has allowed us to offer an outstanding program. We wish to acknowledge and thank the following contributors:

Central Power and Light Company
Corpus Christi Area Economic Development Corporation
Corpus Christi State University
Department of Wildlife and Fisheries Sciences, Texas A&M University
Guadalupe-Blanco River Authority
Gulf States Utilities Company
Jackson Electric Company
Lower Colorado River Authority
Matagorda County Navigation District Number 1
Texas Agricultural Experiment Station - Corpus Christi
Texas Department of Agriculture
Texas Food Industry Association
Texas General Land Office
Texas Parks and Wildlife Department
Texas Water Commission
Wharton County Electric Cooperative, Inc.

FORWARD

This document was generated in an effort to evaluate the status of the aquaculture industry in Texas for the occasion of the 1990 Texas Aquaculture Conference on January 30 - February 1, 1990, in Corpus Christi, Texas. This conference marked several important events including the passage of the "Fish Farming Act of 1989" through the Texas legislature, the 20th anniversary of the Texas Aquaculture Association, the first year that the conference location was changed from its traditional venue on the campus of Texas A&M University in College Station, and the first year that TAA used the conference as a fund-raising event. The conference planning committee, which consisted of the following individuals is acknowledged for their role in initiating the preparation of this report:

Brian Brawner, Red Ewald,Inc.
George Chamberlain, Texas Agricultural Extension Service
Michael Haby, Texas Agricultural Extension Service/Sea Grant
David Maus, Redfish Limited
Russell Miget, Texas Agricultural Extension Service/Sea Grant
Vance Schultze, Tank Hollow Fisheries
William Younger, Texas Agricultural Extension Service/Sea Grant

The authors of each chapter of this report were asked to survey the current status of the industry, especially the impediments hindering development, and recommend actions needed to stimulate growth. This process has relied heavily on participation by industry, university, and agency staff. The final step in the review process will be to provide a copy of this preliminary draft to all participants at 1990 Texas Aquaculture Conference to solicit their review and comment. Plans are to incorporate the revisions into a final status report which will be printed as a Texas A&M University Sea Grant College Program publication.

ACKNOWLEDGMENTS

We acknowledge the efforts of Robert Stickney and James Davis who compiled the 1981 publication, "Aquaculture in Texas, a Status Report and Development Plan", which was used as a guide for this report.

We would like to thank Rick DeVoe and Sandy Harris of the South Carolina Sea Grant Consortium for their guidance which was particularly helpful since South Carolina completed a similar aquaculture review shortly before this one. The line art used in the species chapters is the work of Mr. John Norton (Dept. of Biol. Sc., Clemson University, Clemson, S.C 29634) some of which first appeared in "The Strategic Plan for Aquaculture Development in South Carolina".

It has been considered vital to the accuracy of this document to utilize wide industry and governmental input on both a state and national level. In order to describe the present status and identify the relevent issues, many individual contacts, group meetings and surveys were conducted throughout the state during the Fall of 1989. We have attempted to recall all who participated in this process to individually recognize them in the listing given below. We apologize to the many who inadvertently have been omitted from this list.

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EXECUTIVE SUMMARY

Aquaculture is playing a steadily increasing role in world seafood production due to increasing demand for fishery products, limited capacity of traditional capture fisheries, and advancements in aquaculture technology. World aquaculture production in 1985 was estimated to account for 11% of the total world harvest of fishery products. In the United States, 12.5% of the U.S.-supplied edible fish and shellfish was produced via aquaculture in 1988. Aquaculture is the fastest growing agricultural sector in the United States, increasing over 20% annually in the last decade.

The majority of U.S. aquaculture production occurs in the South. Mississippi, Arkansas, Alabama, and Louisiana account for about 90% of U.S. catfish production, which is valued at over $300 million per year. Louisiana contributes about 80% of the U.S. crawfish production. Arkansas is the center of the U.S. baitfish industry, accounting for 75% of its annual value of $71.5 million. Florida accounts for 95% of the $24 million tropical fish industry.

The objective of this report is to describe the current status of aquaculture in Texas and describe its potential for growth. The first part of the report describes the overall aquaculture environment in Texas. Major topics include: natural resources, regulations, infrastructure for processing and financing, and technical information sources. The second part of the report deals with the status of each ofthe major fresh and salt water species being cultured in Texas.

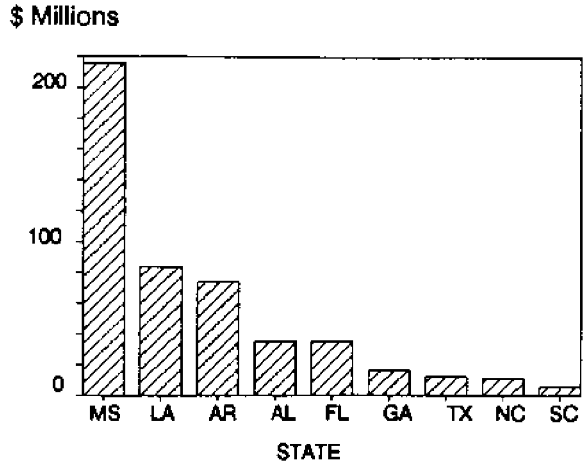
Estimates of 1989 farm-gate value collected during this study total approximately $12.2 million (Table 1). This value excludes the wholesaling and distribution aspects of the aquarium industry and the live bait industry. It also excludes the production value of private oyster leases ($2.7 million), since those presently seem more related to fisheries management than aquaculture. Thus, the Texas aquaculture industry is relatively small in comparison to that of other southern states (Fig. 1).

Table 1. Estimated 1989 farm-gate value of of major cultured species in Texas

SPECIES	VALUE ($ thousands)
Catfish	3500
Aquatic plants	2400
Penaeid Shrimp	1670
Crawfish	1600
Sportfish	1500
Tilapia	500
Baitfish (freshwater)	250
Red Drum	250
Alligators	50
Baitfish (marine)	100
Buffalo	10
Chinese/Indian Carp	80
Common Carp	10
Crabs	150
Freshwater Shrimp	25
Goldfish	150
Total	12245

$ 12.2 mill

FIGURE 1. ESTIMATED AQUACULTURE VALUE OF SELECTED SOUTHERN STATES



In general, Texas aquaculture is characterized by small, family- owned farms which sell their product to local markets. A compelling question is "Why isn't Texas aquaculture bigger?"

A key issue is whether the natural resources in Texas are adequate to support expanded aquaculture operations.

NATURAL RESOURCES

Fresh Water

Water supply is thought to be the most crusial natural resource limiting freshwater aquaculture in Texas. Water requirements for an integrated aquaculture development (4000 surface acres of ponds and a moderate sized processing plant) were estimated at 35,000 acre feet per year. Probable locations for groundwater and surface water availability in Texas are presented by the Texas Water Development Board (TWDB) and the Texas Water Commission (TWC). However, it is unlikely that 35,000 ae feet per year will be available as surplus in most areas of Texas. It may be necessary to purchase or negotiate use of irrigation water rights to accomodate such a large water demand.

Salt Water

Texas is unique in its salt-water aquaculture resources. Unlike other southern states, Texas has relatively large tracts of undeveloped property suitable for pond construction adjoining several of its bay systems. Salt water ponds can also be constructed in certain inland areas such as the Trans Pecos area of West Texas where saline groundwater is available.

Soils and Climate

Suitable soils for pond construction are widely available; however on-site evaluations are recommended because of local variability. Rainfall and temperature in the eastern two-thirds of the state are generally conducive to aquaculture.

REGULATORY ENVIRONMENT

Restrictive or cumbersome regulations are a common complaint of the industry. A summary is provided of federal, state, and local aquaculture regulatory requirements which may reduce difficulties that arise due to incomplete information about the agencies involved. Much of the regulatory problem may relate to the historically small, fragmented nature of the industry and its inability to unify and gather support for needed changes. Furthermore, licences and permits have traditionally been issued by the resource management agency, Texas Parks and Wildlife Department, whose primary responsibility is conservation and management of the state's natural resources. Industry promotion has not been forthcoming with this arrangement. Recently, aquaculture licensing and promotional responsibilities were transferred to the Texas Department of Agriculture.

A number of specific regulatory issues have been identified as problematic by industry members. These include:

- ban on marketing of hybrid striped bass for human consumption
- proposed ban on certain exotic species. Existing regulations allow only two species of tilapia (*Oreochromis aureus* and *O. mossambicus*) and their hybrids and a proposed ruling would limit carp to two species (silver and black).
- other issues include policies regarding shrimp virus disease, water intake filtration, certification of oyster growing areas, bird depredation, and approved chemicals

Many of these problems are likely to be resolved through the improved administrative structures established by the Fish Farming Act of 1989 and the growing size and unity of the Texas aquaculture industry.

INFRASTRUCTURE

One seemingly contradictory answer to the question of: "Why isn't Texas aquaculture bigger?" is that "it isn't big enough to get bigger". Most farms are unable to expand beyond the capacity of their local markets, because major markets are dominated by highly competitive integrated industries from other states or countries.

The term, "integrated", is meant to imply a fully developed production system taking advantage of appropriate economies of scale in the hatchery, grow-out, feed production, processing, and marketing components. Due to the relatively small size of the aquaculture industry in Texas, important support facilities are relatively undeveloped. Infrastructure, such as feed mills, processing plants, offal rendering plants, marketing networks, and financing systems, is critical in reducing costs of inputs and maximizing value of aquaculture products. Without improved infrastructure, Texas will be at a competitive disadvantage with other states and countries.

Feed Mills

Although some aquaculture feed is produced in Texas, no feed mills are presently dedicated to production of aquaculture feed. Thus, benefits of feed quality, variety, and price have not yet been achieved. Most of the feed used in Texas is imported from other states, especially Arkansas, Mississippi, and Idaho. A single dedicated aquaculture feed mill in Texas could stimulate aquaculture development over a broad area by reducing freight costs and offering a wider variety of specialty feeds. Reducing feed costs is a major concern, because feed is the single largest cost in most aquaculture operations.

Processing Plants

The typical family-owned fish farm in Texas markets its products fresh to local markets to avoid competition with frozen fish produced by large integrated farms in other states. Some hand processing occurs at the farm on a custom basis. Until this year, no dedicated aquaculture processing plant existed in Texas. The Naiad Corporation, a large new catfish farm being developed near Angleton, expects their plant to be operational by mid-January 1990. The development of this plant will provide an important outlet for farm-raised fish within a 30-50 mile radius of the plant. Some growers plan to haul their fish over 100 miles to the new facility. Eventually, several additional processing facilities will be required in other areas of Texas.

Lack of processing capability also limits the growth of the Texas crawfish industry, which presently markets all of its product in live form. Shrimp producers are fortunate in having access to processing plants built to handle wild catch.

Marketing Networks

Marketing networks for Texas farm-raised seafood are poorly established. Many seafood wholesalers and distributors are simply unaware of the products being produced in Texas. This problem could be solved by periodic distribution of a Texas aquaculture products directory to logical marketing outlets. Major markets are often inaccessible to individual Texas producers, because their production quantities are too low or inconsistent. Pooling of products from several farms could qualify producers for some larger markets.

Financing

Financing aquaculture development is difficult in Texas at this time. Contributing to this situation are the generally unstable status of Texas banks, the lack of an industry track record, and the relative inexperience of bankers in dealing with aquaculture projects. A description is provided of the various government and non-government funding sources. The lack of readily available crop insurance contributes to the difficulty in financing projects.

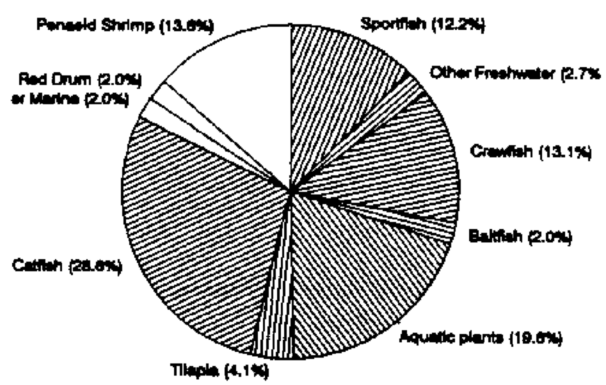
Education and Training

Three Texas universities presently offer academic programs in aquaculture: University of Texas, Texas A&M University, and Corpus Christi State University. Extension services are available to provide aquaculture advisory assistance, disease diagnostic support, and assistance in field trials. Other sources of technical information from the literature and electronic media are also identified.

SPECIES EVALUATIONS

The majority of the farm-gate value of the Texas aquaculture industry is composed of freshwater rather than salt-water species (Fig. 2).

FIgure 2. Relative Value Of Freshwater (stipled) and Salt Water (clear) Aquaculture Species In Texas



Status of Freshwater Species

Catfish

As stated above, the catfish farming industry in Texas is characterized by many small family-owned farms which sell their product to local markets. These farms cannot compete in major markets with large integrated farms in Mississippi, Arkansas, Louisiana, and Alabama, because they pay higher prices for feed and fingerlings and have no access to processing plants.

Another disadvantage is the proposed regulatory restriction prohibiting the use of certain carps, which are routinely introduced into catfish ponds to control excess algae, zooplankton, and bottom organisms. Not only do carp improve water quality and thereby reduce water replacement, they also provide an important additional source of income. Carps are thought to be particularly important in Texas aquaculture where adequate water availability is an issue.

Entry into larger markets will require construction of necessary infrastructure (feed mills and processing plants) and provision of financing mechanisms. An important step in this direction has already occurred with the construction of the new Naiad Corporation ponds and processing plant near Angleton. More facilities of this type should be encouraged to develop in areas with appropriate natural resources to support major development.

Crawfish

The Texas crawfish farming industry operates an estimated 5,000 acres of ponds which are concentrated in the eastern and mid coastal areas of the state. This industry competes directly with both wild and farm-raised crawfish from Louisiana. Marketing limitations are caused the seasonal nature of crawfish production and the nearly exclusive sale of live product. Technological assistance is needed to improve efficiency of artificial feeds, develop less labor intensive harvesting methods, and extend the production season.

Baitfish

The baitfish industry, which primarily utilizes golden shiners, produces only about $ 250,000 of minnows, on less than 100 acres of ponds. However, the Texas baitfish industry sells an estimated $ 10 million of product annually. This is because most of the fish are produced in Arkansas and simply distributed in Texas.

The Texas bait industry seems unable to compete against the large mature farms in Arkansas. One exception is in the production of tilapia for use as bait, because Texas has a climate more suitable for this tropical fish than does Arkansas. However, current regulations prohibit the use of tilapia as bait. Opportunities may arise for baitfish production in Texas, as the size of the industry in Arkansas seems to be approaching its limit.

Tilapia

According to USDA figures, tilapia is the fastest growing U.S. aquaculture commodity, showing an impressive 25 million pounds of production in 1988. Tilapia is a common name which refers to many fishes of the cichlid family which are native to tropical Africa. Several species have exhibited excellent aquaculture potential in culture systems ranging from low density fertilized ponds to high density indoor tanks. Current regulations permit the culture of only two tilapia species and their hybrids (see above). Texas producers feel a competitive disadvantage with other states who have access to additional species, particularly *O. niloticus*.

Sportfish

Sportfish production in Texas utilizes about 250 acres of private ponds and 150 acres of public-sector ponds. The largemouth bass is the most important of the sportfish stocking species; others include: bluegill, redear sunfish, hybrid sunfish, black and white crappies, and hybrid striped bass. Forage species include: tilapia, fathead minnows, golden shiners,and threadfin. The sportfish industry feels that additional research is needed on such topics as pedigree certification of largemouth bass and development of reducing predation by cormorants. Other issues are regulations, water rights, and competition from government sources producing sportfish fingerlings.

Other Freshwater Species

The production of aquatic plants comprises a higher than expected proportion of the value of the Texas aquaculture industry. In Florida, it has been reported that this is the fastest growing segment of the aquaculture industry. Much of the Texas production consists of ornamental waterlillies for landscaping. However, plants needed for wetlands mitigation are also produced.

Other freshwater species such as ornamental plants and fish, alligators, freshwater shrimp, and various carps, goldfish, and buffalo have potential for growth in Texas. The ornamental fish industry in particular has considerable potential for expansion to support the $1.5 billion aquarium business in Texas. Both freshwater and marine tropical aquarium fish should be considered.

Salt Water Species

Penaeid shrimp

Penaeid (salt water) shrimp have been farmed commercially in Texas for about 8 years. Most of the nine existing farms have been operating for only the last 3 years. Despite considerable advances in production techniques, some farms are still suffering from poor or inconsistent production rates. Supply of postlarvae was considered the most serious issue facing the industry during 1989. Complicating this were concerns about regulatory policy regarding virus diseases of exotic shrimp species. Improved communication and planning are expected to relieve postlarval supply problems during 1990. Other issues which strongly affect profitability are the need for improved marketing and the need for a less expensive, locally produced, high quality feed.

Red Drum

Interest in red drum farming has been high in Texas since restrictions on commercial harvest began during the early 1980's. Recent legislation bans sales of all red drum in Texas except those from farm-raised sources. Despite the high demand and exceptional prices that now exist for red drum, producers have been unable to supply significant quantities of product. Unlike the initial years of development when fingerling availability was the bottleneck, the major problem now is mortality of fish during the winter due to low temperature intolerance. Although a variety of pond warming techniques were tried during 1989, the record freeze of December, 1989, proved most of these to be inadequate. Some producers intend to begin moving fish indoors during the winter, or simply raising them indoors throughout the production cycle. A compromize, such as greenhouse -covered overwintering ponds may prove to be the most economical solution. Other issues include the need for additional research an a variety of topics, especially disease control and the need for cooperative arrangements among growers for cheaper feed, processing, and marketing.

Hybrid Striped Bass

The striped bass fishery of the east coast of the United States has dramatically declined, and it is now severely restricted by regulations. As a result, aquaculture groups have begun producing the hybrid bass, a cross between striped and white bass that much resembles a striped bass. The aquaculture performance of the hybrid is superior to that of either parent. This fish performs well in both fresh and saline water, tolerates cold winters, and commands a high market price. Some producers feel that this may be an ideal choice for culture in Texas. Unfortunately, current regulations prohibit sale of farm-raised hybrid bass for human consumption in Texas. Ironically, it is not illegal for out-of-state producers to sell hybrid bass in Texas. Despite this regulatory problem, several Texas have begun pilot-scale trials of hybrid performance Texas to gain production experience in anticipation of an imminent change in the law.

Bivalves

Although potential exists to culture a variety of bivalves oysters, clams, and scallops in Texas, only oysters are attracting commercial aquaculture interest at this time. An oyster hatchery and a raceway grow-out operation were recently initiated on Matagorda Bay. In addition, several shrimp growers have attempted to rear oysters in shrimp ponds as a means of removing excess algae and producing a valuable second crop. Unfortunately, current regulations prohibit marketing of oysters harvested from private waters, because those waters don't presently fall under the certification program of the Texas Department of Health Shellfish Sanitation Program. This regualtion must be modified before oyster culture in private ponds or raceways will be possible.

A relatively large infrastructure for private oyster leasing exists in the Galveston Bay area. Oyster lease holders practice mariculture to a degree when they harvest oysters from closed reefs and transfer them to approved reefs for depuration and growth. Considerable potential exists to increase the production of oysters from private leases through more intensive aquaculture.

Other Saltwater Species

As commercial harvest of popular saltwater species is steadily restricted, their demand and value is expected to increase to the point where aquaculture may become feasible. A variety of Gulf of Mexico fishes are likely to fall into this category in the next 5-10 years. These include red snapper, grouper, dolphin fish, and pompano. Other crops such as soft-shell crabs, bait shrimp, and brine shrimp also have much potential.

CONCLUSION

Texas has a variety of fresh and salt water resources which can support a diversity of aquaculture systems. However, producers will have to be careful in matching the appropriate species and culture system with the resources in agiven region. Regulations currently inhibit the growth of the industry in several areas, but needed changes are thought to be possible through a united industry-wide educational effort.

Lack of appropriate infrastructure is a major impediment to industry growth. State supported financial incentives may be necessary to stimulate initial development of critical support facilities such as feed mills, processing plants, rendering facilities, and financing systems. A common interest of virtually every producer was for more research and development on practical production techniques. However, appropriate facilities do not presently exist in Texas. The industry would benefit from development of a Texas Aquaculture Center for developing, comparing, and field testing new technologies.

AQUACULTURE OUTLOOK

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INTRODUCTION

Experts closely associated with food-related industries have stated that the 1990's will show a greater reliance on aquaculture to supply the growing demand for fishery products worldwide. The Virginia Agriculture Commissioner recently stated "I see aquaculture produced products becoming a major supply and a reliable source of food by the mid 1990's and into the year 2000. Every 10 million pounds of aquacultural production will produce 1,300 jobs on farms and in related industries." This chapter will address some of these trends.

The Food and Agriculture Organization of the United Nations (FAO, 1986) reported the average per capita world consumption of fish and shellfish to be 26.7 pounds or 12.1 kilograms. The following three factors point to an increasing role for aquaculture in fishery markets: (1) limitations on world landings and world supplies of fishery products, (2) increasing world demand for fishery products; and (3) technological advancements in aquaculture production (U.S. Dept. of Commerce, 1988).

U.S. Consumption of Fishery Products

There is a rising demand for fishery products in the U.S. Consumer demand for fishery products (fish and shellfish) has grown through the 1980's. From 1980 to 1988, the U.S. per capita consumption of edible fishery products rose from 12.8 pounds (5.8 kg) to 15 pounds (6.8 kg) (NMFS, 1989). This represents an increase of 17 percent. U.S. per capita consumption of fishery products (including aquaculture and recreational catch), was estimated at 19.8 pounds (USDA, 1989). In 1988, the U.S. per capita use of all fishery products (edible and industrial) was 59.4 pounds (27 kg) round weight. This figure was up from 49.9 pounds in 1980. Some factors which contribute to this rising demand and increased consumption are changing lifestyles, increasing incomes and increasing awareness of the health benefits associated with eating fishery products.

The U.S. demand for fishery products is satisfied by domestic supplies and by imports. As catches of these fishery products have approached or exceeded their maximum sustainable yields in the United

States, imports from capture fisheries and from aquaculture have helped to meet the ever-increasing demand. In fact, next to petroleum and automobiles, fishery products now account for one of the United State's largest trade deficits. (Fig. 1). Historically, the U.S. has incurred a substantial fishery trade deficit since 1895.

Sources of Commercial Fishery Products

In 1987, the most recent year for which data are available, world commercial fishery products were 93 million metric tons. Japan continued to be the leading nation (Fig. 2) in the production of fishery products, followed by the U.S.S.R., China, U.S.A., Chile, and Peru (NMFS, 1989). The Food and Agriculture Organization of the United Nations (FAO) projects that global demand for fish (all aquatic species) could reach 114 million metric tons by the year 2000, and estimates world production of 94 million metric tons, resulting in a shortfall of 20 million metric tons. (U.S. Dept. of Commerce, 1988 and FAO, 1987).

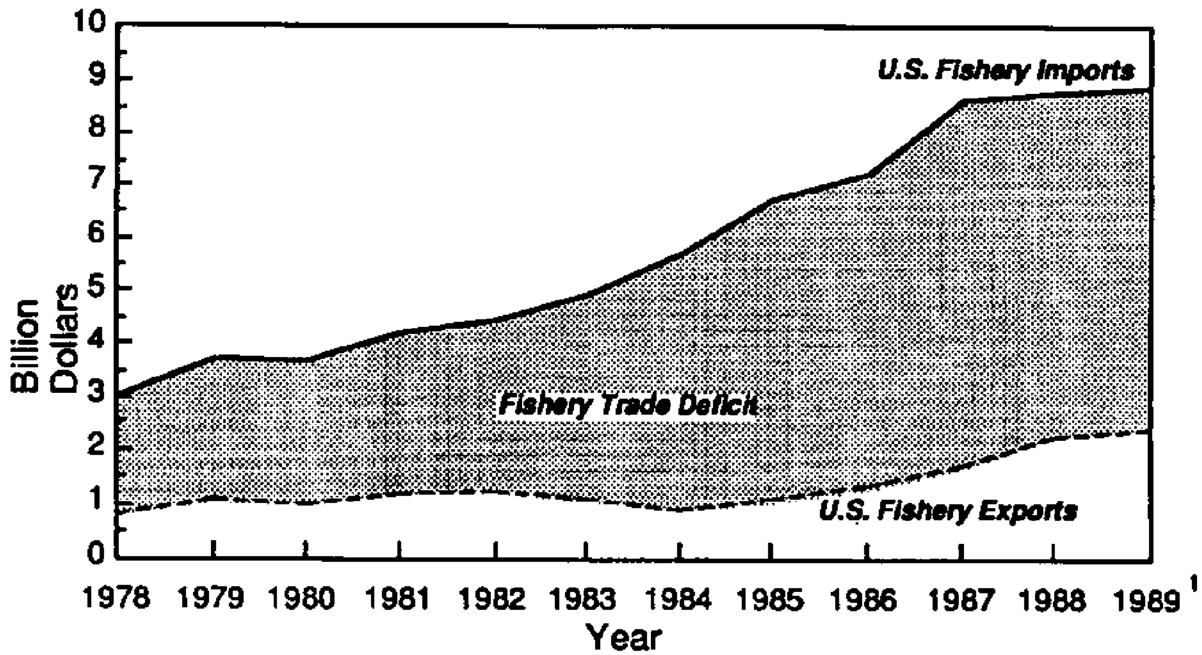
U.S. Production and Consumption

The U.S. ranks 4th in fishery products production among the major producing countries. U.S. commercial landings (edible and industrial) were 7.2 billion pounds (3.3 million metric tons) valued at $3.5 billion in 1988 by fishermen at ports in the 50 states. In addition, commercial landings by U.S. fishermen at ports outside the 50 states totaled 3.8 billion pounds (1.7 million metric tons) valued at $489.9 million (NMFS, 1989). In 1987, the U.S. produced a total of 5.8 million metric tons of fishery products, if landings at foreign ports are counted (FAO, 1987).

According to Business Communications Company, Inc. (1989), U.S. commercial harvesting of fish and shellfish for food is a $3.36 billion industry and processed fishery products are valued at over $5 billion. Purchases of fishery products, both processed and unprocessed, by food service and food stores totaled $13 billion in 1988, and consumer sales value of all fishery products sold in the U.S. totaled almost $30 billion in 1988. However, the United States

Figure 1

U.S. Foreign Trade of Fishery Products



[1] 1989 Projected

Source: NMFS, 1989

imported $5.5 billion worth of edible fish and fishery product such as fish meals and fish oils in 1988. The value of fish and fish products were exceeded only by that of Petroleum products ($16.7 billion in 1987).

Much of U.S. seafood production appears to be at or near maximum sustainable yield. The U.S. supply of tuna, for example, appears to have leveled off since 1979, (Fig. 3) with imported tuna supplying increases in demand. Canned tuna was a $1.02 billion business in the U.S. in 1988.

U.S. shrimp landings appear to have leveled off since 1976 (Fig. 4; compiled from Current Fishery Statistics, U.S. Department of Commerce, 1976-1989). Shrimp imports have increased to satisfy increasing demand. The 1988 U.S. trade deficit for imported shrimp was $1.8 billion.

Other species are showing similar trends. The wild salmon catch has been relatively stable in the U.S. since 1980, but imports of salmon into the U.S. have increased dramatically during the same period (U.S. Dept. of Commerce, 1988). Fresh pen-raised salmon first appeared on the U.S. market in significant quantities in 1979 and 1980. Not long after its introduction, it became one of the most widely sought after specialty fishery products in the United States. Imports of fresh, farmed salmon rose from 726 metric tons in 1980 to more than 12,700 metric tons in 1986. The import value jumped from $3.9 million to almost $78 million.

Commercial catches of other U.S. fishery products have also stabilized or declined as can be seen for oysters taken from four different regions in

Figure 2

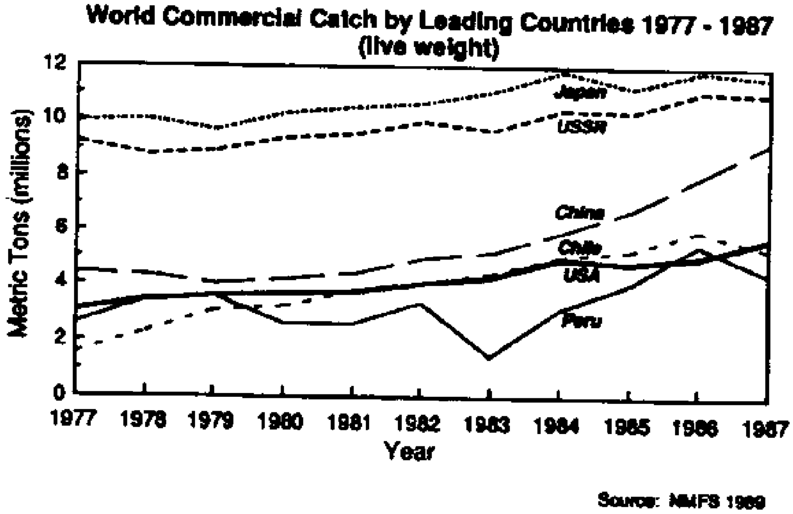


Figure 3

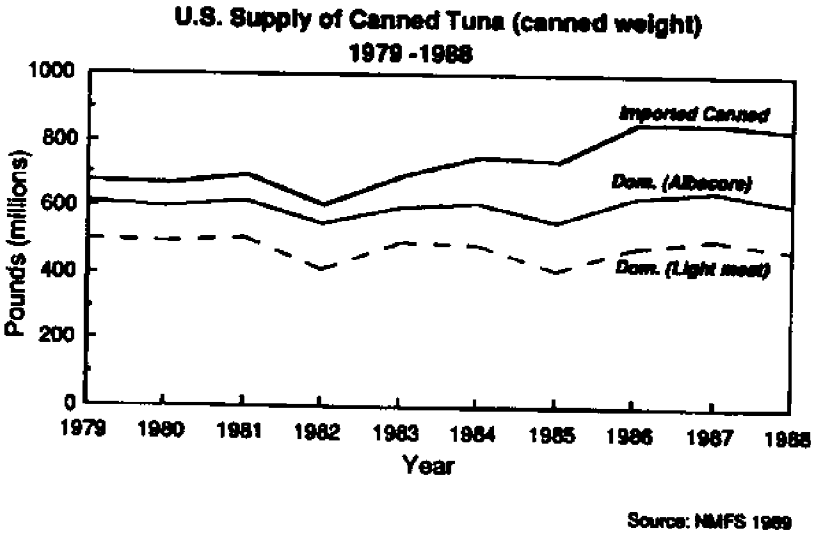
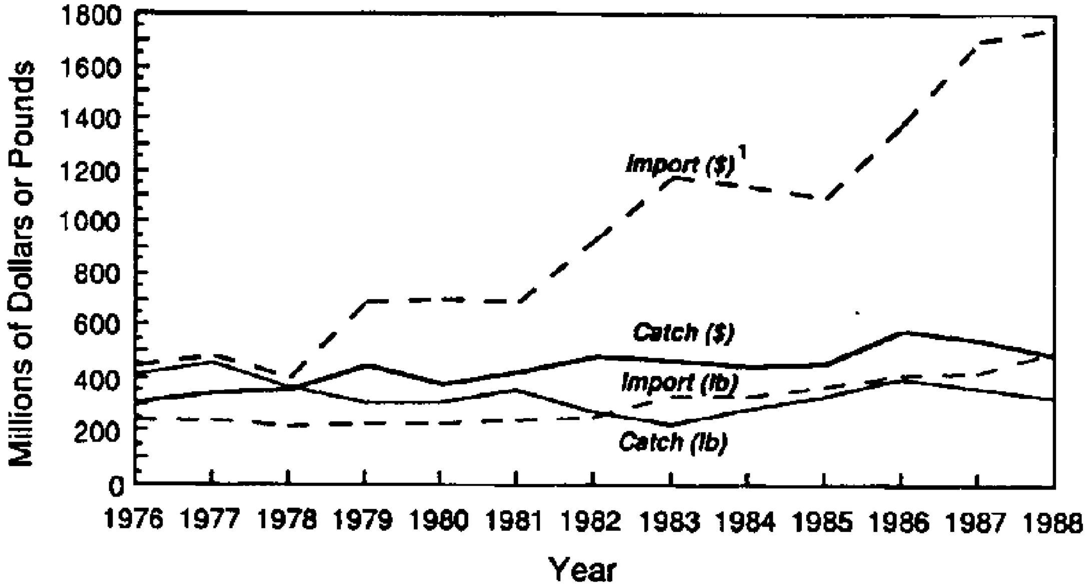


Figure 4

U.S. Shrimp Catch (——) and Imports (– –)

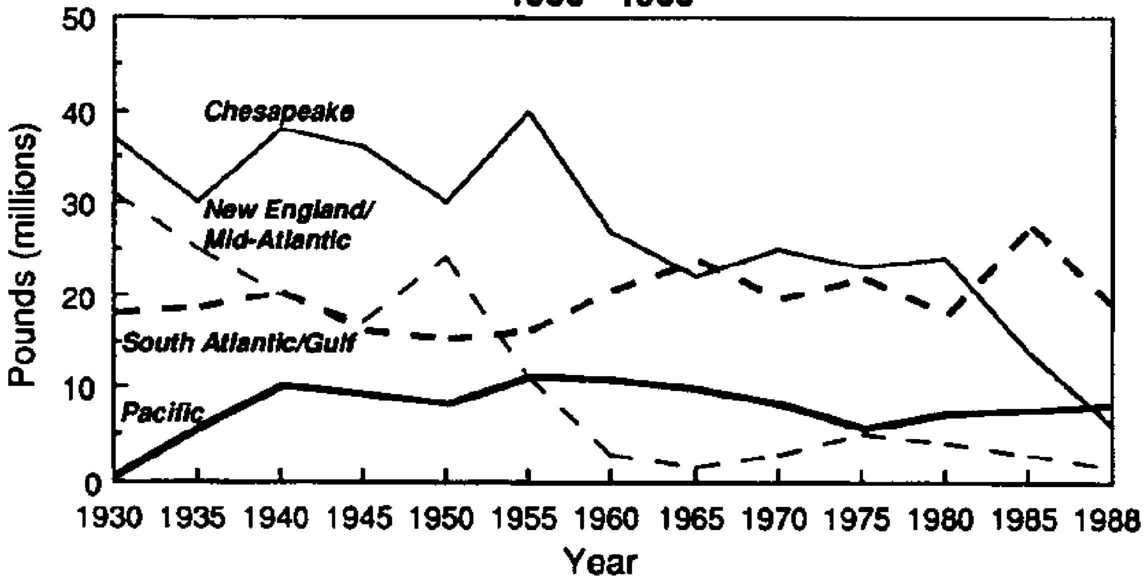


[1] Includes all shrimp forms; raw, peeled-deveined, etc.

Source: U.S. Department of Commerce, 1976 - 1989

Figure 5

Historical Oyster Landings in U.S., by Regions 1930 - 1988



Source: NMFS 1989

the U.S. from 1930 to 1988 (Figure 5). The total for U.S. mollusk landings in 1988 was 317 million pounds of meat valued at $415 million (USDA, 1989). Mollusk imports were estimated at 120 million pounds of meat and $250 million, and exports were 15 million pounds and $20 million. This leaves 420 million pounds of mollusks available for consumption. While this shows that mollusks are a sizable market, the volume available for consumption has not increased greatly since 1980 and for some mollusks (notably oysters) domestic harvest has fallen greatly (USDA, 1989).

In general, the entire U.S. supply of both edible fishery products (Fig. 6) and industrial fishery products (Fig. 7) has been relatively static during the last decade, and imports have increased to meet the demand. There has been an increase in pollock landings from 1986 to 1988 which accounts for the upward inflection of U.S. commercial landings in Figure 6. According to U.S.D.A. (1989) pollock landings have grown more than 1.1 billion pounds in the last two years, but if pollock were excluded from U.S. edible fish landings, the catch would have decreased 17 percent from 1980 to 3.3 billion pounds

Figure 6

U.S. Supply of Edible Fishery Products (round weight) 1979 - 1988

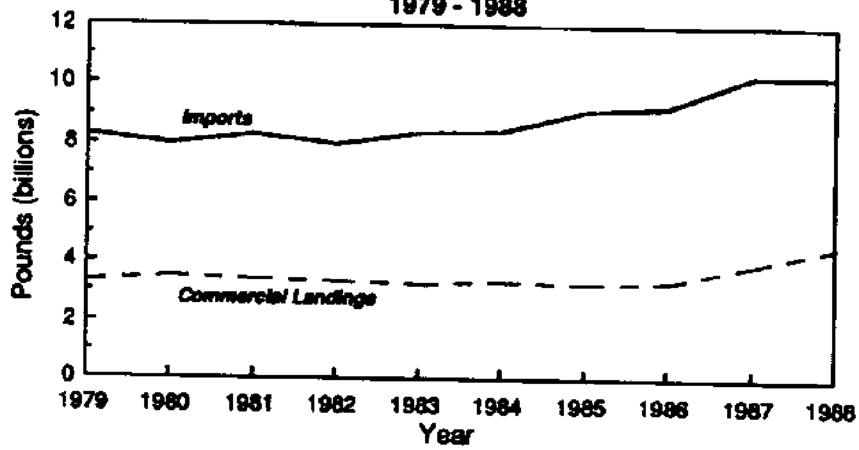
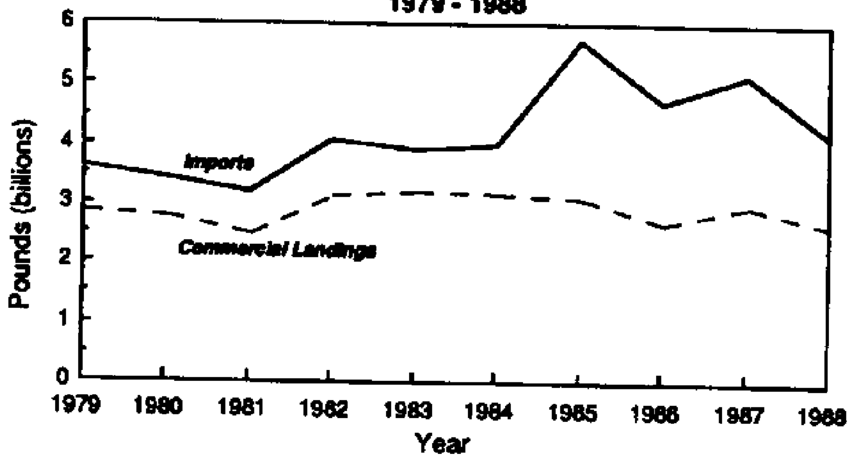


Figure 7

Supply of Industrial Fishery Products (U.S., round weight) 1979 - 1988



Source: NMFS 1989

in 1988. Figure 7 demonstrates the leveling off or slight decrease in the commercial landings of industrial fishery products. When these commercial landings of industrial fishery products are combined with the commercial landings of edible fishery products and the landings are averaged, then a leveling trend is apparent. There is growing evidence that most traditional commercial species are being fisshed near their maximum sustainable yields. Significant increases in landings are not expected. In fact, declines could occur with some species due to overfishing, lack of freshwater inflow to estuaries, loss of wetlands, and pollution.

As the upward trend in the demand for fishery products continues, the U.S. is ever-seeking new sources of fishery products. One area which has grown rapidly is the U.S. production of surimi or seafood analogs. (see Figure 8). Surimi is a tasteless, odorless fish paste made from the washed flesh of bland white-fish. It is the raw material for many seafood products called analogs, the most popular of which is kamaboko, or imitation crab. Other analog products are imitation versions of lobster, scallops, and shrimp, which are shaped and colored like the real thing. Surimi is made mostly from pollock, although other fish have been used such as the croaker. The first U.S. surimi plant opened in 1981 in Southern California. In 1982 U.S. consumption of surimi jumped from 6 million pounds to 18 million and since then consumption has grown steadily. Consumption of surimi in the U.S. was 135 million pounds in 1988 (primarily imitation crab), up 20 percent over 1987. The U.S. surimi exports are projected to climb to 249 million pounds in 1989, most of which will go to Japan. The business Communications Company, Inc. (1989), predicts that U.S. production of surimi will total 470 million pounds by 1995, experiencing an average annual growth rate of 20.7 percent.

Figure 8

United States production of Surimi, ie., imitation crab, lobster, scallops, and shrimp.

YEAR	PRODUCTION
1987	40 Million Pounds
1988	126 Million Pounds
1989 (projected)	344 Million Pounds

Resource managers in the U.S. are facing unprecedented pressures to provide opportunities for the recreational fishery, while still meeting demands of the commercial fishery. In 1985, 46.4 million recreational fishermen spent $28.1 billion and landed an estimated 20% of the fish produced in the United States. At the current rate of expansion, recreational demand for fish will double before the year 2010. As a result of this growing conflict over resource allocation, U.S. fisheries are heavily regulated and new regulations are being imposed on the fisheries continually. Some recent examples have been the ban of the commercial fishing of red drum, the new reef fishery management plan, and the U.S. Department of Commerce's T.E.D. regulations. Regulations and the associated permits, licenses, inspections and certifications are intended to protect the citizenry, their rights and property, related business interests, and common specific resources (the fishery for example), including the general environment. Increasing regulations are inevitable.

Texas Fisheries Production

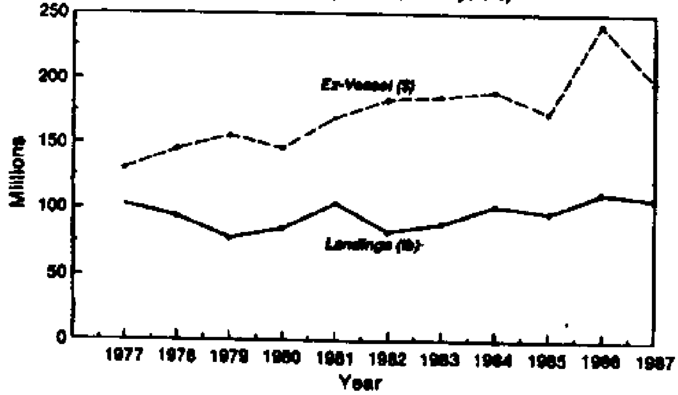
Texas fishery products have shown many of the same trends described above. Texas fisheries are also facing increasing regulations. For example, the sale of red drum and spotted sea trout was prohibited by the 67th Texas Legislature in September, 1981, and shrimp and oyster fishery management plans have recently been introduced. However, in the 11-year period of 1977-87 more than 1.1 billion pounds of fishery products valued at more than $1.9 billion were reported harvested from Texas bays and the Gulf of Mexico, and landed in Texas. These fishery products continue to consitiute a very important industry in Texas. Approximately 98 million pounds of these products are harvested annually with an average ex-vessel value of $175 million (Texas Parks and Wildlife, 1988).

Shrimp continue to be the most important commercial fishery product landed in Texas, followed by crabs, oysters and finfish. Texas fishery landings have also been relatively static since 1977. Shellfish landings (including shrimp, crabs and oysters) have consistently totaled about 100 million pounds since 1977 (Fig. 9). Texas finfish landings declined from 1977 to 1981 and have essentially leveled off since 1981 (Fig. 10). When all fishery products landings in Texas are combined for the same period (1977-87) a general leveling trend can be seen. Total coastwide annual landings fluctuated around 100 million pounds during this period, ranging from 81 to 116 million, while total ex-vessel prices ranged from $133 to $246 million (Fig. 11).

Competition for the fishery resources is increasing in Texas. The number of commercial fishing licenses sold in Texas has increased from 10,382 in 1956 to 11,042 in 1987. There were 125 Gulf shrimp boat licenses sold in 1959 and 3,038 licenses sold in 1987.

Figure 9

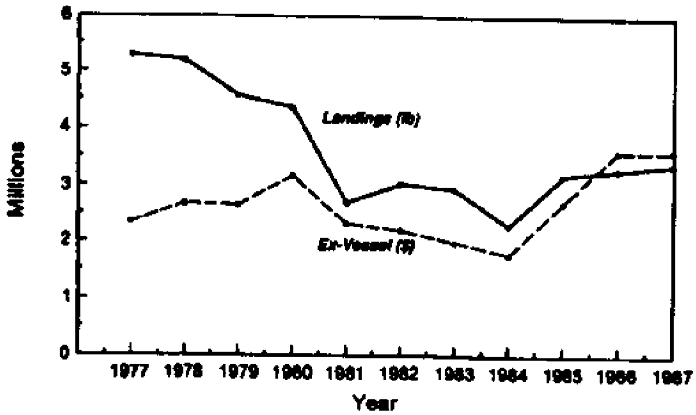
Texas Commercial Shellfish Landings
(including shrimp, crabs, and oysters)



Source: Texas Parks & Wildlife, 1988

Figure 10

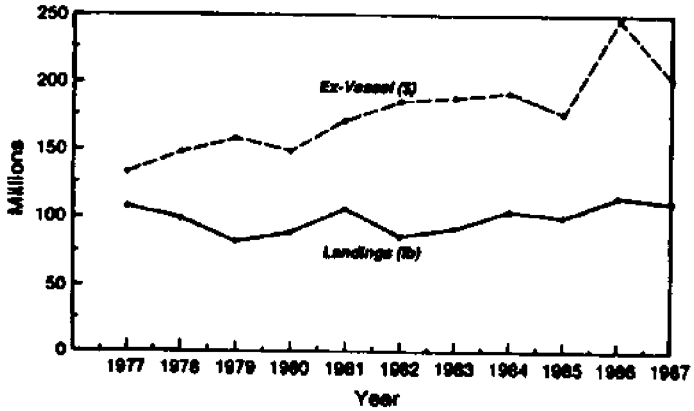
Texas Commercial Finfish Landings



Source: Texas Parks & Wildlife, 1988

Figure 11

Texas Commercial Landings of All Fishery Products



Source: Texas Parks & Wildlife, 1988

There were 24 Bay boat licenses sold in 1963 and 3,402 licenses sold in 1987. There were 150 commercial oyster dredge licenses sold in 1956 and 221 sold in 1987 (Texas Parks and Wildlife, 1988).

Increased competition for the natural fishery resources, increased regulation of the resources, as well as a leveling or declining of the fishery landings will surely continue as demand for the product increases. These factors all point to an increasing role of aquaculture as a food source.

STATUS OF AQUACULTURE

World Status

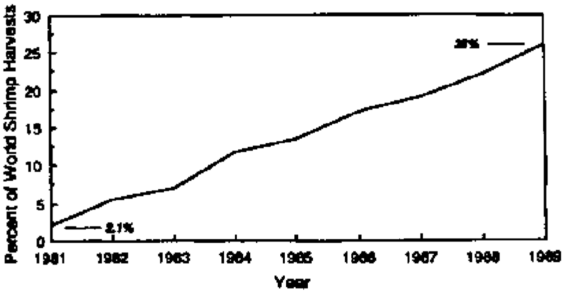
At lease 181 aquatic animal species (102 fishes, 32 crustaceans, 44 mollusks, and 3 miscellaneous) as well as a host of plant species are cultured worldwide (Ratafia and Purinton, 1989). The Food and Agriculture Organization of the United Nations continues to give a strong growth forecast for aquaculture (FAO, 1988). In 1989, FAO revised their data for world aquaculture production in 1985. Their estimate for total production of both marine and freshwater species was 11.1 million metric tons (24 billion pounds), which accounted for over 11 percent of the total world harvest of fishery products. A more recent estimate from a different source puts world aquaculture production over 22 billion pounds per year (Water Farming Journal, 1989). Most of this production came from Asia, followed by Europe, then North America, U.S.S.R, South America and Africa (Table 1). The 1986 world aquaculture production (FAO, 1989) also seen on Table 1 showed an increase of almost 1 million metric tons in one year.

Much of this production was the result of freshwater finfish culture, followed by molluscs and seaweeds. Most of the molluscs are produced in Asia, followed by Europe and North America. Almost all of the world's supply of seaweed is produced in Asia and this sector of aquaculture is growing rapidly. Much of the cultured seaweeds are for human consumption while the wild seaweed is used for the colloid industry. Japan is the largest producer and consumer of seaweed, followed by Korea, Philippines and China. Crustaceans made up a smaller amount of total aquaculture production (Table 1).

In 1989 world shrimp farmers harvested 565,000 metric tons of live shrimp, up 18 percent from the record harvest of 480,000 metric tons 1988. This percentage has increased since 1981 (Fig. 12).

Figure 12

World Production of Farm-Raised Shrimp



Sources: World Shrimp Farming 1989, Aquaculture Digest, Jan 1990

In 1988, at the farm gate, shrimp production alone was estimated to have sold for $2.66 billion; at retail, $6.4 billion, mostly in Japan, the U.S. and Europe. Aquaculture Digest (1989) estimates world shrimp farming involved 3,500 hatcheries, 31,000 shrimp farms and 1,092,300 hectares of shrimp ponds. Production in 1988 would have been closer to 500,000 metric tons, or 25% of world production, if there had not been major crop losses in Bangladesh and Taiwan. The U.S. Department of Commerce's (1988) estimate for world shrimp aquaculture production in 1990 (490,000 metric tons) was apparently surpassed in 1989. World shrimp farming is in a booming stage.

Salmon ranching is also booming. Western Europe continues to lead world production of farmed (pen-raised) salmon. By 1990, the U.S. Department of Commerce estimates that world production of farm-raised Atlantic and Pacific salmon could approach 226,000 metric tons and account for 26% of the world production of fishery products (aquaculture and wild). A further breakdown of production and producers by region can be seen in Figure 13. Estimates are much higher from other sources. As reported by Eidem (1989), the Ministry of Fisheries, Oslo, Norway is estimating 246,500 metric tons as the world production of farmed salmon by 1990, with Norway producing 160,000 metric tons itself.

As aquaculture production increases, many countries around the world are planning expansion. China, for example, is planning to double its output of all aquatic products to about 18,000,000 metric tons by the year 2000. It is projecting to increase its farm-raised shrimp output alone from 165,000 metric tons in 1989 to 2,000,000 metric tons by the turn of the century (Aquaculture Digest, 1990). The present status and the future prospects of aquaculture world-wide look very good.

Status of Aquaculture in the U.S.

Aquaculture is the fastest growing agricultural industry in the United States, increasing over 20 percent annually in this decade (USDA, 1988). Only 1% of the U. S. supply of fish was produced by

Table 1

Summary of Aquaculture Production (tonnes) by FAO Regions

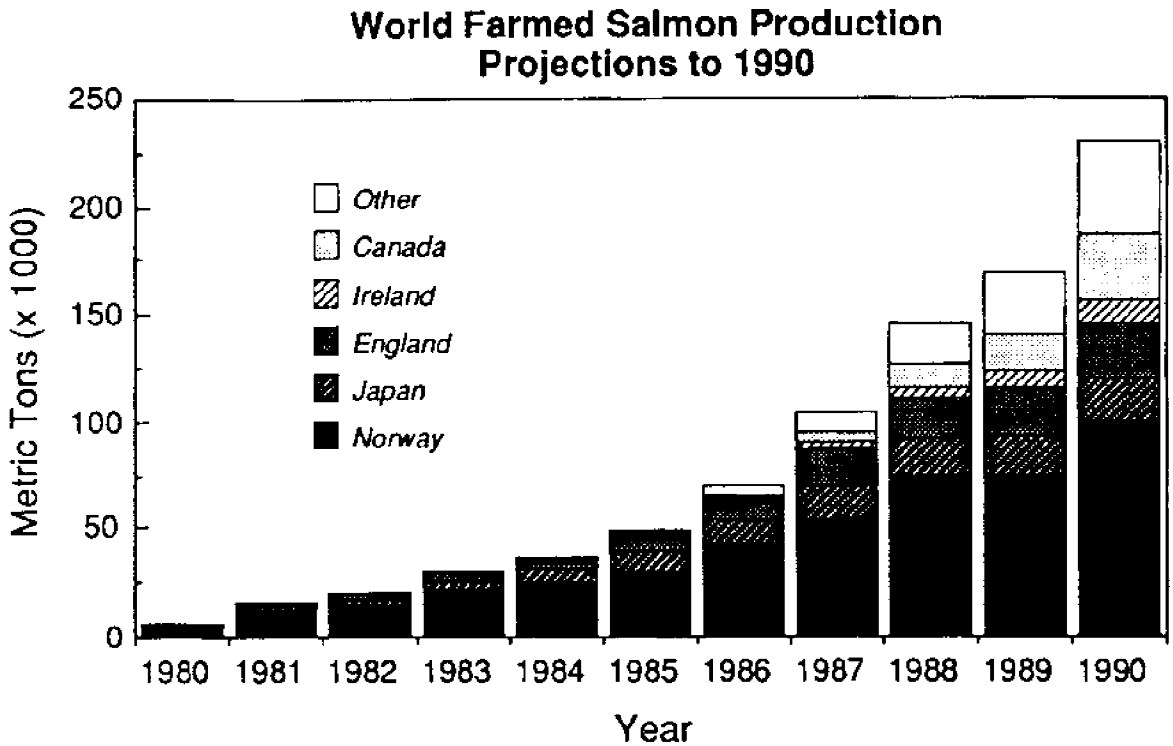
FAO Regions	Finfish	Mollusca	Crustacea	Seaweeds	Others	
1985						
Africa [1]	11,790	202	70	----	50	
North America	236,137	174,473	64,148	230	37	
Latin America	53,774	7143	4309	4924	----	
Asia/Oceania	3,795,503	2,299,748	258,292	2,818,248	28,091	
Europe	347,395	650,482	34	6	----	
Near East	55,640	224	----	----	----	
USSR	296,000	----	----	----	----	
Total	4,796,239	3,132,272	326,853	2,823,408	28,178	*1985 Grand Total* 11,106,950
1986						
Africa [1]	11,616	204	74	----	----	
North America	262,149	186,664	80,863	210	----	
Latin America	61,744	2834	5893	5332	----	
Asia/Oceania	4,358,981	2,644,196 [2]	311,833	2,736,463	30,260	
Europe	399,153	643,636	98	----	----	
Near East	56,061	214	----	----	----	
USSR	305,000	----	----	----	----	
Total	5,454,704	3,477,748	398,761	2,742,005	30,260	*1986 Grand Total* 12,103,478

[1] Excludes North African countries in Near East grouping

[2] Includes additional 1,135,000 tonnes not reported by China in 1986 but included in the 1985 estimate

Source: FAO Fisheries Circular No. 815 (1989)

Figure 13



Source: U.S. Department of Commerce, 1988

aquaculture in 1970, but this increased to 7% by 1987 (Manzi, 1989). The total output of aquacultured edible food products in 1988 was 790 million pounds, valued at more than $650 million. In addition, USDA (1988) estimated that non food production aquaculture (including bait and tropical fish) in the U.S. was worth $100 million in 1988, putting the total industry value at $750 million. Similar estimates have come from other groups. A study by Business Communications Company, Inc. (1989) stated that aquaculture production of edible fish and shellfish increased from 375 million pounds in 1983 to 675 million pounds in 1988, a 12.5 percent average annual rate of growth. This study also predicted a slower growth averaging 6.5 percent annually for edible farm-raised fish and shellfish valued at $900 million in 1995 (Aquaculture Magazine, 1989).

Key aquaculture species include catfish, crawfish, salmon, trout, tilapia, shrimp (freshwater and saltwater), baitfish and tropical (or ornamental) fish, mussels, oysters, and clams. There are many more species less widely established, but with growing production, including alligator, hybrid striped bass, carp, eel, red drum, northern pike and sturgeon.

USDA (1988) estimates of aquacultural (fish and shellfish) production in the U.S. portray an increase from 203 million pounds in 1980 to 750 million pounds in 1987, to 790 million pounds in 1988. The International Aquaculture Foundation has predicted that the U.S. industry will increase to 1.26 billion pounds by the year 2000 and almost 2 billion pounds by 2010. The National Academy of Sciences estimated that domestic aquaculture production would reach 2.2 billion pounds by the year 2000.

These estimates are very conservative and do not take into account production of new species. Tilapia for example, accounted for 25 million pounds of production in the U.S. in 1988 (greater than shrimp). Production values from species such as tilapia, alligators and tropical fish likely will be significant. For instance, when the above estimates were made, the estimated value of "other species" was $217 million (including tropical fish and alligators).

A recent report by Winfree (1989) indicates sales in Florida, where the U.S. tropical fish culture industry is centered, represent $22 million/year at the farm level alone. The retail value of aquarium live-stock sold annually in the U.S. has been estimated at $250-700 million, and the worldwide market for livestock and aquarium products is as much as $4 billion. In the U.S. 10-20 million aquarium enthusiasts keep about 95 million tropical aquarium fish, and aquariums are found in about 7 percent of U.S. households. According to Winfree, in terms of popularity, the aquarium hobby is second only to photography. The Florida tropical fish industry is one of the best examples of aquaculture success in the United States.

When other values associated with the aquaculture industry are considered, total aquaculture production is strongly increased. For example, according to USDA (1988), although nearly 90 percent of commercial trout production occurs in Idaho, other fee fishing operations stocking trout throughout the U.S. may number between 4,000 and 5,000 and have a combined production of at least 25 million pounds. This could increase current estimates of trout production by almost 50 percent (58.9 million pounds of rainbow trout were produced by farmers in the U.S. in 1988, according to a USDA survey).

A recent report by the Louisiana Department of Agriculture and Forestry stated that farm-raised alligator production in that state has grown from 2,500 alligators produced in 1987 to 16,500 in 1988 and projects 50,000 for 1989 and 75,000 alligators for 1990. The following numbers (in thousands of pounds) depict the North American alligator harvest from 1986. Projections for 1990 and total alligators for each year are given.

	1986	1987	1988	1989	1990
Louisiana					
Wild	17	20	23	24	24
Farm-raised	3	2.5	16.5	50	75
Florida	6	6	13	13	13
Texas	1	1	1	1	1
TOTAL	27	29.5	53.5	88	113

In 1988, 12.5 percent of the U.S.-supplied edible fish and shellfish was produced via aquaculture (Aquaculture Magazine, 1989). About 80 percent of that is catfish, crawfish, salmon and trout. Figure 14 shows U.S. production from selected aquacultured species.

Catfish

Catfish accounts for 45 percent of all U.S. farmed fish and is the basis for one of the fastest growing agricultural industries in the nation. Consumers ate almost 190 million pounds of catfish in 1987, over .75 pound per capita according to USDA. A total of 295 million pounds were processed in 1988 (Fig. 14), and catfish sent to processors during the first 7 months of 1989 totaled 197 million pounds, up 19 percent from 1988 (USDA, 1989).

Figure 14

U. S. Production (in millions of pounds of edible meat) of Selected Cultured Species (USDA, 1988).

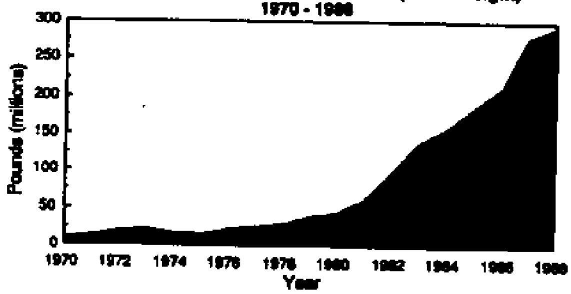
SPECIES	YEAR	POUNDS
Catfish	1988	295.0
Crawfish	1988	200.0
Pacific Salmon	1986	74.3
Pen-Raised Salmon	1988	6.0
Trout	1988	58.9
Clams and Oysters	1987	26.6
Tilapia	1988	25.0
Shrimp	1988	2.2
Mussels	1987	1.4

According to Seafood Business (1989) the farm-raised catfish industry in the U.S. realizes at least $300 million a year. Business Communications, Inc. (1989) states that the U.S. farm-raised catfish industry had a value of $380 million in 1988. USDA (1989) also reports that the commercial and non commercial production of catfish for 1988 totaled 388 million pounds valued at $321 million (commercial production was 359 million pounds worth $284 million and non commercial was 29 million pounds worth $36 million).

U.S. catfish aquaculture production has increased steadily since 1970 (Fig. 15). During the period from 1982-1988, the number of catfish farms increased from 987 to 2,003 and water surface acreage increased from 73,840 to 130,252 (Table 2). USDA (1989) reports that the acreage as of July 1, 1989 had increased to 140,392, but the number of operators or growers had dropped to a total of 1,830. USDA also

Figure 15

U.S. Catfish Aquaculture Production (round weight)
1970 - 1988



Sources: 1970 - 1987 U.S. Department of Commerce,
1988 - U.S.D.A.

Table 2

U.S. Catfish: number of operations, water acreage, and average size per operation, 1982 and 1988

State	Total operations		Percent of Total		Water Surface		Percent of Total		Average Size per operation	
	1982	1988	1982	1988	1982	1988	1982	1988	1982	1988
	Number		Percent		Acres		Percent		Acres	
Alabama	250	352	25	18	8200	12,490	11	10	33	35
Arkansas	130	194	13	10	9310	15,000	13	12	72	77
California	50	91	5	4	1330	2836	2	2	27	31
Georgia	30	78	3	4	980	1891	1	2	33	24
Louisiana	20	116	2	6	790	5720	1	4	40	49
Mississippi	280	356	28	18	49,540	83,000	67	64	177	233
Missouri	70	200	7	10	1130	2500	2	2	16	13
Tennessee	16	35	2	2	260	384	2/	2/	16	11
Texas	115	173	12	9	1550	1936	2	2	13	11
Other 1/	26	408	3	20	750	4495	1	4	29	11
Total	987	2003	100	100	73,840	130,252	100	100	75	65

1/ Data for 1982 are as of January 1; for 1988 July 1. 1982 included FL, ID, NC, PA, SC, and VA. 1988 included FL. ID, IL, IN, KS, KY, NC, OK, PA, SC, and VA. 2/Less than 0.5 percent

Source: National Agricultural Statistics Service, USDA reported that an additional 3,135 acres were being renovated and another 8,388 acres were being constructed, mostly in Mississippi.

Catfish producers and marketers are working hard to take the whiskered fish out of the commodity class and move it up to premium, center-of-the-plate status. Pushed by a $3.5 million advertising campaign, catfish is gaining acceptance with the public, which traditionally has regarded it as a not very glamorous, scavenging, bottom-dweller. Most of the farm-raised catfish in the U.S. are grown in ponds scooped from the heavy, nonporous clay soil of the Mississippi Delta.

Mississippi accounts for 78 percent of total U.S. catfish production, with most of the remaining production coming from other states such as Alabama, Arkansas, California, Florida, Georgia, Louisiana, Missouri, Tennessee, and Texas. USDA (1989) states that while acreage fell in some of the smaller growing states, acreage in the top four states (Mississippi, Arkansas, Alabama and Louisiana) increased an average of 10 percent. The four states account for 91 percent of U.S. catfish pond acreage.

Crawfish

Crawfish accounted for 200 million pounds of production in the U.S. in 1988. Eighty-five percent of crawfish production comes from Louisiana farms, where crawfish are grown in ponds and rice fields and are often produced as an alternating crop with rice. Louisiana has approximately 54,700 ha (135,000 acres) of crawfish and with the wild harvest included produces 90 percent of the total U.S. production of crawfish (all sources included). According to USDA (1988) the Louisiana pond crop continues to suffer from depressed prices. The latest marketing development is soft-shell crawfish. Soft-shell crawfish production climbed to 80,000 pounds in 1988, but the price has already dropped from 1988 highs of $10 per pound to lows of $5 and $6. The profitability of crawfish farming has been affected by depressed prices and USDA (1988) predicts slow growth for this industry in the next few years.

Salmon

Total U.S. private aquaculture production of Pacific Salmon was 74 million pounds in 1986 and 80 million pounds in 1987 (Table 3). Farmed (pen-raised) salmon production in the U.S. increased 70 percent in 1988 to six million pounds (USDA,1988). USDA (1989) estimates this figure closer to 7 million pounds. More growth is expected for this industry, but competition will be fierce with both imports and the wild harvest. According to Painter (1988) the state of Alaska has placed a ban on all marine finfish pen culture for at least two years. While there are many state, federal, and private hatcheries across the U.S., the commercial salmon aquaculture industry is based in Washington, Oregon, California, and more recently in the state of Maine. A study by the National Marine Fisheries Service estimated that the salmon aquaculture (pen-raised) industry in the U.S. will more than triple in size by 1990. Similarly, the U.S. Embassy and U.S. Department of Commerce (1988) projected the U.S. farm-raised (pen culture) salmon production to be 7,700 metric tons (live weight) by 1990, or about 17 million pounds. This figure is almost triple that of the 1988 production figures quoted earlier. Outlook of this industry appears bright even with the threat of imports. Demand remains very high. During January-June 1989, salmon imports (all forms) into the U.S. were approximately 40 million pounds. This is 65 percent more than in 1988 (USDA, 1989).

Trout

Farmers in the U.S. produced 58.9 million pounds of rainbow trout in 1988, not including the estimated 25 million pounds produced by the fee-fishing operations. Trout exports for food in the first half of 1989 totaled 440,000 pounds valued at almost $900,000 (USDA, 1989). Most of the trout were farmed in southern Idaho and are well known for consistent high quality. All commercial rainbow trout are raised, by law, in captivity. Most are raised in outdoor concrete raceways. Smaller trout farms use earthen ponds which farmers claim prevent damaged fins and help keep skin colors bright. State import laws continue to restrict this industry in some areas. Problems have also emerged with the recent appearance of VHS (viral haemorrhagic septicemia) and IHNV (infectious haemopoietic necrotic virus) diseases. A slow steady growth is projected for the short term but a lack of water in some areas may cause problems over the long-run (USDA, 1988). Recirculating systems may eventually alleviate the water shortages.

Tilapia

According to USDA, Tilapia is the fastest growing U.S. aquaculture commodity, showing an impressive 25 million pounds of production in 1988. It is marketed as an alternative to white-fish or farmed catfish. Tilapia is a warm water food fish native to Africa. It cannot tolerate water temperatures much below 55 degrees F; however, it adapts well to a variety of growing conditions and is highly prolific. For more detailed information on growing costs, etc. refer to USDA, 1989.

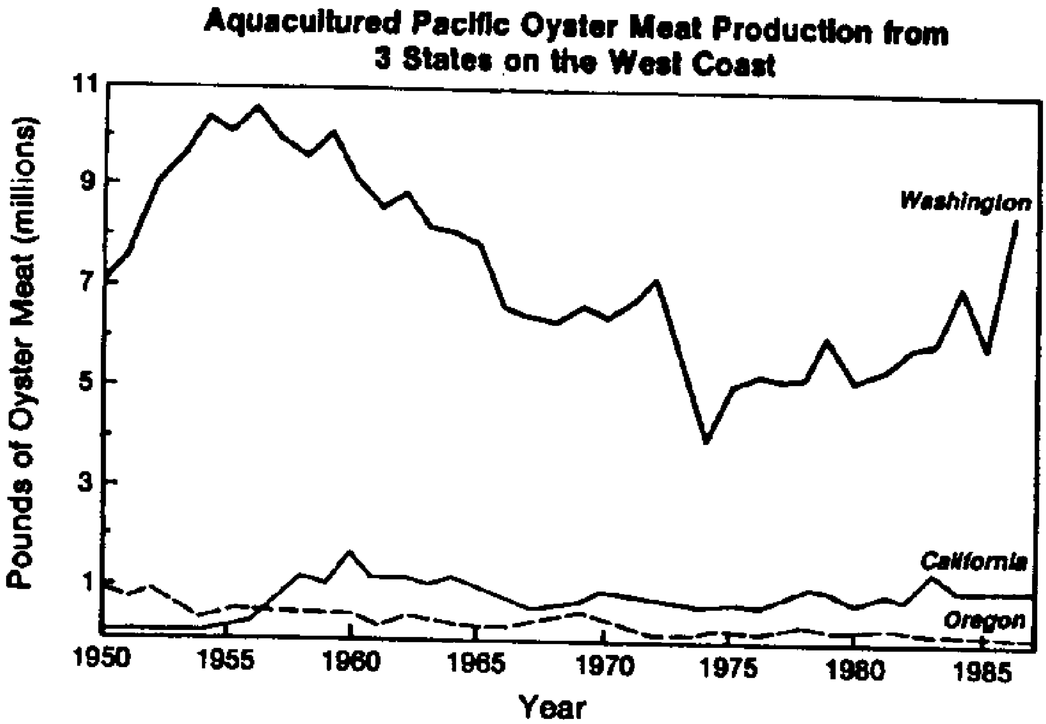
Table 3

U.S. Private Aquaculture Production and Value 1/												
Species	**1980**	**1983**	**1984**	**1985**	**1986**	**1987**	**1980**	**1983**	**1984**	**1985**	**1986**	**1987**
	1000 pounds 2/						1000 dollars					
Baitfish 3/	22,046	22,046	23,598	24,807	25,247	27,000	44,000	44,000	47,045	51,280	51,522	56,000
Catfish	76,842	220,000	239,800	271,357	326,979	375,000	53,572	132,000	191,840	189,194	228,886	285,000
Clams	561	1689	1689	1588	2506	3500	2295	9500	4178	4717	8307	11,600
Crawfish	23,917	60,000	59,400	64,999	97,500	105,000	12,951	30,000	29,700	32,500	48,750	53,000
Freshwater Prawns	300	275	317	267	178	150	1200	1500	1698	1540	893	750
Mussels	NA	775	917	928	1206	1800	NA	1500	1584	1248	1725	2575
Oysters	23,755	23,300	24,549	22,473	24,090	26,000	37,085	31,500	38,970	39,977	42,797	46,190
Pacific Salmon	7,616	20,600	45,086	84,305	74,398	80,000	3400	6800	17,252	25,439	32,751	37,000
Shrimp	- - - -	255	528	440	1354	1500	- - - -	874	1566	1687	3408	3775
Trout	48,141	48,400	49,940	50,600	51,000	59,000	37,474	50,000	54,435	55,154	55,590	65,000
Other Species	NA	7,000	9,900	14,000	15,500	68,000	NA	7000	9900	20,000	21,700	85,000
Total	203,178	404,340	455,733	535,764	619,959	746,950	191,977	314,674	398,168	422,736	496,329	645,890

1/ Some data were not used so that the confidentiality of the person or business submitting the statistics was not disclosed. This is the case where data cannot be aggregated. 2/ Data shown are live weight except for oysters, clams, and mussels which are meat weight. Excluded are eggs, fingerlings, etc., which are an intermediate product level. 3/ Not used for food consumption. NA = not available

Source: Office of Aquaculture, USDA

Figure 16



Source: Chew, 1988

Clams and Oysters

Clam and oyster aquaculture in the U.S. accounted for more than 29 million pounds (Table 3) of edible meat in 1987. Increased production has coincided with declining wild catches, and this is expected to continue. However, demand may drop as more and more beach closings and incidents of pollution occur, giving the public a feeling that waters are environmentally damaged and unsafe for shellfish culture and consumption.

Oyster meat production from aquaculture occurs in a number of states. The Pacific coast has become a major center of cultured oyster production (Fig. 16). Note that Washington has produced an average of 7 million pounds of Pacific oyster meat since 1950 (with a high of 10.5 million pounds and a low of 4 million pounds). The cultchless oyster and the triploid oyster are also offering promising culture results for the future expansion of the shellfish culture industry.

Shrimp

The U.S. farm-raised shrimp production for 1988 was 2.2 million pounds. Major producing states are Texas, Hawaii, South Carolina and Florida. There has been an increase in production since 1980 as can be seen in Table 3. The U.S. remains one of the largest markets for shrimp, importing over 500 million pounds per year, at a value of $1.8 billion (Figure 4). The U.S. shrimp fleet caught 331 million pounds in 1988. Even the most optimistic projections for the U.S. shrimp aquaculture industry expect that it will never supply more than a very small percentage of the total domestic supply (USDA, 1989). To remain competitive with foreign aquaculture operations and wild catch, the U.S. shrimp aquaculture industry must develop strong ties to markets that are willing to pay premium prices for special products.

As mentioned earlier, there are numerous other species grown on a limited basis in the United States:

(1) Mussels accounted for 1.8 million pounds (Table 3) of edible meat in the U.S. in 1987, most of which were cultured in the state of Maine.

(2) Carp production involves a number of species in many southern states. They are grown for food and for weed control, often in a polyculture with catfish.

(3) Redfish are grown in Texas, Louisiana, Mississippi, and Florida in ever-increasing numbers. Over-wintering in shallow ponds is still a major

constraint to the industry, but the high market value and the ban on commercial fishing of this species provides incentive to the expansion of this industry.

(4) Striped bass also brings a high market price and is being considered as an aquaculture candidate in Mississippi, Texas, California, Virginia, as well as other states. The first commercial striped bass production occurred in North Carolina in 1988. Virginia now has 15 active permitted hybrid striped bass facilities with fingerlings to be harvested in 1990. Like redfish, striped bass production is expected to grow rapidly over the next few years. As cultural systems improve, increased interest in rearing these fish with aquacultural techniques is expected to continue because of a ban on commercial fishing of this species in some major market areas. Striped bass and hybrid striped bass are among the newest species in aquaculture and are being grown in raceways, net pens, tanks, and ponds. USDA (1989) estimates that markets of both the hybrid and true striped bass over the last year totaled 1.5 million pounds. Annual sales may reach 3-5 million pounds by the early 1990's. If the wild catch does not expand, sales may climb 2-3 million pounds per year after 1995, providing as much as 20 million pounds annually by the year 2000 (USDA, 1989).

(5) Sturgeon is grown in California and is a by-product of the caviar industry. An attempt is being made to build a working industry with this species.

(6) Lobsters, freshwater shrimp (Table 3) and abalone are still relatively small industries operating mainly in California, Hawaii and Puerto Rico.

(7) Non-edible fish and other species such as baitfish (Table 3) and tropical fish are also noteworthy because of the high dollar value associated with these industries.

(8) Alligators (harvest numbers given earlier) are also being grown using aquaculture techniques since regulations were placed on the hunting of wild stocks.

There are indeed many new opportunities provided by the U.S. aquaculture industry. It provides new sources of employment, new markets for agriculture products used as feed materials, and the industry offers diversification opportunities for farmers. The status and outlook for this industry looks very good in the United States.

Status of Aquaculture in Texas

Texas aquaculture is a fledgling industry. There is a large number of freshwater aquaculture farms in the state. Most of the farms are small facilities geared either toward local sales of fresh fish or sales of fingerlings for farm pond stocking. Even though the small farms are large in number, there is an insufficient infrastructure to compete with large scale development in other southern states. For example, Texas catfish farms numbered 173 in 1988 and had an average size of 11 acres, whereas Mississippi had 356 operations, averaging 233 acres in size (Table 2). Total acreage for Texas catfish farms was 1,936 compared to Mississippi's 83,000 acres under culture in 1988. USDA (1989) reports that some changes have occurred since 1988. The total number of farms listed for Texas has dropped to 136 in 1989 and the total acreage has also dropped to 1,636. In comparison, Mississippi farms have also decreased from 356 to 314, but the acreage increased from 83,000 to 88,000. The saltwater aquaculture industry in Texas is considerably smaller than the freshwater industry. Saltwater farms have traditionally cultured penaeid shrimp and redfish. Some shellfish culture has been and is presently being attempted. Most of these farms are attempting to adapt new technology for production of these high value crops, but thus far, yields have generally been inconsistent for a variety of technical reasons.

The infrastructure for the aquaculture industry in Texas is poorly developed. As a result, Texas faces higher prices for major items such as catfish fingerlings and feed. This makes it difficult to compete in major food fish markets (USDA, 1989).

CONCLUSION

Indeed, there is an increasing role of aquaculture as a food source in the U.S. and in the world. As limitations on wild fishery stocks continue; as the demands on these fishery products increase; and as technological advances in aquaculture production continue, this increasing role will become more evident. Texas currently has a relatively minor aquaculture industry in comparision to other areas of the U.S. and other arease of the world. The opportunity exists for conciderable growth if the appropriate infrastructure, regulatory base, and technological expertise can be assembled.

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NATURAL RESOURCES

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Texas has a wide diversity of natural resources, and aquaculture production occurs to some degree in virtually every region of the state. However, most Texas aquaculture operations are small, family-owned farms which have difficulty competing with integrated operations (large grow-out facilities with associated processing plants, feed mills, and other infrastructure) being developed in other states. The issue that will be addressed in this chapter is whether suitable natural resources are available in Texas to support competitive integrated aquaculture developments, and, if so, which regions of the state are most appropriate for this purpose.

A variety of resources are required for aquacultural development. These can be categorized as water (quantity and quality), land (including soil type, elevation, and topography), climate (including temperature, evaporation, and precipitation) and infrastructure (access to roads, utilities, qualified labor, processing plant, feed mill, etc.). In most areas of Texas, The most crucial of the natural resources for aquaculture is the water supply.

WATER REQUIREMENTS

A multi-agency effort was recently implemented to identify locations with adequate water resources for integrated aquaculture operations in Texas. A review of the evaluation process and preliminary results will be presented here.

Hypothetical Farm Assumptions

The first step in this process was to estimate the quantity of water required for an integrated aquaculture development. The following scenario was adopted based on catfish farming experience (pers. comm., Dr. Tom Wellborn):

The hypothetical farm was assumed to consist of 4000 surface acres of ponds producing 4000 lbs/acre/year. This would yield an annual production rate of 16 million pounds, which is sufficient to support a moderate sized processing plant (64,000 pounds/day assuming 250 operating days per year). Alternate farm sizes of 3,000 acres (sufficient to support a relatively small processing plant, 48,000 pounds/day) and 8,000 acres (sufficient to support a large processing plant and a small feed mill) were considered, but the 4,000-acre partially integrated scenario (with a processing plant, but without a feed mill) was used for calculations.

Water Requirement of Ponds

All ponds in the 4,000 acre hypothetical development were assumed to have a depth of 4 feet and to require an average of one fill and one change of water per year. Thus, 200 % of the total volume would be required annually to operate the ponds. This would amount to 32,000 acre feet/year (4,000 surface acres x 4 foot depth x 2 volumes). Additional water would be needed if the facility were located in an area where evaporation exceeds precipitation.

Although the projected water requirement of 32,000 acre feet per year could be satisfied with a continuous year-round pumping rate of approximately 20,000 gallons per minute, higher flow rates would be needed for periodic management activities. For example, relatively high flow rates are needed if a large proportion of the ponds are being filled simultaneously. In order to avoid problems with aquatic vegetation, it is necessary to fill ponds in 10-15 days. Thus a flow rate of about 25 gallons per minute per acre is recommended for filling.

Water Requirement Of Processing Plant

Assuming that the processing activity requires 2 gallons of water per pound of fish, then about 100 acre feet of water would be required annually for the processing plant (16,000,000 pounds of fish x 2 gallons per pound + 325,851 gallons per acre foot).

Based on the above calculations, we assume that approximately 30,000 - 35,000 acre feet of water per year is required to support the hypothetical integrated catfish farm.

WATER AVAILABILITY

The calculated water requirement for an integrated freshwater farm represents a relatively large water use which is not readily available in most areas of Texas. However, some areas which apparently have insufficient surplus water for large-scale development will qualify through economic substitution. That is, water rights can be purchased from existing users to allow aquaculture development. It is anticipated that a combination of ground and surface water sources may be necessary for the development of large scale aquaculture operations in any region.

Experts from the Texas Water Development Board (TWDB) and the Texas Water Commission (TWC) have performed a preliminary review of areas in Texas generally having sufficient quantities of water supplies for aquaculture development. Water availability is discussed below under the headings of fresh groundwater, fresh surface water, saline groundwater, and saline surface water

Fresh Groundwater Supplies

Texas has seven major and 17 minor aquifers (Figs. 1 and 2, respectively). Water quantity and quality vary significantly among aquifers and also among different regions within an aquifer.

In many parts of Texas, annual pumpage of ground water exceeds recharge, and available ground water is expected to decline as this practice continues. This is especially true of the western irrigation areas of the state. Some aquifers that supply major portions of Texas with fresh water have saline aquifers associated with them which may either underlie or overlie the freshwater ones.

Depletion of freshwater aquifers is followed by encroachment of saline waters, thus reducing the usefulness of the remaining freshwater for many uses, in some cases including aquaculture. Therefore, when selecting potential areas for aquaculture, particular attention should be paid to areas where ground water is being utilized more rapidly than the natural recharge rate.

In areas of declining water supplies, pressures for uses other than aquaculture could affect the availability of ground water in the future. For example, the Harris-Galveston Coastal Subsidence District issues permits for withdrawal of groundwaters under its jurisdiction.

In addition, the Edwards Underground Water District was created under Section 59 of Article 16 of the Texas Constitution for the purpose of conserving, protecting and recharging the underground water-bearing formations within the District (Bexar, Comal, Hays, Medina and Uvalde Counties). The Edwards District does not issue permits, but it does have the right to purchase water and water rights and has powers of eminent domain for the erection of recharge dams and wells.

Figure 1. Major Aquifers of Texas

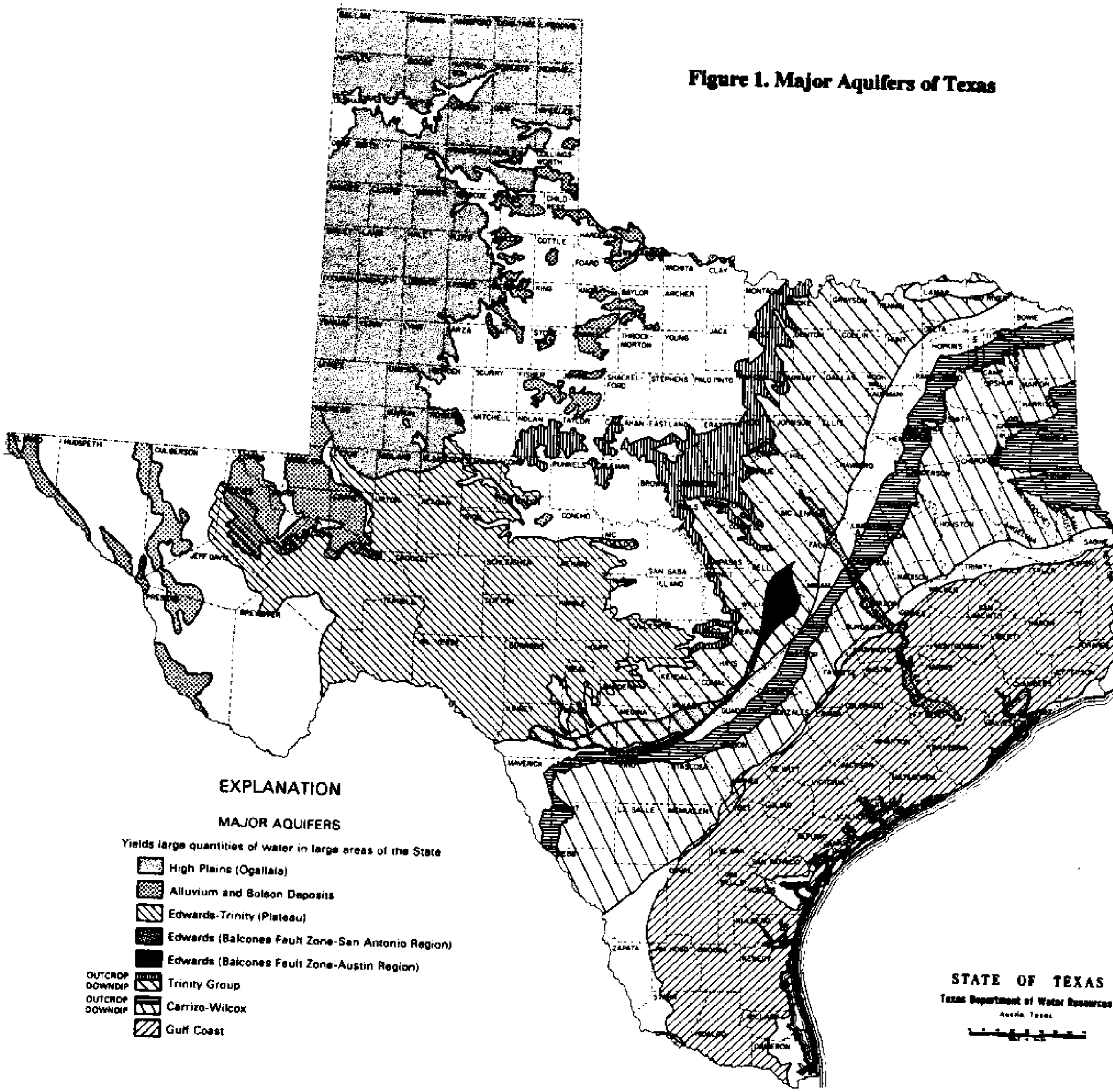
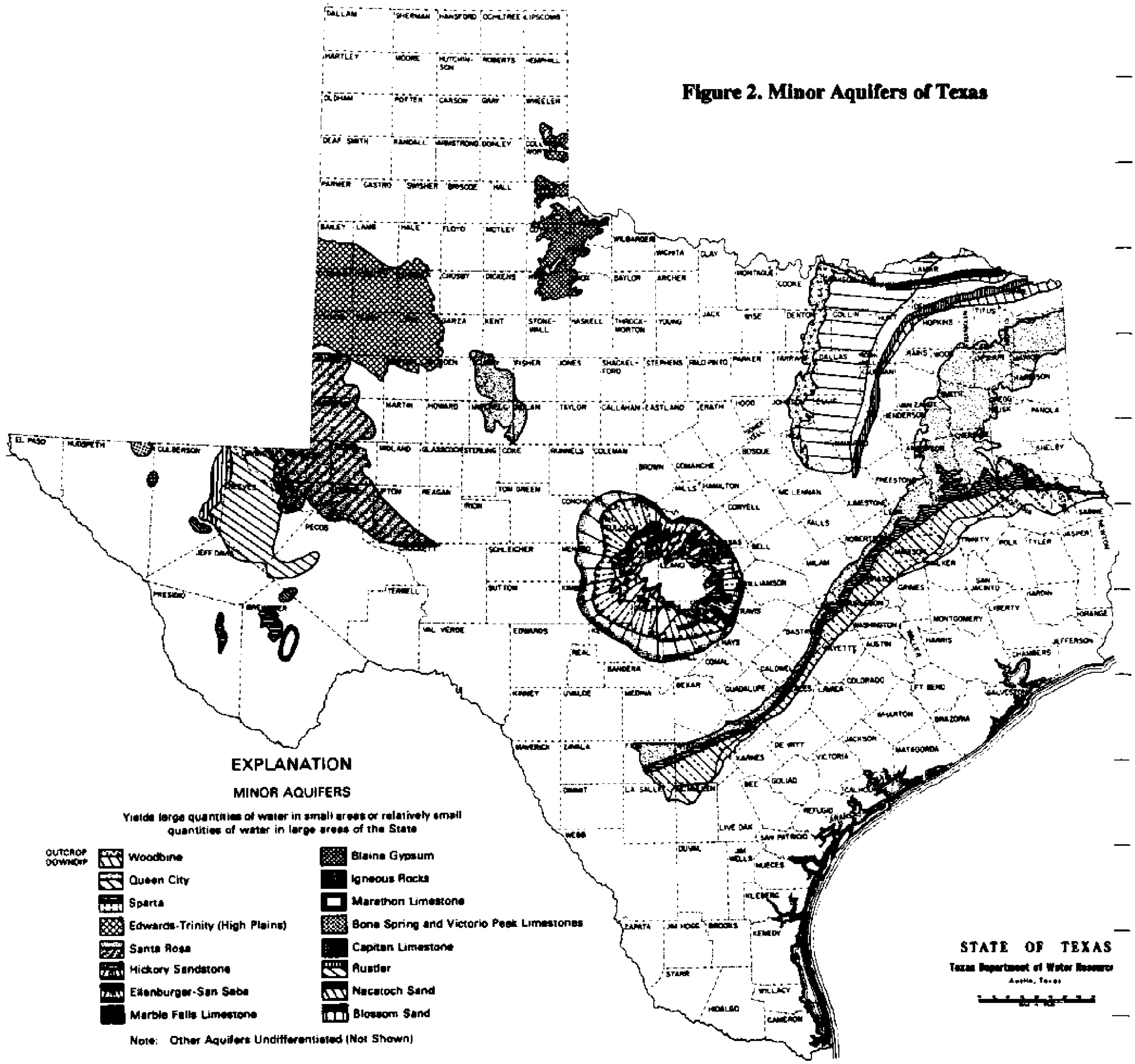


Figure 2. Minor Aquifers of Texas



Potential exists for aquaculture development in association with several major and minor aquifers (Figs 1 and 2). The following areas were identified by the TWDB:

- the Gulf Coast Aquifer originating above the Lower Rio Grande Valley, excluding the Counties of Harris, Galveston, Fort Bend, Brazoria, and Montgomery;
- the Carizzo-Wilcox Aquifer stretching from the Dimmi-La Salle County area up through East Texas;
- the upper northeast portion of the Trinity Aquifer in the Sulphur and Cypress River Basins; and
- the Ogallala Aquifer in West Texas.

Fresh Surface Water Supplies

Surface water is available in the form of springs, streams, and watershed runoff and in water from various sources provided by the numerous irrigation districts in the state. Each river basin has different amounts of authorized or claimed water (Table 1). The geographical locations of the river and coastal basins of Texas are presented in Figure 3.

Diversion of Surface waters

A potential water user interested in diverting surface water from a stream for aquacultural purposes has three options:

- obtaining run of the river water rights through the water permitting process administered by the Texas Water Commission;
- purchasing existing water rights; or
- arranging for water use through contractual agreements with existing water rights permit holders in the areas. This option is the most likely in many of the basins.

Some surface water is available for appropriation in the southeast area of Texas. However, streamflow in sufficient quantity to satisfy a projected annual demand of 35,000 acre-feet may not be available without storage to provide water through extensive dry periods.

An application for a water use permit would require detailed studies to determine the amount of water available at a specific location without impairing downstream water rights. The Texas Water Code also requires environmental assessments of the effects of proposed diversions.

It may be more expedient to consider contracts with authorized water suppliers or the purchase of existing water rights that can be amended to authorize use for industrial (fish farming) purposes. For example, there are a number of irrigation water rights

Table 1. Projections of surface water availability (in units of 1,000 acre feet) for aquaculture estimated by subtracting municipal and manufacturing water use from total water supply of each zone.

Basin/Zone	Year 2000	Year 2030
Canadian River, Zone 1	1391.2	791.7
Zone 2	1765.5	976.1
Red River, Zone 1	1535.7	637.8
Zone 2	263.6	5.9
Zone 3	292.9	289.6
Sulphur Creek	268.1	774.3
Cypress Creek	237.2	238.3
Sabine River, Zone 1	417.2	443.0
Zone 2	1218.3	1558.6
Neches River, Zone 1	295.3	266.4
Zone 2	758.3	1287.7
Neches-Trinity, Zone 1	196.7	197.0
Zone 2	168.6	168.4
Trinity River, Zone 1	454.1	299.3
Zone 2	45.4	152.3
Zone 3	1718.5	1752.5
Trinity-San Jacinto	57.4	69.0
San Jacinto	298.7	195.5
San Jacinto-Brazos	204.7	202.9
Brazos River, Zone 1	2411.1	1345.9
Zone 2	99.8	102.0
Zone 3	506.7	576.1
Zone 4	257.5	62.0
Zone 5	257.5	25.7
Zone 6	562.1	669.3
Brazos-Colorado	201.5	201.2
Colorado River, Zone 1	1063.8	542.8
Zone 2	328.8	292.2
Zone 3	508.2	478.8
Colorado-Lavaca	95.0	97.7
Lavaca River	214.8	212.9
Lavaca-Guadalupe	68.6	68.7
Guadalupe River, Zone 1	44.9	47.9
Zone 2	288.4	252.3
San Antonio , Zone 1	113.5	133.5
Zone 2	214.8	527.2
San Antonio-Nueces	5.8	5.0
Nueces	440.5	454.0
Nueces-Rio Grande	11.7	22.4
Rio Grande, Zone 1	149.6	-107.5
Zone 2	1663.5	1527.4
Zone 3	282.2	161.1

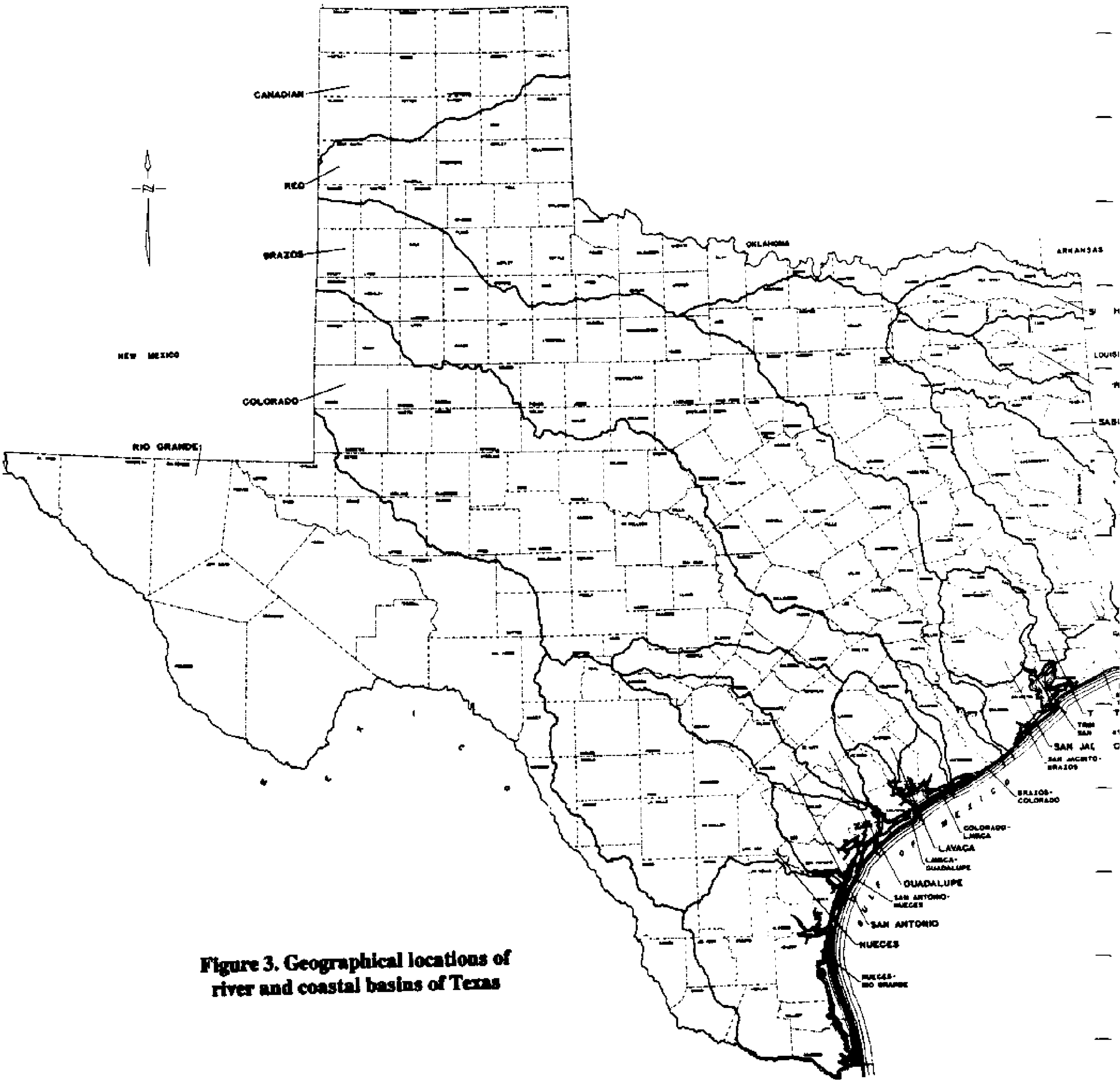


Figure 3. Geographical locations of river and coastal basins of Texas

that may be available for purchase and conversion to aquaculture use. Table 2 lists irrigation water right holders that may have sufficient water for an aquaculture operation of this size.

According to the TWDB, fresh surface water supplies suitable for varying degrees of aquaculture development may be available in the following river basins:

- the lower reaches of the Sabine, Neches, and Trinity River Basins;
- the Cypress River Basin;
- the Lavaca River Basin;
- the Sulphur River Basin;

The following rice irrigation areas also have potential:

- the lower Colorado River Basin,
- the San Jacinto - Brazos Coastal Basin,
- the Colorado-Lavaca Coastal Basin,
- the Brazos-Colorado Coastal Basin, and
- the Lavaca-Gualalupe Coastal Basin.

Management of Existing Impoundments

At present, there are approximately 1.16 million ha (2.9 million acres) of freshwater in Texas. This figure includes natural rivers and lakes plus waters impounded by numerous U.S. Army Corps of Engineer projects, Bureau of Reclamation projects, P.L. 566 Flood Control projects and thousands of small, privately owned farm ponds.

Within Texas impoundments, there is great diversity of physical, chemical and biological characteristics. Both flowing and still waters are suitable for use in some form of aquaculture, although the probability for success will vary significantly from one region and water source to another. Most of the existing impoundments in Texas already yield a certain amount of aquatic animal production. However, the majority are not presently managed for aquaculture. Aquatic production could be increased in nearly all existing freshwater in Texas through the implementation of more intensive management. The potential for aquaculture production in farm ponds is great. The organisms produced in farm ponds could provide a significant amount of animal protein for the landowner at relatively little expense, and in some instances farm ponds can be adapted to commercial aquaculture. Pond design, water source and distance between ponds will be factors that determine whether farm ponds can be used for commercial production.

Saline Groundwater Supplies

The extensive saltwater aquifers of West Texas should not be overlooked in terms of aquaculture potential. Although there is considerable variation in total dissolved solids and ionic composition among ground water sources, preliminary trials with a variety of estuarine species indicate general acceptability of remarkably different water types. More definite research on saline groundwater quantity and quality is needed to fully evaluate the potential for inland mariculture in Texas. Permeability of soils is another factor which must be considered in selecting a pond site in West Texas.

Already, some West Texas areas which support little agriculture are being utilized on a small scale for brackish water aquaculture. If sufficient care is taken in the introduction of new stock into such areas, many problems of parasite and disease transmission, aquatic vegetation infestation and predation could be reduced relative to occurrence in the natural habitat of the culture organisms.

Figures 4, 5, and 6 are maps showing areas having varying degrees of total dissolved solids which could provide for marine species production.

Saline Surface Water Supplies

Approximately 607,000 ha (1.5 million acres) of bay and estuarine water exists within Texas with an additional 445,000 ha (1.1 million acres) of adjacent marshland and tidal flats. Such areas are important in the life cycles of the species of finish and shellfish which contribute a large percentage of the annual commercial and sport catches of the state.

Texas is unique in its salt-water aquaculture resources. Unlike other southern states, Texas has several large, relatively undeveloped bays surrounded by flat land with clay soils and sufficient elevation for pond construction. A great deal of aquaculture potential exists for species such as penaeid shrimp, red drum, and hybrid striped bass. Ample water is available for integrated developments. However, the aquaculture permitting process is more lengthy and complex for coastal than for inland sites.

A final saline resource that merits consideration is the Gulf of Mexico. It is not inconceivable that current offshore net pen technology used for salmon culture could be deployed in the Gulf for the culture of valuable warmwater marine species such as red snapper, grouper, dolphin fish, etc.

FUTURE WATER PLANNING

Considering the crucial importance of water resources for aquaculture development in Texas, continued effort will be devoted to this issue. Obtaining more definitive water resource information will be a two-phase effort. The short-term effort will determine water surpluses in aquifers and watersheds. Following this, a ranking of surface and ground waters in reference to supply and

Table 2. Summary of irrigation water right holders with access to greater than 20,000 acre feet of surface water per year (from Texas Water Commission records)

AUTHORIZED WATER SUPPLIER	STREAM DIVERTED	RIVER BASIN	ACRE FEET PER YEAR	ACRES IRRIGATED	COUNTY	DIVER SION RATE (CFS)
Reeves Co. WID 1	Toyah	Rio Grande	41,400	13,800	Reeves	
El Paso Co. WID 1	Rio Grande	Rio Grande	135,000	45,000	El Paso	81.3
Reeves Co. WID 1	Rio Grande	Rio Grande	45,000	15,000	Reeves	41.0
Hudspeth Co. C-R Dist 1	Rio Grande	Rio Grande	27,000	9,000	El Paso	400.0
Hidalgo Co. Irr. Dist. 16	Rio Grande	Rio Grande	30,949	13,580	Hidalgo	
La Feria Irr Dist Cameron 3	Rio Grande	Rio Grande	76,330	30,532	Cameron	
Santa Cruz Irr Dist 15	Rio Grande	Rio Grande	77,180	30,872	Hidalgo	
Donna ID Hidalgo Co 1	Rio Grande	Rio Grande	94,064	37,625	Hidalgo	
Valley Acres Water Dist	Rio Grande	Rio Grande	22,300	8,920	Hidalgo	
Hidalgo Co Irr Dist 2	Rio Grande	Rio Grande	160,275	64,110	Hidalgo	
Engleman Irr Dist	Rio Grande	Rio Grande	20,856	8,342	Hidalgo	
Delta Lake Irr Dist et al	Rio Grande	Rio Grande	174,776	69,911	Hidalgo	
Hidalgo-Cameron WCID 9 et al	Rio Grande	Rio Grande	180,152	72,061	Hidalgo	
Hidalgo Co Irr Dist 1 et al	Rio Grande	Rio Grande	85,615	34,246	Hidalgo	
Hidalgo Co Irr Dist 6	Rio Grande	Rio Grande	51,445	20,578	Hidalgo	
Cameron Co WCID 6	Rio Grande	Rio Grande	54,782	21,913	Hidalgo	
Harlingen Irr Dist et al	Rio Grande	Rio Grande	93,857	37,543	Hidalgo	
Cameron Co Irr Dist 2 et al	Rio Grande	Rio Grande	142,817	57,127	Hidalgo	
Brownsville Irr & Drain Dist	Rio Grande	Rio Grande	33,950	13,950	Hidalgo	
United Irrigation Dist	Rio Grande	Rio Grande	81,964	32,796	Hidalgo	
San Angelo W S C	Middle Concho	Colorado	25,000		Bell	
Chocolate Bayou Water Co et al	Brazos	Brazos	70,000		Fort Bend	
Bexar-Medina-Atascosa WCID	Medina	San Antonio	65,830	33,000		
Maverick Co WCID 1	Rio Grande	Rio Grande	135,000	45,000	Kinney	600.0
Brazos River Authority	So Fk Dbl Mt K	Brazos	21,000	10,000	Lubbock	
Trinity River Authority	Trinity	Trinity	104,450		Polk	
Boyt Realty Company	Trinity	Trinity	47,500	79,000	Liberty	
Trinity River Authority	Trinity	Trinity	30,000		Chambers	
Dayton Canal Co	Trinity et al	Trinity	38,000	9,238	Liberty	215.6
Chambers-Liberty Cos ND	Trinity et al	Trinity	110,000	30,000	Chambers	744.4
Lower Neches Valley Authority	Neches & Angelina	Neches	110,000		Jasper	
Lower Neches Valley Authority	Neches & Pine	Neches	326,360	85,000	Jefferson	
Sabine River Authority	Sabine	Sabine	50,000		Newton	
Sabine River Authority	Sabine	Sabine	46,700	28,000	Orange	
Farmers Canal Company	Tres Pal. et al	Colorado-Lavaca	20,615	15,000	Matagorda	111.1
Wichita Co WID 2 et al	Wichita	Red	120,000		Wichita	
Brazos River Authority	Brazos	Brazos	50,000	25,000	Fort Bend	600.0
Guadalupe-Blanco R. A. et al	Guadalupe	Guadalupe	32,615	21,308	Calhoun	500.0
Richmond Irr Co & HL&P	Brazos	Brazos	28,000	15,179	Fort Bend	355.0
Chocolate Bayou Water Co.	Brazos	Brazos	155,000	41,200	Fort Bend	900.0
Chocolate Bayou Water Co. et al	Chocolate & Trib.	San Jacinto-Brazos	23,900	6,600	Brazoria	201.0
Garwood Irrigation Company	Colorado	Colorado	168,000	32,000	Colorado	750.0
Red Bluff Water Power Control	Pecos	Rio Grande	292,500	145,000	Reeves	
Pecos County WCID No. 1	Comanche Creek	Rio Grande	25,205	6,008	Pecos	90
Lower Colorado River Authority	Colorado	Colorado	131,250	25,000	Colorado	820.3
Lower Colorado River Authority	Colorado	Colorado	262,500	50,000	Matagorda	1267.2
Lacy Withers Armour Trust et al	Colorado	Colorado	111,000	25,000	Wharton	400

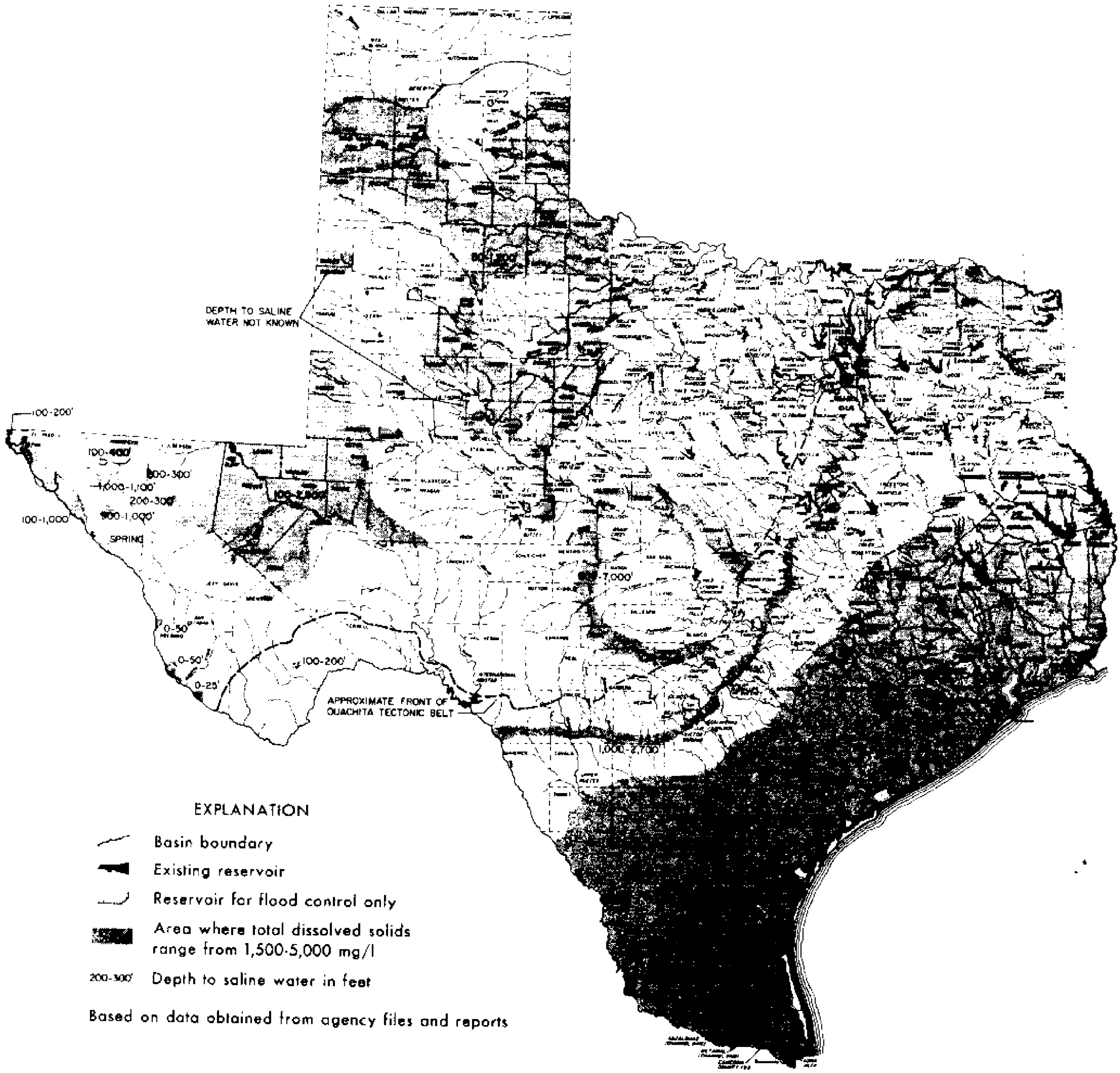


Figure 4. Known Areal Extent of Ground Water Containing 1,500-5,000 Milligrams Per Liter Total Dissolved Solids in Texas

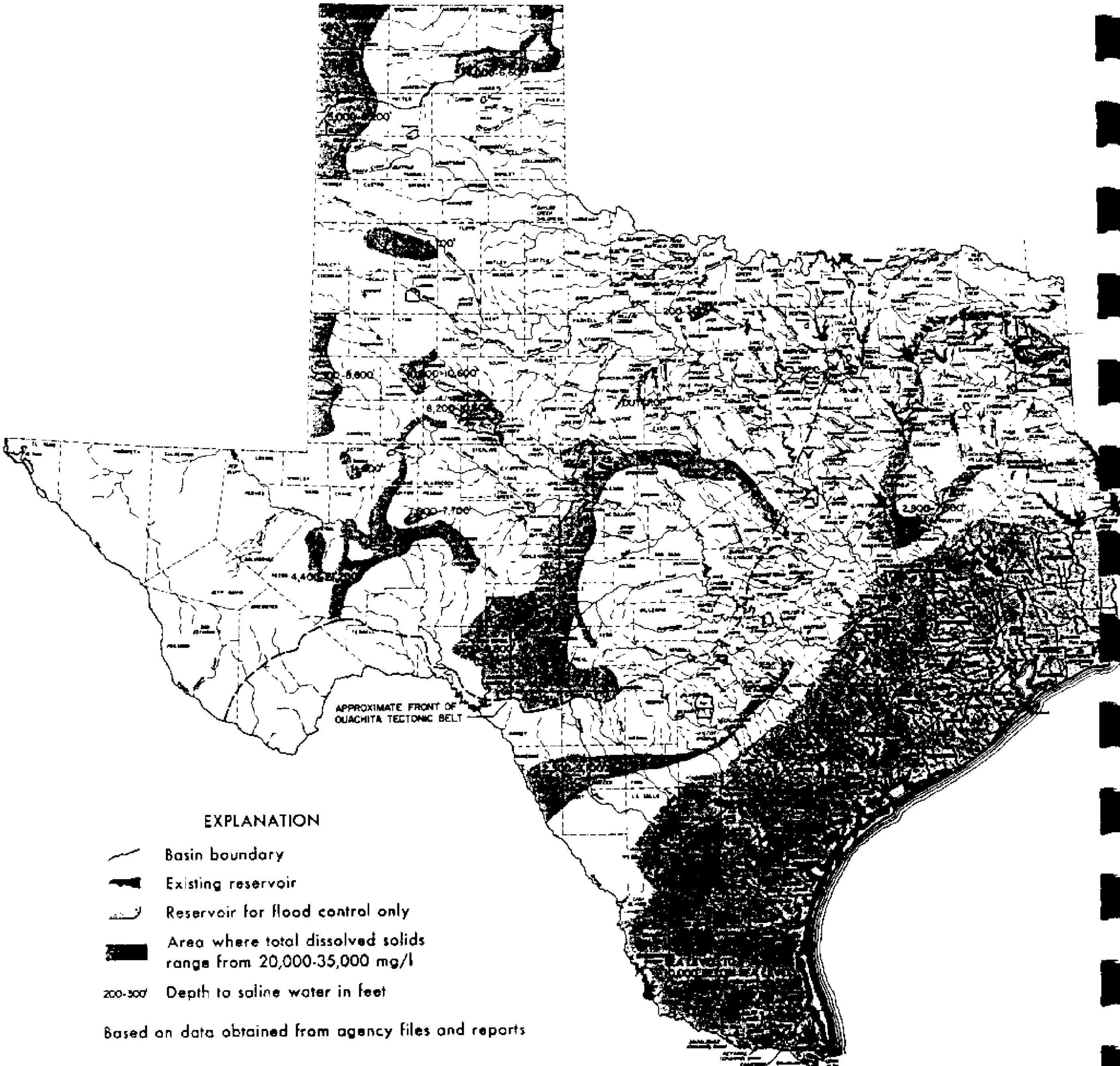


Figure 5. Known Areal Extent of Ground Water Containing 5,000-20,000 Milligrams Per Liter Total Dissolved Solids in Texas

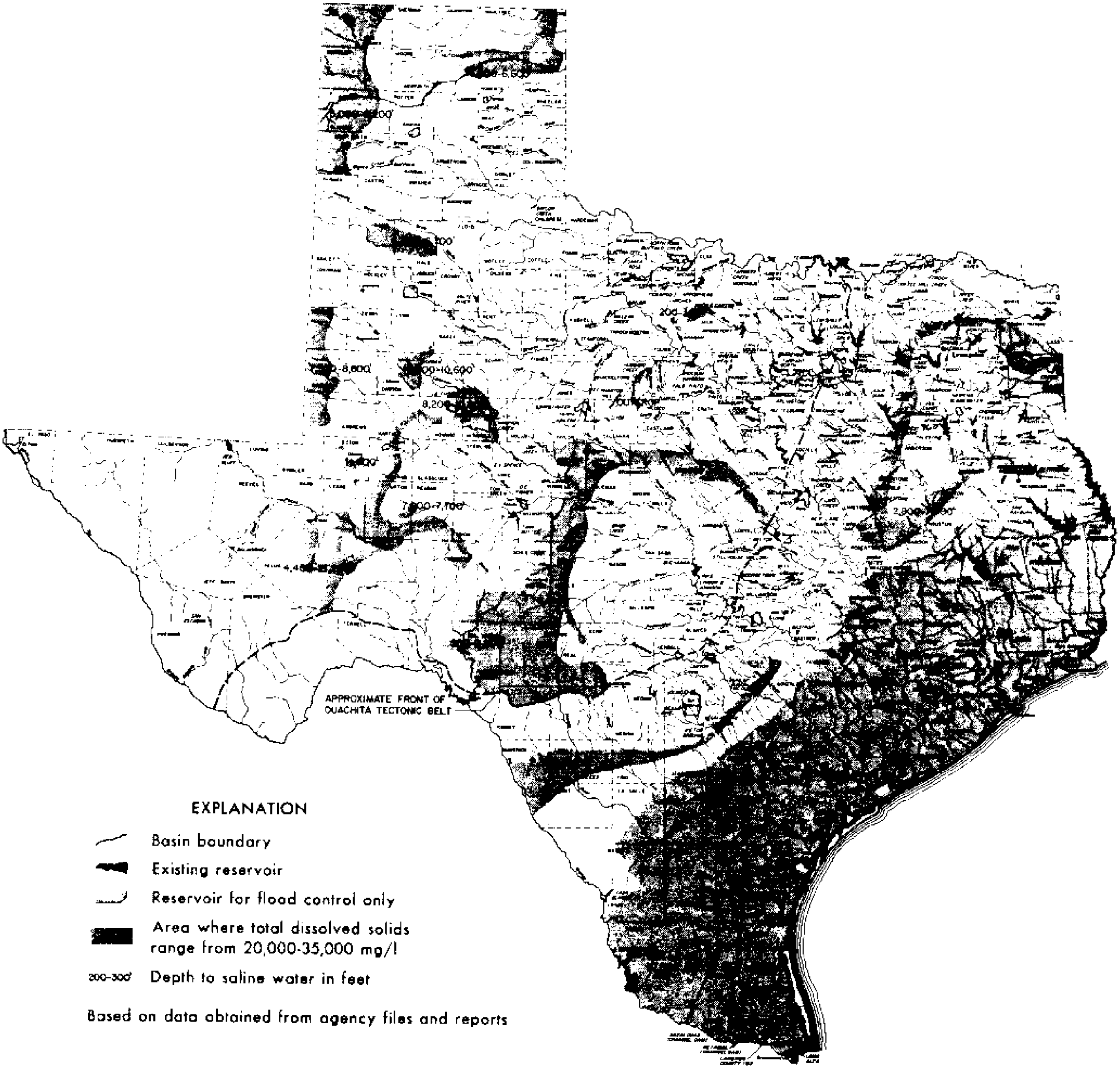


Figure 6. Known Areal Extent of Ground Water Containing 20,000-35,000 Milligrams Per Liter Total Dissolved Solids in Texas

demand by location will be established. Maps displaying this information will be produced.

The long-term program will coordinate the Texas Aquaculture Plan and its associated water requirements with the 50-year planning cycle of the Texas Water Plan. Data, such as water costs and sustainable yields, will be the focus of this effort. In addition, economic feasibility studies comparing the aquaculture industry to other Texas water users will be initiated. An area of interest here would be comparing the profitability of aquaculture to that of irrigated crops. Other long-term interests are the projection of water surpluses over time and the availability of saline ground water.

Texas water allocation information is primarily the responsibility of the Texas Water Development Board (TWDB) and the Texas Water Commission (TWC). Contacts have been made with both agencies, and their staff have initiated procedures to develop both the short- and long-term water resource data needed for aquaculture planning.

TWDB is estimating groundwater by counties and determining pumping capacity in aquifers. It is probably too late for aquaculture water projections to be input into TWDB allocation modeling for the current water plan, however, the current water plan could include a discussion of aquaculture in the narrative section. For example, this might describe the emerging industry, estimate total water needs statewide, and list potential species. Aquaculture water requirements could then be used in allocation modeling the next water plan.

Although the initial stages of this important planning effort are proceeding without funds, ultimately, funds will be needed to support the economic analysis of aquaculture versus irrigated agriculture. Also, funding will be required for computer mapping of potential aquaculture sites in Texas.

CLIMATE

Climate has a substantial influence on both aquaculture management practices and productivity. In an attempt to characterize various regions of Texas in terms of their suitability for aquaculture as a function of climate, mean annual temperature and mean annual rainfall data have been examined (Figs. 7 and 8, respectively). In general, climate becomes more limiting as one proceeds from east to west and from south to north across the state.

Temperature plays an important role in the aquatic environment in that the metabolic rates of all aquaculture species are controlled by that parameter. Thus, growth rate and productivity are intimately linked with water temperature.

Temperature, in conjunction with humidity, also plays an important role in the extent of evaporation from a given aquaculture facility. In areas where the availability of water is marginal, evaporation may be the difference between success and failure.

Assuming that aquaculture in Texas will be largely restricted to what are generally accepted to be warmwater species, i.e., those which have temperature optima at or above about 25 C, (77 F) virtually all of the state can provide a suitable thermal regime in ponds during at least part of the year. However, since the growth of warmwater species is drastically reduced or ceases below about 20 C, (68 F), the duration of the nonproductive season is important. Areas having annual mean temperatures above 18 C are potentially suited for warmwater aquaculture, although certain species may still require special overwintering facilities to prevent cold death due to cold.

The major effect of rainfall relative to aquaculture development is in to compensate for loss of water through evaporation. Many pond managers allow pond water levels to drop considerably due to evaporation before resorting to pumping replacement water. Proper management can utilize precipitation to conserve water use.

Some farms rely on the use of surface water runoff. While the use of runoff water is not always desirable for freshwater culture, it is sometimes necessary to utilize this resource. In order to be useful to the aquaculturist, surface runoff volumes must exceed the water lost to evaporation and seepage. In addition, the runoff water must be available during the proper times of the year. Areas of high and predictable rainfall may be suitable for aquaculture systems which use only runoff, although well water and other sources of surface water (reservoirs, lakes, streams or springs) should be available as backups to surface runoff. Areas in Texas which receive 100 cm (40 inches) of rain annually may receive sufficient runoff to support aquaculture, while areas receiving between 40 and 100 cm (16-40 inches) require a source of backup water. Culturists in areas receiving less than 40 cm (16 inches) of rainfall per year should not depend upon runoff as a water source.

LAND

Proper land resources are important when ponds are to be constructed but are of less importance in tank, silo or cage culture. Land characteristics needed for pond construction include: suitable

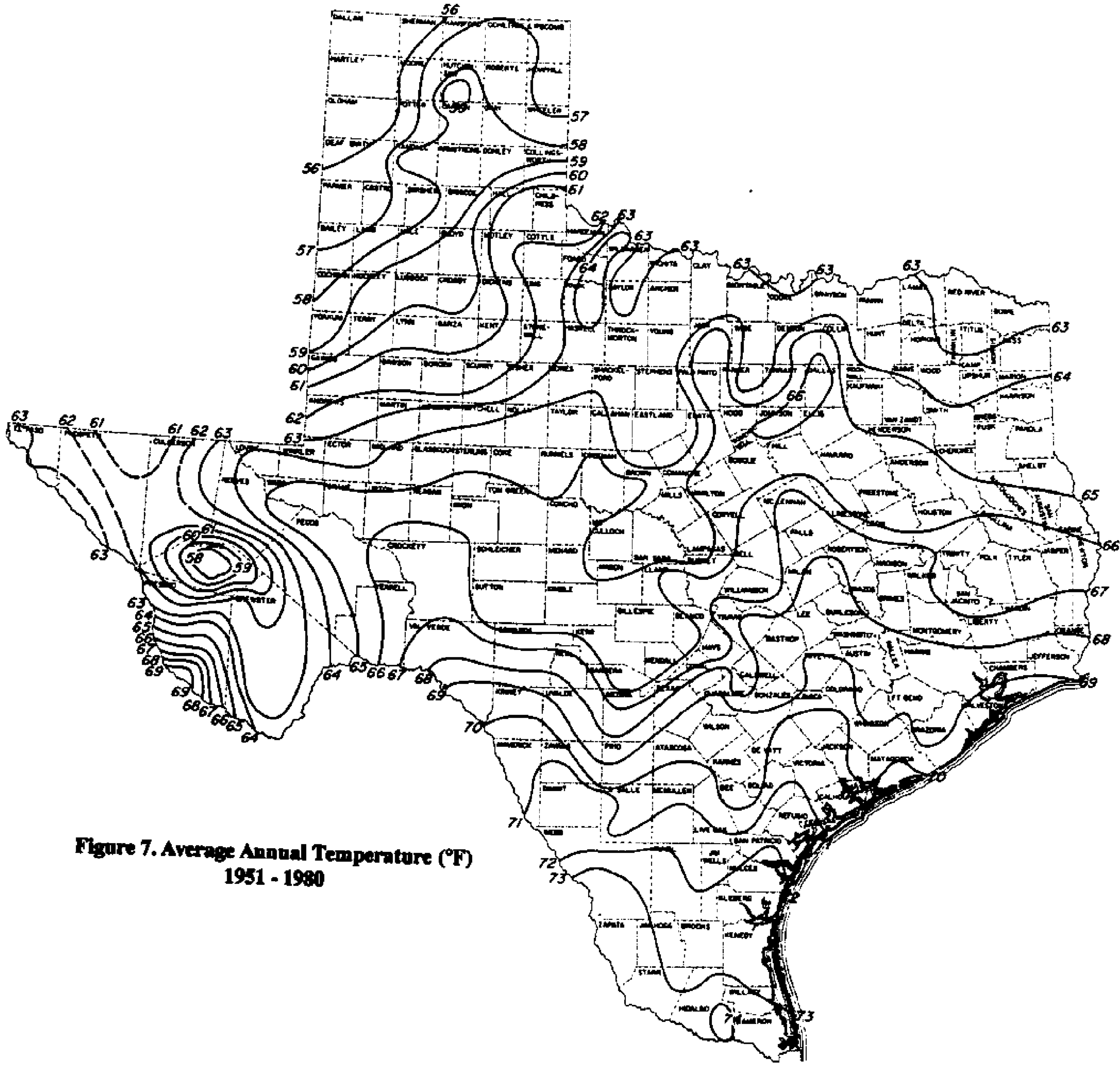


Figure 7. Average Annual Temperature (°F)
1951 - 1980

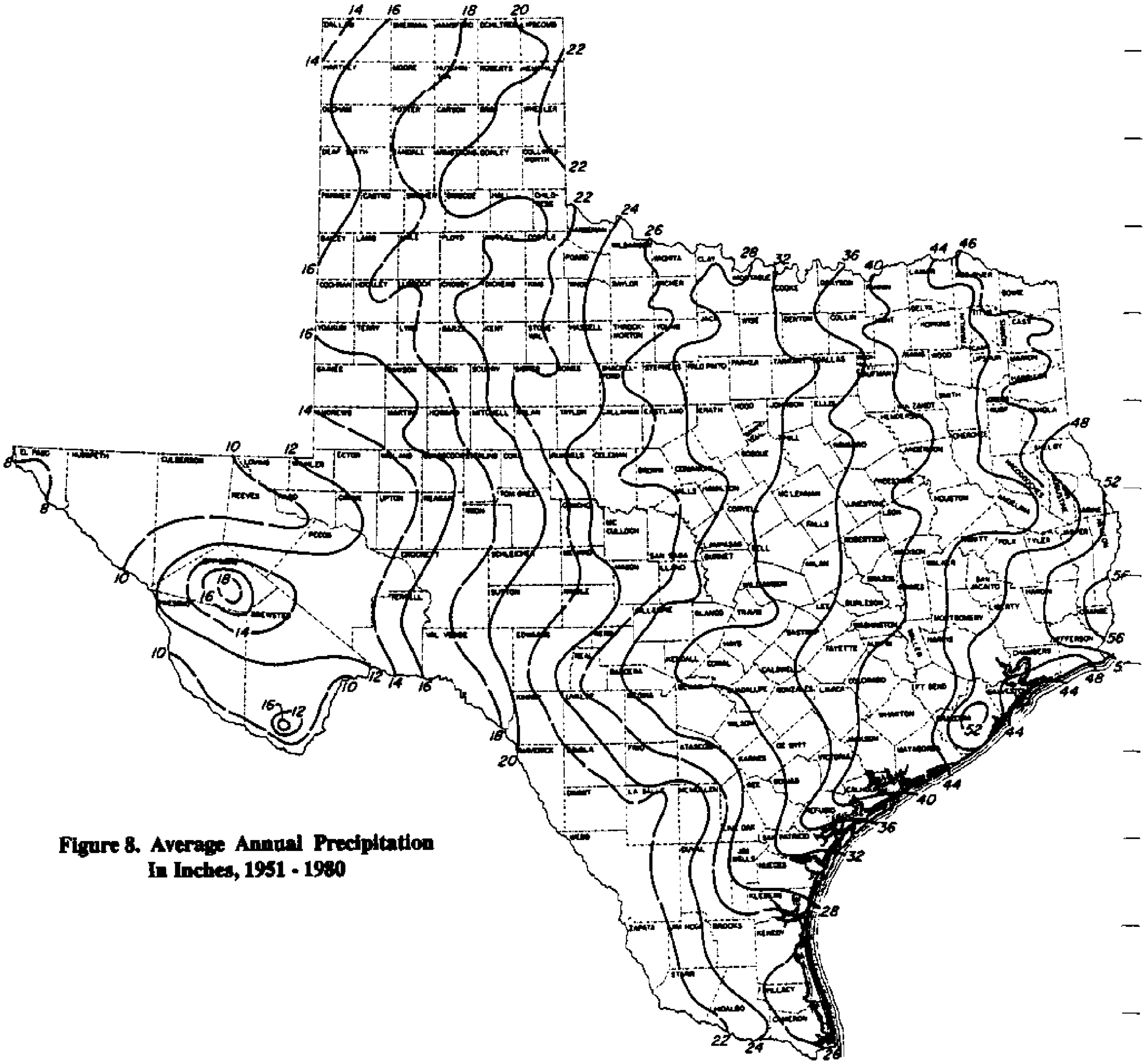


Figure 8. Average Annual Precipitation In Inches, 1951 - 1980

elevation for drainage, absence of a high water table, and low permeability of soils. Of these factors, soil type poses the most frequent limitations.

Soil Resources

Texas has a wide variety of soil types, and it is not uncommon to find discontinuities in soils, such as areas with sufficient clay percentages for ponds occur interspersed among highly porous, sandy soil. This is particularly the case in alluvial areas. Because it is not possible to predict the precise soil type on any specific piece of property by referring to a general ized soil may (Figure 9), it will be necessary for prospective aquaculturists to have an evaluation of the soil before construction begins. In general, soils with 25 percent or more clay are suitable for pond construction. Soil borings on prospective culture sites should be sufficiently deep to ensure that a surface layer of clay is not underlain by sand. In some instances sandy surface soil may be underlain by a thick clay layer beginning at a depth of only a few cm which can then be utilized to seal the pond basin.

While ponds have been built in areas with highly porous soils, the costs of lining ponds or other methods of sealing are often prohibitive. In areas of high water tables and sufficient hydrostatic pressure, seepage may be so great that water will rapidly enter ponds which are being drained.

SUMMARY

Water supply is thought to be the most crucial natural resource limiting freshwater aquaculture in Texas. Integrated aquaculture operations are estimated to require about 35,000 acre feet of water per year. This is a large water requirement that is unavailable as surplus in most areas of the state.

Some areas may have diversion rights available for sale or contract use. Information is presented about potential areas with available groundwater and surface water. Further evaluation of the location and extent of available water would be valuable to Texas aquaculture development.

Estuarine and oceanic water supplies are not limited by quantity considerations, but their use is associated with a greater engineering and permitting costs.

The large tracts of low-value property with access to brackish ground water in portions of West Texas may offer much presently unrecognized aquaculture potential.

Rainfall and temperature patterns in the eastern two-thirds of the state are generally suitable for aquacultural development.

Suitable soils for pond construction also are widely available, but on-site evaluations are recommended because of local variability.

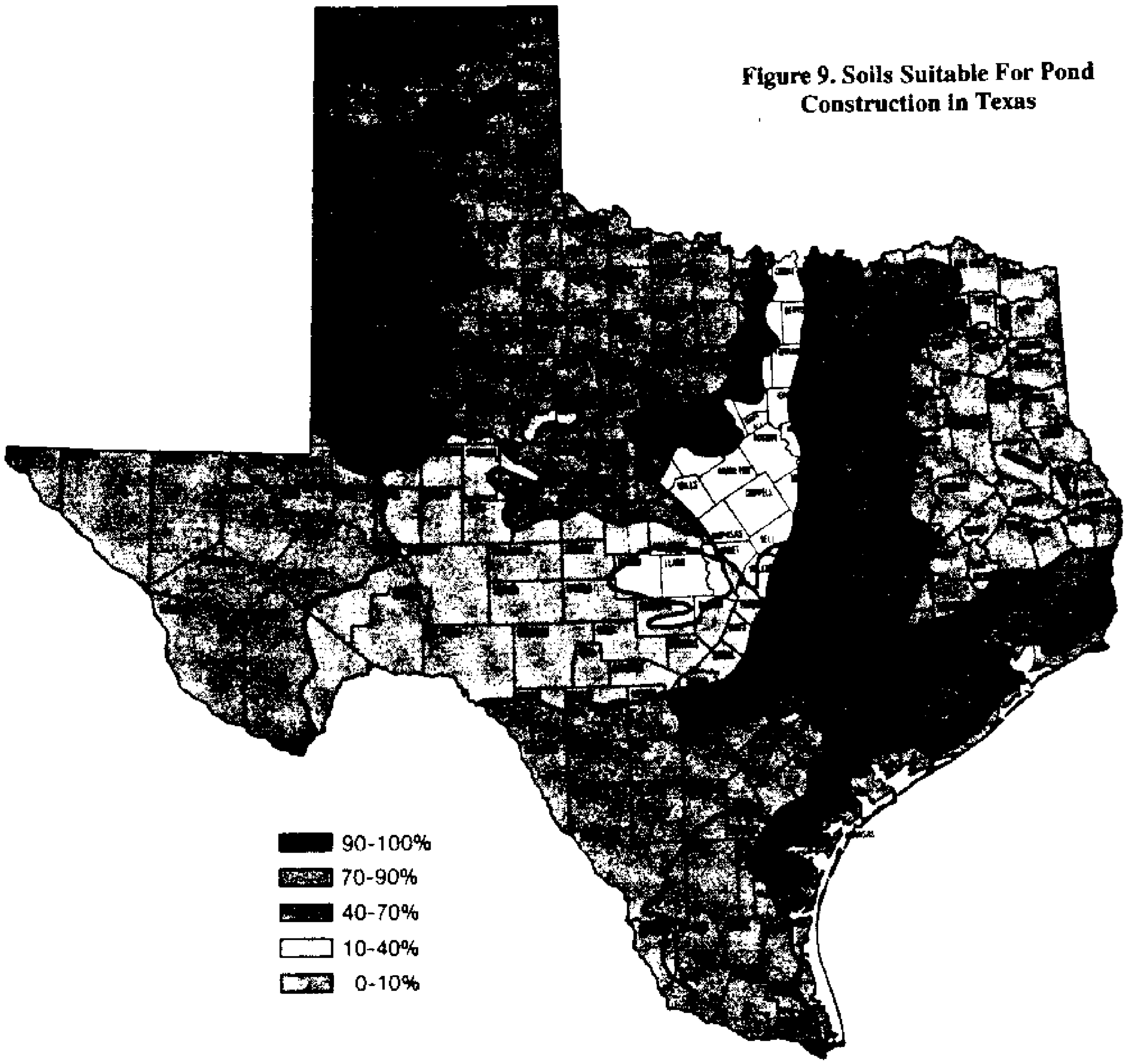


Figure 9. Soils Suitable For Pond Construction in Texas

LEGAL, REGULATORY AND PERMITTING*

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INTRODUCTION

A significant number of federal, state, and local government agencies may be involved in the regulation of an aquaculture operation. This involvement can include site selection and development, facility design and construction, species procurement, operations, processing, and marketing.

The regulatory environment is often a source of concern to individuals, investors, and corporations due to the possibility of unanticipated delays and increased capital and operating expenses, regardless of the endeavor. The source of this concern is frequently based on that small percentage of proposed projects which encounter regulatory difficulties.

In most cases, regulatory difficulties arise because of inadequate planning, lack of knowledge, and incomplete information concerning the agencies involved and their respective requirements. This is not to imply that improvements cannot be made in the regulatory environment, but rather to point out that information on government regulations is available and agency representatives are usually responsive to requests for assistance which fall within their agency's jurisdiction. It is not the responsibility of an agency representative, however, to be knowledgeable of the regulations of all other agencies which may have regulatory authority over some phase of a proposed

* The information contained in this chapter is excerpted from a manuscript entitled "Coastal Aquaculture Planning and Permitting Manual" which the authors expect to complete by the summer of 1990.

project. This responsibility remains with the project applicant.

In view of the need to provide prospective aquaculturists with information and sources of contact regarding applicable government agencies, the following lists each federal and state agency which has been determined to have authority over aquaculture operations. Under each agency heading are descriptions of the agency's role, responsibility, and regulatory or permitting requirements. In most cases, the following format is used for presentation of regulatory or permitting requirements:

- Agency Role and Responsibility
- Regulatory Requirements (permit, license, certification, etc.);
- Procedures and Contacts;
- Review and Coordination;
- Processing Time Requirements; and
- Issuance, Fees, and Term

Local government agencies also are presented and discussed in general terms.

FEDERAL GOVERNMENT

U.S. Army Corps of Engineers

Agency Role and Responsibility

The U.S. Army Corps of Engineers (COE) is responsible for preventing the alteration or obstruction of the navigable waters of the United States, protection of wetlands resources, and the maintenance and protection of the nation's water resources.

These responsibilities are carried out through the issuance, or denial, of permits authorizing certain activities involving wetlands, and navigable or other waters of the United States.

Regulatory Requirements

Section 10 Permit. A Section 10 Permit is required by Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403) for any structure and work in or affecting navigable waters. Examples include piers, intake pipes, discharge pipes, dikes for ponds, open water grow-out or depuration facilities, or any other structure which is determined to be an alteration of navigable waters or a potential hazard to navigation.

Section 404 Permit. A Section 404 Permit is required by Section 301 of the Clean Water Act (33 U.S.C. 1344) for the discharge of dredged or fill material into waters of the United States or which may affect wetlands. Coastal submerged lands, wetlands, or marshes, may be publicly or privately owned and are generally characterized as lying between terrestrial uplands and the aquatic system. It must be emphasized that the COE does not make ownership determinations as their authority regulates a public resource, regardless of ownership. The elevation of these wetlands is usually less than three (3) feet above mean sea level. Freshwater wetlands may include natural lakes, playa lakes, man-made lakes, and marshes adjacent to rivers and streams. Some examples of activities requiring a 404 permit include bulkheads, road fills, dredging canals or channels, pumping basins, levees any fill operation, spoil disposal, etc.

U.S. Environmental Protection Agency

Agency Role and Responsibility

The U.S. Environmental Protection Agency (EPA) is responsible for the protection of the nation's air and water quality, including potential adverse impacts to public health and fish and wildlife resources. These responsibilities are carried out through regulatory, permitting, and enforcement programs.

Regulatory Requirements

National Pollutant Discharge Elimination System Permit. Of significance to aquaculture operations in Texas is EPA's regulation of pollutant discharges into U.S. waters under the Clean Water Act, as amended (33 U.S.C. 1251 et seq.). Section 402 of the Act requires that a National Pollutant Discharge Elimination System (NPDES) permit be issued by the EPA prior to the discharge of any pollutant into the waters of the United States.

A hatchery, fish farm, or other aquatic animal production facility is normally a point source of discharge and subject to the NPDES permit program (40 CFR, Part 122, Subpart B, 122.24(a) & (b)). EPA rules (40 CFR, Part 122, Appendix C), however, authorize the granting of exemptions from the NPDES permitting program if a production facility contains, grows, or holds aquatic animals which satisfy the following criteria:

Facilities raising cold water fish species or other cold water aquatic animals in ponds, raceways, or other similar structures which:

(1)Produce less than 9,090 harvest weight kilograms (approx. 20,000 lbs) of aquatic animals per year; and

(2)Feed less than 2,272 kilograms (approx. 5000 lbs) during the calendar months of maximum feeding.

Facilities raising warm water fish species or other warm water aquatic animals in ponds, raceways, or other similar structures which:

(1)Produce less than 45,454 harvest weight kilograms (approx, 100,000 lbs.) of aquatic animals per year; or

(2)Closed ponds which discharge only during periods of excess runoff.

Aquatic animal production facilities determined by EPA to be ineligible for an initial exemption, or a continued exemption, will be required to apply for a NPDES permit.

Aquaculture projects within a "defined managed area" of U.S. waters which discharge pollutants into that area for the maintenance or production of harvestable freshwater, estuarine, or marine plants or animals are subject to the NPDES permit program (Section 318; Clean Water Act, as amended, and in accordance with 40 CFR, Part 125, Subpart B).

Aquaculture facilities engaging in processing activities which result in wastewater discharges into U.S. waters are subject to NPDES permitting requirements. This means production facilities which are exempt from NPDES permitting requirements (above) would be required to obtain a permit if they undertake processing activities which result in wastewater discharges.

Discharges into publicly owned treatment works (local sewage treatment systems) are not subject to NPDES requirements. However, pretreatment standards of the treatment works will apply to the wastewater discharges. The applicant should consult with the publicly owned treatment facility for standards and authorization prior to any discharges into their system.

U. S. Fish and Wildlife Service

Agency Role and Responsibility

The U.S. Fish and Wildlife Service (FWS), U.S. Department of the Interior, is primarily responsible for the protection and management of fish, migratory birds, and wildlife. With the exception of migratory birds and endangered species, the FWS's jurisdiction generally covers the inland, non-tidal, areas of Texas.

Programs administered by the FWS which could affect aquaculture development and operation include review and comment on proposed construction projects and the regulation of fish and wildlife imports and exports.

Regulatory Requirements

Construction Project Review. Federal agencies which issue permits, loans, loan guarantees, or grants for construction projects must coordinate with and consider FWS comments concerning impacts to fish and wildlife which may be associated with the project (Fish and Wildlife Coordination Act, 16 U.S.C. Section 661 et seq., as amended). This includes Section 404/10 permits issued by the U.S. Corps of Engineers and NPDES discharge permits issued by the U.S. Environmental Protection Agency. An objection raised by the FWS is usually a serious impediment to permit approval and may result in the need to modify the proposed project or offset damages to fish and wildlife species and/or their habitat. This especially is the case if endangered species are involved (Endangered Species Act, 16 U.S.C. Sections 703-712).

Fish and Wildlife Import/Export License. Any person who imports or exports live animals or fish with a value exceeding $25,000 per year for purposes of propagation or sale must first apply for and obtain a Fish and Wildlife Import/Export License from the FWS.

Designated Port Exemption Permit. There are nine (9) designated ports-of-entry for the import or export of fish and wildlife species and include: Dallas, New Orleans, Miami, Chicago, New York, Seattle, Los Angeles, San Francisco, and Honolulu. Ports-of-entry are usually at international airports or seaports. If a different city is preferred as the port-of-entry, a Designated Port Exemption Permit may be obtained.

National Marine Fisheries Service

Agency Role and Responsibility

The National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration, U.S. Department of Commerce, is primarily responsible for the management and protection of marine fish, habitat, and certain marine animals (16 U.S.C. Section 1361 et seq., as amended). To some extent, the NMFS is the marine counterpart to the U.S. Fish and Wildlife Service in regard to fisheries management and protection.

Construction Project Review

As was the case with FWS, the Fish and Wildlife Coordination Act requires federal construction and permitting agencies to coordinate with and consider the comments of the NMFS prior to issuing permits, loans, loan guarantees, or grants for projects which may affect marine fish species (16 U.S.C., Section 661 et seq., as amended). Generally, the NMFS reviews the construction project application for any potential impacts to fish species and fisheries habitats located in tidal (salt) water.

United States Coast Guard

Agency Role and Responsibility

One of the U.S. Coast Guard's (CG), U.S. Department of Transportation, major roles is maintaining and regulating safe navigation in U.S. navigable waters. The marking of obstructions which may present a hazard to navigation is a specific regulatory program administered by the CG and was authorized by the Rivers and Harbors Act of 1899. Specific regulations concerning the marking of obstructions are described in 33 CFR, Part 66.

Regulatory Requirements

Regulation for the Marking of Structures and Floating Obstructions. Any structure, mooring, buoy, or dam in or over U.S. navigable waters, as determined by the CG, must be marked by lights and other signals for the protection of maritime navigation in the manner required by the CG. The prescribed lights and signals must be installed, maintained, and operated at the expense of the owner, or operator, of the obstruction (33 CFR, Part 66, Subpart 66.01). The required lights and signals are referred to as "Private Aids to Navigation". This could include piers, water intake pipes, discharge pipes, floating cages, and other similar obstructions which may be associated with an aquaculture operation.

Private Aids to Navigation. Where it is determined that proposed obstructions in U.S. navigable waters constitutes a potential hazard to navigation, the CG will notify the owner or operator of the obstruction that a private aid to navigation is required. Generally the CG becomes aware of proposed obstructions through the required coordination with the U.S. Army Corps of Engineers (COE) in the processing of Section 404 and Section 10 permits for construction in or near U.S. navigable waters. Where navigational aids are required, the requirement usually will be a condition of the COE permit.

The CG also investigates complaints from mariners regarding unmarked obstructions and may require either the removal or marking of the obstructions, if they constitute hazards.

Food and Drug Administration

Agency Role and Responsibility

One of the Food and Drug Administration's (FDA) responsibilities is the approval and regulation of drugs which may be used in aquaculture operations (Federal Food, Drug, and Cosmetic Act, 21, U.S.C. 301 et seq.).

Drug regulations include the use of drugs as additives to feed as well as drugs used for the treatment of diseases and parasite infestations in aquatic animals to be sold for human consumption. The Texas Department of Health also has authority over drug additives to feed (It is important to note that drugs do not include pesticides, which are regulated by the EPA).

Regulatory Requirements. Depending upon the drug and the drug concentration, commercial feed mills as well as individuals who desire to produce medicated feed, may be required to first submit an application and obtain approval from the FDA. Medicated feed mixtures which require a "waiting period" prior to marketing will usually require FDA approval. In most cases aquaculture operations who purchase commercially prepared feed will not be affected by these regulations. However, larger operations could fall under these regulatory requirements if they produce their own feed mixtures.

Drugs used for the treatment of diseases and parasite infections also require FDA approval. The process involves two steps. First, the drug must be approved; and second, the use of the drug for aquaculture applications, including dosage, must be approved. It is important that the aquaculturist use only FDA approved drugs and carefully follow the application instructions. In some cases a waiting period will be recommended between treatment and marketing. The waiting period should be carefully observed. Otherwise, the aquaculture products may be declared by the FDA, TDA, or local health authorities as being unfit for human consumption and confiscated from the market.

STATE GOVERNMENT

Texas General Land Office

Agency Role and Responsibility

The Texas General Land Office (GLO) is responsible for the management and use of state owned public lands. State owned public lands include:

- Public school lands;
- Emergent and submerged lands up to the mean high tide line in Texas bays; and
- Submerged lands extending from mean high tide out to three (3) marine leagues (10.35 miles) into the Gulf of Mexico.

A lease or easement must first be obtained from the GLO before any activity involving state lands may be undertaken (Texas Natural Resources Code, Chapters 33 and 51).

The majority of state owned lands, which might be affected by aquaculture activities, are coastal submerged lands which begin at the mean high tide line and extend out into the bays and estuaries.

Regulatory Requirements

Lease/Easement. A lease or easement is required from the GLO for any activity which would involve the use of coastal submerged lands. Some examples include dredging of channels, levees, construction of piers or docks, bulkheading, road construction, and pipeline placement.

Texas Department of Agriculture

Agency Role and Responsibility

The Texas Department of Agriculture (TDA) is responsible for encouraging the raising of cultured fish, the development of the fish farming industry, and the marketing of fish farm products (Section 12.009(C), Texas Agriculture Code, as amended by the Fish Farming Act of 1989).

Effective September 1, 1989, the TDA also was made responsible for establishing a comprehensive fish-farm program which addresses fish farming on owned or leased lands and waters (Section 13.003 Agriculture Code). The objective of the fish-farm program is to develop and expand the fish-farm industry in order to expand the state's economy and offer alternative farming opportunities. At a minimum, the program must include:

- A plan for promoting fish-farm products;
- Licenses and regulations for fish-farming operations;
- Licenses and regulations for farm-raised fish and shellfish processing plants;
- Technical assistance to fish farmers;
- Coordinated support to fish farmers from colleges and universities and other governmental entities; and
- Solicitation of financial support from the federal government for the fish-farm industry.

The fish-farm program will be implemented and necessary rules adopted by the TDA by early 1990 (Section 12(b), Fishing Farming Act of 1989, Acts of the 71st Texas Legislature, Regular Session, 1989).

Regulatory Requirements

Fish Farmer's License. Any person engaged in the business of producing, propagating, transporting, possessing, and selling cultured fish or shellfish raised in private ponds for resale, consumption, or stocking purposes must first acquire a Fish Farmer's License from the TDA. Temporary licenses are currently being issued for a $10.00 fee. New rules for license issuance, fees, and terms are presently under consideration and should be completed by early 1990. (Sections 134.011, 134.014, 134.015(a) (b) (c), Agriculture code).

Fish Farm Vehicle License. A vehicle used to transport fish from a fish farm for sale from the vehicle is required to have a Fish Farm Vehicle License. A vehicle owned and operated by a licensed fish farmer is exempt from this licensing requirement. New rules for license issuance , fees, and terms are presently under consiideration and should be completed by early 1990 (Sections 134.012, 134.014, 134.015(a) (b) (c), Agriculture Code).

Cultured Fish Processing Plant License. Any person operating a cultured fish or cultured shellfish processing plant must first obtain a Cultured Fish Processing License from the TDA. The adoption of rules for the licensing of cultured fish processing plants are presently under consideration and should be completed by early 1990 (Subchapter C, Sections 134.031, 143.032, 143.033, 143.034, Agriculture Code).

In addition to this license, state law requires that a Certificate of Compliance (Shellfish), Crabmeat Plant License, or a Food Manufacturer (all other aquatic species) Registration also must be obtained from the Texas Department of Health. Both agencies have rule making and inspection authority.

Texas Parks and Wildlife Department

Agency Role and Responsibility

The Texas Parks and Wildlife Department (TPWD) is responsible for the conservation, management, and protection of the state's fish and wildlife resources.

These responsibilities are carried out through various planning, management, research, regulatory, and enforcement programs. Of significance to aquaculture operations are TPWD's programs which involve the regulation of imported fish, shellfish, and aquatic plants and the issuance of certain leases, licenses, and permits .

Regulatory Requirements

Sand, Gravel, Shell, and Marl Permit. This permit is required prior to disturbance or the removal of materials from state waters including streams, rivers, and bay bottoms (Texas Parks and Wildlife Code, Chapter 86.002).

Private Oyster Leases. Any Texas Citizen or U.S. corporation (composed of U.S. citizens) may lease up to 100 acres of bay bottom for purposes of culturing oysters (Texas Parks and Wildlife Code, Chapter 76, Subchapter A).

Oyster Transplanting Permit. An Oyster Transplanting Permit must be obtained prior to taking oysters from public waters for the purposes of transplanting to a private oyster lease located in public waters (Texas Parks and Wildlife Code, Chapter 76, Subchapter B).

Oyster Harvest Permit. A permit is required to harvest oysters from private oyster leases (Texas Parks and Wildlife Code, Chapter 76, Subchapter B).

Commercial Oyster Boat License. A Commercial Oyster Boat License is required for each boat used in transporting or for the taking of oysters for pay, sale, barter, exchange, or for any other purpose from state public waters by the use of a dredge, tongs, or any other mechanical means (Texas Parks and Wildlife Code, Chapter 76, Subchapter C). The license includes the boat and crew for oysters only. A licensed fish farmer culturing oysters in state waters, including oyster lease holders, is also subject to the requirements of this license.

Shellfish Culture License. Each person engaged in the business of producing, propagating, transportation, selling, or processing for sale shellfish raised on private land must first acquire a Shellfish Culture License (Texas Parks and Wildlife Code, Chapter 51). Shellfish means aquatic species of crustaceans and mollusks, including oysters, clams, shrimp, prawns, and crabs of all varieties. A separate license is required for each tract of land on which shellfish are cultured.

General Exotic Shellfish Culture Permit. The holder of a Shellfish Culture License must obtain a General Exotic Shellfish Culture Permit prior to the importation, possession, propagation, or transport of exotic shellfish into or from the state (Texas Parks and Wildlife Code, Chapter 51.009). Exotic shellfish means non-native species of oysters, clams, shrimp, prawns, and crabs of all varieties.

Shellfish Sourcing Permit. The holder of a Shellfish Culture License may obtain shellfish broodstock during closed shellfish harvesting seasons, from public waters, by obtained a Shellfish Sourcing Permit (Texas and Wildlife Code, Chapter 51.010). Note: This permit is not required when shellfish are taken during open season.

Red Drum and Speckled Sea Trout Sourcing Permit. This permit is required for the taking from public waters of a limited number of red drum (redfish) and/or spotted sea trout (speckled trout) of spawning size for broodstock purposes (Texas Parks and Wildlife Code, Chapter 48.0101 and Texas Administrative Code Title 31, Chapter 57.362). Only licensed fish farmers may obtain a permit.

Exotic Species Permit. An Exotic Species Permit must be obtained in order to possess, propagate, transport or sell certain exotic species which are considered harmful or potentially harmful to native species (Texas Parks and Wildlife Code 66.007 and 66.015, Agriculture Code 134.020). Species for which Exotic Species Permits may be obtained include:

- blue tilapia (*Tilapia aurea*);
- Mozambique tilapia (*Tilapia mossambica*);
- Hybrids between the above species;
- silver carp (*Hypophthalmichthys molitrix*);
- and black carp (*Mylopharyngodon piceus*), also known as the snail carp).

(Title 31, Texas Administrative Code, Chapter 57.113) Qualifications for obtaining an Exotic Species Permit to culture one or more of the above species in private ponds (pond, reservoir, vat or other structures) include:

- Applicant must be a licensed fish farmer;
- The fish farm must be designed to prevent discharges of water containing adult or juvenile exotic species or their eggs from the perittee's property;
- Fish farms which are within the 100 year floodplain must be enclosed within an earthen or concrete dike or levee constructed to exclude all flood waters and such that no section of the crest of the dike or levee is less than one foot above the 100 year flood elevation. Dike or levee dessign or construction must be approved before issuance of a permit; and the
- Applicant has not violated any provision of the exotic species rules during the previous year.

(Title 31, Texas Admin. Code, Chapter 57.116).

General Commercial Fisherman's License. Any person who catches fish, oysters, or other edible aquatic products from state waters for pay, sale, barter, or exchange must purchase a General Commercial Fisherman's License (Texas Parks and Wildlife Code, Chapter 47.001 and 47.002). This includes an individual harvesting oysters from a private oyster lease or any other species which was cultured in state waters. A licensed fish farmer who wishes to sell cultured aquatic products to wholesale fish dealers, retail fish dealers, shrimp house operators, or restaurants may be required to purchase one of the following licenses:

- Commercial Fisherman's License;
- Wholesale Fish Dealer's License; or
- Shrimp House Operator's License.

(Texas Parks and Wildlife Code, Chapter 47.0091,47.0111, and 47.012)

Fresh Water Commercial Fishing Boat License. This license is required when a boat equipped with a motor or sails is used in non-tidal state waters to catch fish, oysters or other edible aquatic products for pay or for the purpose of sale, barter, or exchange (Texas Parks and Wildlife Code, Chapter 47.005). This includes boats used to harvest aquatic species which were cultured in non-tidal state waters (freshwater).

Saltwater Commercial Fishing Boat License. A Saltwater Commercial Fishing Boat License is required when a boat is used for the catching or assisting in catching fish, oysters, or any other edible aquatic life (except for shrimp and menhaden) from tidal waters for pay or for the purpose of sale, barter, or exchange (Texas Parks and Wildlife Code, Chapter 47.007). This includes a boat used to harvest aquatic species which were cultured in tidal waters.

Bait Dealer's License. A person who catches or transports for sale, or who is engaged in the business of selling minnows, fish, shrimp, or other aquatic products for fish bait is required to purchase a Bait Dealers License (Texas Parks and Wildlife Code, Chapter 77.001(10), 77.043, and 77.044).

Wholesale Fish Dealer's License. A person who engages in the business of buying for the purpose of selling, canning, preserving, processing or handling for shipments or sale fish, oysters, shrimp, or other commercial edible aquatic products to retail fish dealers, hotels, restaurants, cafes, or consumers must purchase a Wholesale Fish Dealer's License (Texas Parks and Wildlife Code, Chapter 47.001(3) and 47.009). A licensed fish farmer who buys aquatic products for the above stated purposes is required to purchase this license. However, a licensed fish farmer who provides services to others (such as custom processing, packaging, labeling, shipping, etc.) for a fee is not required to purchase the license.

Wholesale Fish Truck Dealer's License. A person who engages in the business of selling edible aquatic products from a motor vehicle to retail fish dealers, hotels, restaurants, cafes, or consumers must have a Wholesale Truck Dealer's License. In most cases thiis license will not apply to a licenses fish farmer. However, if the fish farmer engages in the buying and selling of edible aquatic products the license may be required.

Retail Fish Dealer's License. A person engaged in the business of buying for the purpose of sale to a consumer, fresh or frozen edible aquatic products is required to purchase a Retail Fish Dealer's License (Texas Parks and Wildlife Code, Chapter 47.001(4) and 47.011). A licensed fish farmer who buys cultured or other fish products for sale at retail may be required to purchase this license.

Retail Fish Truck Dealer's License. A Retail Fish Truck Dealer's License is required to sell edible aquatic products from a motor vehicle to consumers (Texas Parks and Wildlife Code, Chapter 47.013). A licensed fish farmer who buys and sells from a motor vehicle at retail could fall under this licensing requirement.

Alligator Farmer's Permit. Any person who wishes to possess live alligators or propagate alligators for the purpose of selling the alligators, hides, meat, or other parts of an alligator must first obtain an Alligator Farmer's Permit (Texas Parks and Wildlife Code 65.003, 31 Texas Administrative Code 65.351-65.369).

Alligator Import Permit. An Alligator Import Permit is required to bring live alligators and alligator parts into the state (Texas Parks and Wildlife Code, Chapter 65.003 and Title 31, Texas Administrative Code, Chapter 65.351 and 65.369).

Alligator Hide Tag. Hides of all alligators harvested must be tagged (Texas Parks and Wildlife Code, Chapter 65.003 and Title 31 Texas Administrative Code, Chapter 65.351-65.369).

Alligator Broodstock Regulations(Texas Parks and Wildlife Code, Chapter 65.003 and 31 Texas Administrative Code 65.351-65.369)

Authorized Sources

- Live alligators and alligator eggs may be obtained by:
- Purchasing from licensed alligator farmers in other states;
- Purchasing from licensed alligator farmers in Texas;
- Purchasing nuisance alligators which are occasionally available through the department;
- Purchasing tagged hatchlings from a hatchling tag recipient (land owner), or a licensed alligator hunter; and
- Purchasing alligator eggs from an authorized egg collector, or an alligator nest stamp recipient (land owner).

Texas Water Commission

Agency Roles and Responsibilities

The Texas Water Commission (TWC) is responsible for the protection of the state's water resources. These responsibilities are carried out through planning, development of water quality standards, issuing discharge permits, enforcement of discharge limitations, regulating water use, and issuing permits for construction activities affecting state waters.

Regulatory Requirements

Section 401 Certification. Any activity which requires a Section 404 permit from the U.S. Corps of Engineers COE also requires a Section 401 certification from the TWC prior to issuance of the COE permit (Section 404, Clean Water Act, as amended). The certification is a statement from the TWC that the proposed construction activity would not cause a violation of the state's water quality standards.

Discharge Permit. The Texas Water Code (Section 11.121) requires that a discharge permit be obtained prior to the discharge of wastes into or adjacent to the waters of the state. This includes the treatment, storage, or disposal of waste water by land treatment or evaporation. The federal Clean Water Act, as amended, also requires that a NPDES permit be obtained from the Environmental Protection Agency (EPA). (Refer to Federal Government for a description).

Certain discharges may be authorized by the TWC by rules or orders, instead of a permit. This includes certain aquaculture flow-through operations where discharge waters are high quality. Discharges of small and medium size shrimp packing operations are also regulated by rule.

Reclamation Engineer Permit. Construction within the 100 year flood plain of any stream, river, or other flood prone area which is an effort to control, regulate, or otherwise change the flood water of the stream is prohibited unless prior approval is obtained from the TWC or the appropriate city or county, if such city or county is participating in the National Flood Insurance Program (Texas Water Code 16.236).

Cities and counties participating in the Federal Flood Insurance Program, authorized by the National Flood Insurance Act of 1968, have jurisdiction over construction within the 100 year flood plain. This includes construction, maintenance, or improvements to levees, dams, or other improvements with the flood plain.

All coastal counties, and many other counties within the state, are currently participating in the federal program. In these counties, the local Flood Plain Administrator should be contacted for information on permitting requirements. The TWC has permitting authority in all other areas.

Water Use Permit. The TWC has regulatory authority over the diversion, impoundment, and/or use of all state waters. The use of brackish or marine waters for land based aquaculture operations is exempt from the Water Use Permit requirements (Texas Water Code 11.1421). However, a notice must be submitted to the TWC prior to taking such water for .aquaculture purposes. The aquaculturist also must submit a report every year which states the amount of water that has been diverted during the past year. The TWC has the authority to limit or stop water use during droughts or other emergencies.

The use of state waters, other than brackish or marine, is prohibited without first obtaining a permit from the TWC. However, an individual property owner may, without obtaining a permit, construct a dam to impound up to 200 acre feet for domestic and livestock purposes. Aquaculture is considered an industrial use. Conversion of existing or creation of new impoundments for aquaculture would therefore require a Water Use Permit (Texas Water Code 11.1421 and 11.143).

In addition to the requirement for a Water Use Permit, unappropriated (surplus) water rights must be available in the water body from which the water is to be taken. In certain areas of the state where all water rights (to rivers and reservoirs) have been appropriated. In these limited situations it would be necessary to purchase water rights from an existing water rights holder. The purchase of water rights may require TWC approval.

Texas Department of Health

Agency Role and Responsibility

The Texas Department of Health (TDH) is responsible for the protection of the public health, including the regulation of food, drugs, and cosmetics which may ultimately affect consumers.

These responsibilities are carried out by various licensing, registration, labeling, certification, inspection and regulatory programs. Legal authority for carrying out these programs is provided by the Texas Food, Drug, and Cosmetic Act (Article 4476-5) and the Federal Food, Drug, and Cosmetic Act (Title 21 U.SC. 301 et seq.).

The Food and Drug and the Shellfish Sanitation Control Divisions, within the TDH, are responsible for programs which affect aquaculture operations in Texas. These programs provide for the regulation of aquatic species which are raised in public and private waters and include water quality, production, harvesting, processing, transporting, storing, handling and packaging of cultured aquatic products to be sold for human consumption.

Regulatory Requirements

Transplant Permit. A Transplant Permit must be obtained from the Texas Parks and Wildlife Department.

TDH Notification. Information on the quantity of shellfish transplanted, origin of shellfish, where placed and the date the transplant permit expired must be provided to the TDH. Transplanting to a depuration facility has similar, but more detailed, reporting requirements. In addition, the waters from which shellfish may be gathered for delivery to a depuration facility are more stringently regulated and the gathering and transportation must be supervised.

Harvest Permit. A Harvest Permit must be obtained from the Texas Parks and Wildlife Department. No shellfish may be harvested for marketing in less than 15 days following the date of expiration or cancellation of the Transplant Permit. Marketing of shellfish from a depuration facility does not require a harvest permit. The TDH has specific regulations governing depuration facilities (Texas Molluscan Shellfish Rules, TDH, Sections 241.85 - 241-100).

Certificate of Compliance. Any person who processes or packages shellfish for sale as food after they have been harvested is classified as shellfish dealer or shipper and must first obtain a certificate of compliance from the TDH. During the harvest operation, shellfish are placed in bags or other approved containers. Any activity in which the shellfish are removed from the original containers and placed in other containers would fall under the definition of processing or packaging and thus would require a Certificate of Compliance.

Crabmeat Plant License. A Crabment Plant license is required of any person who engages in the processing and packing of crabmeat for sale for human consumption (Texas Crabmeat Rules, Section 241.01). The TDH rules also cover plant design, construction, and operations. Crabmeat plants are classified into two (2) major categories for licensing purposes:

- Picking and packing plants; and
- Picking, packing, and pasteurizing plants.

Food Manufacturer Registration. With the exceptions of shellfish (oysters, clams, mussels) and crabs, anyone wishing to process aquatic species for sale for human consumption must first be registered as food manufacturer with the TDH (Texas Food, Drug, and Cosmetic Act, Section 23a, Article 4476-5).

In addition, Section 431.222, Health and Safety Code, requires that a food manufacturer must register, annually on or before September 1, each establishment that the manufacturer operates within the state and pay a fee for each establishment.

Manufacture means the process of combining or purifying food and packaging food for sale to the consumer at wholesale or retail (Health and Safety Code, Section 431.221). All food manufacturers in Texas must comply with minimum standards of construction and operation in order to be eligible for registration. Minimum standards are contained in:

Texas Food, Drug, and Cosmetic Act, Article 4476-5;

Diseases Transmitted Through Food, Drink or Utensils Act, Article 4476-10'; and

Current Good Manufacturing Practice in Manufacturing, Processing, Packing, or Holding Human Food, Code of Federal Regulations, Title 21, Part 110, Sections 110, 3-110.110.

Texas Animal Health Commission

Agency Role and Responsibilities

The Texas Animal Health Commission (TAHC) is responsible for the protection of the public and the states' domestic livestock industry from communicable diseases. This responsibility is carried out through inspection and certification of livestock within the state as well as animals which are imported into the state.

Regulatory requirements

Certification of Veterinary Inspection.

The TAHC requires that live animals shipped into the state be free of disease. The Texas Parks and Wildlife Department has primary responsibility for regulating the importation of aquatic animal, fish, and shellfish species. Consistent with TAHC regulations, the Texas Parks and Wildlife Department (TPWD) generally requires a "disease free" certification as a condition to a permit for the importation of aquatic species into the state.

The "disease free" determination is called a Certificate of Veterinary Inspection. The certificate is issued by a veterinarian or qualified testing laboratory. Usually the certification is obtained prior to importation. However, in certain cases the animals may be brought into the state and held under controlled conditions while all, or a representative sample, of the aquatic animals are being tested for diseases.

Texas State Historic Preservation Officer and The Texas Antiquities Committee

Agency Role and Responsibility

The State Historic Preservation Officer (SHPO), acting on behalf of the Texas Historical Commission, and the Texas Antiquities Committee (TAC) are jointly responsible for the protection and preservation of historical and archaeological resources within the state. (National Historic Preservation Act of 1966-SHPO, Texas National Resources Code, Section 191.131(b)-TAC). These responsibilities are carried out primarily through review of loans, grants,, and construction permit applications which propose to undertake land disturbing activities, potentially impacting historical or archaeological resources. Both the SHPO and the TAC have the authority to issue or deny permits for the disturbance of known, or discovered, historic or archaeological resources. Scientific investigations may also be required as a condition of the permit, loan, grant, or in the event of discoveries during construction.

The SHPO has review authority over federal permits, loans, and grant applications for construction on public as well as private lands. The TAC's authority also covers lands owned by the state and political sub-divisions of the state.

Application Review Requirements

Applicants for federal or state construction permits are not required to submit separate applications to the SHPO or the TAC. However, the permitting agencies are required to provide an opportunity for review and comment on permit applications and must consider the comments received from the SHPO and the TAC. The National Historic Preservation Act of 1966 directs federal agencies to coordinate with the SHPO. State laws and agency rules require state agency coordination with both the SHPO and the TAC.

LOCAL GOVERNMENTS

The permit applications from most federal and state permitting agencies ask for information concerning the status of permits required by local political subdivisions. The aquaculturist's failure to identify and obtain necessary permits and approvals from appropriate local jurisdictions may result in project delay.

While federal and state agencies are aware of some of the local permitting requirements and will advise the permit applicant, the ultimate responsibility lies with the applicant. It is important, therefore, that the applicant, or his representative, meet with local officials to describe the project and identify local permitting requirements and regulations. Most of this coordination should be done during the site characterization and evaluation process and prior to development of detailed project design and construction plans.

The following are examples of the types of aquaculture project activities in which local government authorities could require a local permit, assess fees, or impose regulations on the project:

Activity	Local/Regional Authorities
Water Supply	City, Water District, River Authority, Underground water control districts
Wastewater and Solid Waste Disposal	Publicly owned water treatment facilities (cities or municipal utility districts), drainage districts, city or county land-fill regulations, county septic tank regulations
Land Use	City zoning ordinances
Construction	City or county flood plain administrator, flood control or levee districts, city construction codes, county construction requirements as a condition of septic tank permits or use of county rights-of-way, city requirements within "extra-territorial jurisdiction", local health authorities.
Electrical Service	City, River authority, electric power company, rural electric cooperative, municipal utility district.

REGULATORY ISSUES

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Aquaculture was reported to be the fastest growing sector of the agriculture industry in the United States during the 1980's. Unfortunately, much of this growth bypassed Texas in favor of other southern states. Industry representatives have cited a variety of problems inhibiting development of aquaculture in Texas, but a recurrent theme is restrictive regulations. This brief chapter will describe the regulatory background in Texas and identify issues that are currently unresolved.

REGULATORY BACKGROUND

Ironically, part of the reason that Texas regulations are somewhat restrictive toward aquaculture is simply that the industry has historically been relatively small, fragmented, and ineffectual in lobbying for needed changes. Although aquaculturists may feel that the justifications for certain regulatory changes are indisputable, final decisions are often based on political "perceptions" of the situation.

Our state's natural resources are utilized by many different interest groups, which often compete with each other on conflicting issues. Without an effective, concerted effort by aquaculturists to inform other interest groups about the limited impact of needed regulatory changes, active opposition is likely to occur.

Another factor which probably limited aquaculture support in the past was lack of a promoting agency. Until the passage of the Fish Farming Act of 1989, aquaculture licencing and promotion were administered through the state resource management agency, Texas Parks and Wildlife Department (TPWD), which is primarily responsible for protecting the state's natural resources. The responsibility for licencing and promotion of aquaculture has now been transferred to the Texas Department of Agriculture.

CURRENT ISSUES

Need to Simplify Permitting

Aquaculture permitting is a complex and time consuming process. In many cases, several regulatory agencies are involved to obtain the permits, licences, and certifications required. Consequently, extensive and unnecessary delays may occur between the conception of a project and its realization as a functioning operation.The establishment of a state aquaculture permitting office to provide guidance to the applicant and to coordinate regulatory activities would be a valuable contribution to the industry. A related need is a comprehensive permitting manual describing all federal, state, and local regulations impacting aquaculture.

Non-Relevant Regulations

Some regulatory problems are attributed to legislation which simply wasn't written with aquaculture in mind. For example, the Texas Water Commission formerly required coastal aquaculturists who pump bay water to file the same Water Use permit application and pay the same fees as industrial users of river water. Of course, bay water, being directly connected to the Gulf of Mexico, is not faced with the same quantity limitations as are rivers. In this case, the Corpus Christi Economic Development Corporation organized a legislative effort by commercial producers about 3 years ago which resulted in an exemption of this ruling.

Another non-relevant regulation which has not yet been changed is the ban on marketing of hybrid striped bass in Texas. Current TPWD regulations prohibit Texas fish farmers from sellingTexas grown striped bass for human consumption; however, they allow out-of-state fish farmers to sell their product to Texas consumers. This regulation was probably written before commercial aquaculture of hybrid striped bass was considered a possibility.

Several other states have changed their regulations to accomodate the commercial interest in aquaculture of hybrid striped bass. Texas regulations need to be changed also, but such changes are not automatic. In order to avoid conflicts with recreational fishing interests, they must be assured about protection of wild stocks of striped and white bass in Texas. The aquaculture industry could ease concerns by recreational fishermen by recommending certain conditions be established to reasonably limit brood stock collection.

Debatable Information

Some regulatory constraints arise directly from concern about aquaculture activities. The common problem in such situations is that pertinant data about potential aquaculture impacts is generally limited. In the absence of adequate information, management agencies feel compelled to react conservatively to protect the environment. Controversy arises when agency decisions seem unnecessarily conservative and result in economic hardship to producers.

Of course, the obvious solution to such problems is to collect more data and document the actual impact. However, this process can be time consuming and expensive. Also, producers have complained that too much of the burden of proof is placed on the aquaculture community. Examples of controversial situations in which inarguable data are limited are described below:

Exotic Shrimp Virus Ruling

During 1989, a sample of non-indigenous shrimp (*Penaeus vannamei*) from a shrimp farm near Collegeport were found to carry *Baculovirus penaei*, a viral disease common to indigenous shrimp of the Gulf of Mexico. Considering the possibilities that 1) the *Baculovirus* from the non-indigenous species might be different a different strain from that already found in Texas waters (although existence of different strains of *Baculovirus penaei* has never been documented) and 2) that a different strain could have catastrophic impacts on native shrimp, the farmer was compelled by TPWD to destroy the infected portion of his crop and disinfect the ponds. The same situation in South Carolina, where shrimp farming is promoted, resulted in no regulatory reaction.

Exotic Species Policy

Commercial producers are concerned that they are unable to use several carp and tilapia species which are currently on the proposed TPWD list of prohibited species. These species, including *Tilapia nilotica*, grass carp, and bighead carp are being used in other states to the competitive disadvantage of Texas producers. TPWD has assessed several characteristics of these species and contends that they could be damaging to the public waters of Texas. Other states have concluded that these species are permissable. Texas regulations have not been finalized as of the time of this writing.

Some growers have expressed concern that the policy for determining which exotic species are to be prohibited in Texas is too arbitrary and would like to better understand the mechanism used by TPWD to add or remove species from the list. TPWD explains that they carefully review how each species complies with a standard set of criteria (such as ability to reproduce in Texas waters, potential damage to native environments, similarity in appearance of a given species to a prohibited species, etc.). Furthermore, even those species which have been placed on the prohibited list could conceivably be permitted if new information were to demonstrate that risks would be minimal.

Intake Water Filtration

Aquaculture projects filing for U.S. Army Corps of Engineers Section 10 or Section 404 permits for dredging a water intake area or placing an intake structure in navigable waters presently are required to meet two criteria with regard to pumping. First, the intake station must be engineered to generate an approach water velocity not to exceed 0.5 feet per second. Second, the water must be filtered to a mesh size of 0.5 mm before pumpinig to avoid destruction of small planktonic organisms including eggs and larvae. The first criteria (reducing intake velocity) is generally agreed to be a reasonable means of preventing impingement or entrainment of weak swimming organisms. However, aquaculturists have objected to the second criteria on the basis that 1) data demonstrating a significant aquaculture impact on planktonic eggs and larvae is non existent; and 2) the costs of engineering an effective intake screen system to filter rich, turbid, surface water to 0.5 mm before pumping is cost prohibitive. To resolve this conflict, several regulatory agencies have agreed to consider the possibility of allowing filtration to occur downstream from the pump. The proposed filtration system would use self cleaning screens to separate the organisms from the intake water and transport them back to the source water body in a flume of water.

Lack of Adequate Funding

Some regulatory problems arise simply because inadequate funding exists to maintain needed programs. For example, producers are prevented from growing oysters on private property such as ponds or raceways, because the Department of Health, Shellfish Sanitation Division has inadequate budget and personnel to certify the quality of private waters for shellfish. Without the certification, it is illegal to market those oysters. In order for pond culture of oysters to develop in Texas, either the Shellfish Sanitation budget needs to be increased or the regulations need to be changed to allow private labs to perform the certification service for a fee.

Other Regulatory Issues

As aquaculture continues to grow in Texas, many unforeseen regulatory hurdles are likely to emerge. The following is a short list of other issues which are likely to emerge in the near future:

- Developing an expanded list of FDA approved chemicals for use in treating water and feed.
- Developing appropriate mechanisms for inspection of seafood processing plants.
- Establishing authority for leasing of water column for floating cage culture in state and federal waters. This issue will require coordination between inshore and offshore mariculture interests and relevant fishing and navigational interests.
- Developing consistency between federal and state water discharge regulations, e.g. establishing exemptions for operations meeting minimum discharge criteria.
- Developing a general permit for small fish farming projects, similar to the Army Corps of Engineers general permit system. Presently, all TPWD sand, gravel, and marl permits require a public hearing regardless of the size of the project. TPWD presently objects to a general permit because of their philosophy that many small projects can be just as damaging as one large project.
- Incorporating provisions to include non-food forms of aquaculture (such as producers of bait and ornamental organisms for the aquarium industry) into the licencing and benefits available now for food fish.

PROCESSING AND MARKETING

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Efficient processing, distribution and marketing of products is of paramount importance to the success of any food production enterprise. The food processing and marketing sector in Texas is a large, mature, sophisticated complex serving the third most populous state in the nation. However, Texas aquaculture is a relatively small, fragmented, newcomer to the Texas food industry. Appropriate conditions often do not exist between production and utilization interests to facilitate use of local products by processing and marketing firms.

This segment focuses on aquacultural production as a food item which enters customary marketing channels. Processing and marketing of aquacultural production for ornamental use, bait or sport fish stocking programs are not considered. Three components comprise this chapter: 1) a description of the current seafood demand and supply situation in Texas, 2) the traditional infrastructure of the processing and marketing sector, and 3) problematic issues suggested by key leaders within the Texas food processing and marketing complex. The authors are grateful to those who helped identify problems which limit the use of farm-raised seafoods, and suggested potential solutions during telephone interviews.

SEAFOOD DEMAND AND SUPPLY

Demand

On the demand side, the picture is bright, and by any measure (market share, sales, etc.) seafood businesses have prospered over the past 4-5 years as a result of a growing, domestic seafood market. One way of evaluating differences in product markets nationwide is through per capita consumption information. Per capita estimates are synthetic measurements which compute the amount of a certain item each person consumes in a year. It is calculated by first standardizing the annual customer base to include all civilian residents and then dividing the total, annual use of the product by the civilian, resident population for that year.

Between 1978 and 1988, per capita consumption of all seafoods increased from 13.4 pounds to 15 pounds and averaged 13.7 lb. (Table 1). This increase in seafood use has been attributed to: a) increases in personal income, b) lifestyle changes and c) a greater awareness of the health benefits of fish and seafood. Most of the increases in personal income have been the result of extremely low inflation since 1982. Thus, purchasing power has been maintained, because the general level of price increases has been low. This is significant to the seafood industry and the food service sector since, historically, the majority of seafood products have been consumed away from home.

Table 1. United States per capita consumption of all seafood from 1978 to 1988.

YEAR	Per Capita Consumption (pounds)	% Change from previous year
1978	13.4	--
1979	13.0	-3.0
1980	12.8	-1.5
1981	12.9	0.8
1982	12.3	-4.7
1983	13.1	6.5
1984	13.7	4.6
1985	14.4	5.1
1986	14.7	2.1
1987	15.4	4.8
1988	15.0	-2.6

However, this historic dependence on the away-from-home market is being balanced somewhat by food retailers who are developing aggressive seafood programs. Since the mid 80's, the retail food sector has steadily increased its commitment to seafoods as an additional component of the meat mix. In 1987, the retail food sector reported that seafood department sales accounted for 5.7% of total store sales nationwide; an increase of 43% since 1985, or about 17% per year.

Seafood products found a growing niche in the total, domestic food market of the 80's. Whereas 10 years ago, food retailers were skeptical about seafood departmental performance, today their main concern is procurement to meet increasing demand. Similarly, the food service sector has experienced real gains in seafood use. For example, the domestic shrimp market has grown about 8% each year since 1985.

Projections by USDA in 1986 suggested that by the year 2000 per capita consumption would increase 5-17% above 1986 levels, with estimates ranging from 15.5 to 17.2 pounds. Surprisingly, this projected increase was achieved in 1987 when a record per capita value of 15.4 pounds was reported.

What is the outlook for the Texas market? According to the 1980 census, the population of Texas (14.2 million) was exceeded by only New York (17.6 million) and California (23.7 million). Projections of 1990 state populations suggest that Texas will increase about 22% over 1980 levels, and will be the second most populous state with approximately 17.5 million residents. Thus, Texas represents an already large and growing market for, among other things, fish and seafood products.

Data collected by the State Comptroller's Office indicate that $505 million in seafood sales was generated through Texas food service establishments in 1988. Assuming that 30% of all seafood is consumed at home, a rough estimate of the total seafood sales base in Texas (including food service operations and retail food stores) is $721 million. In terms of volume, approximately 262 million pounds of seafood products in ready-to-use market forms, (not live weight pounds) were required to satisfy this demand. (This volume was calculated by multiplying the per capita consumption value of 15 pounds by the Texas population of about 17.5 million.)

A major share of Texas seafood consumption is accounted for by a relatively small number of species. For example, the domestic market for shrimp is large and growing. The U.S. per capita consumption of shrimp has grown from 11% of domestic seafood usage in 1978 to 16% in 1988 (Table 2). While the total per capita consumption of all seafoods has increased about 12% between 1978 and 1988, shrimp consumption has increased 60% over the same time interval. Annual shrimp consumption has increased from 548 million pounds in 1985 to 667 million pounds in 1988 -- a 22% increase in just three years.

Regarding finfish, industry sources cite freshwater, farm-raised channel catfish products as a major component of the Texas seafood demand base. In fact, the Mississippi catfish industry identifies Texas as the major market for farm-raised catfish.

Table 2. Annual United States consumption of shrimp expressed in per capita terms and as a percentage of total seafood consumption

Year	Per Capita Consumption of shrimp (lbs)	Percentage of Total Seafood Consumption
1978	1.5	11.2
1979	1.3	10.0
1980	1.4	10.9
1981	1.5	11.6
1982	1.5	12.2
1983	1.7	13.0
1984	1.9	13.9
1985	2.0	13.9
1986	2.2	15.0
1987	2.3	14.9
1988	2.4	16.0

Numerous other wild-caught fishery products also contribute to seafood demand in Texas. Among these are many varieties currently imported from other regions of the U.S. or other countries such as groundfish (cod, haddock and pollock), various flatfishes (flounder, sole and halibut), and salmon (both wild caught and pen raised).

Supply

The 1980's have marked a period of increasing conflict in allocation of fishery resources between commercial and sportsfishing interests. These conflicts have occurred because of greater demands for both fish as food and fish as a recreational experience. This increased fishing pressure has raised concern about long term yields, so allowable catches (in both the commercial and recreational fisheries) are often reduced as a way to restore fish populations to sustainable harvests. On the commercial side, these reductions in catches, occurring in a period of high demand, can create severe supply problems. Thus, processors, mid-level handlers and retail interests must exert more effort procuring fish and seafood products. And increasingly, global, wild-harvest fisheries are being discounted as a reservoir of untapped supply for new demands.

Supplies of fish and seafood in Texas originate from local production (mostly from wild harvests) and imports from other states, regions or countries of either wild caught or aquacultured products. During 1988, Texas commercial fishermen landed 96.5 million pounds of seafood products; 80% of which were shrimp. Over the last 11 years, total seafood production in Texas has ranged from 81 to 116 million pounds, and averaged 98.4 million pounds (Table 3).

Exact measurement of how much Texas-produced seafood remains in-state is difficult to pinpoint since Texas is a major producer (and therefore a net exporter) of some items -- notably shrimp and oysters. However, when 1988 Texas commercial fisheries landings are compared to estimations of cumulative, statewide demand, it is clear that at least 60% of all seafood used in Texas (116 million pounds in ready-to-use market forms) must come from out of state sources.

Table 3. Texas commercial fisheries landings in millions of pounds from 1978 to 1988

Year	Finfish	Shrimp	Crab	Oyster	Total
1978	5.2	84.1	7.5	1.9	98.7
1979	4.5	67.7	8.3	0.9	81.4
1980	4.4	73.9	9.0	1.7	88.9
1981	2.7	95.7	7.0	1.3	106.7
1982	3.0	70.9	8.0	3.6	85.5
1983	2.9	72.0	8.8	7.9	91.7
1984	2.3	90.2	7.2	5.2	105.0
1985	3.2	82.2	9.7	5.1	100.5
1986	3.3	97.3	9.5	5.6	115.9
1987	3.4	93.5	11.7	2.8	111.5
1988	3.8	80.1	10.9	2.3	96.5
Mean	3.5	82.5	8.9	3.5	98.4
Percent of total	3.6	83.8	9.0	3.6	100.0

INFRASTRUCTURE

In a strict, definitional sense, the food processing and marketing infrastructure refers to the physical facilities required to process, assemble, distribute and market products to end users. Relaxing this definition slightly, infrastructure can also include the various business relationships and communications which link different segments of the entire marketing system into a network. These relationships and the processing plants and distribution centers facilitate a) the conversion of raw materials into consumer products and b) the movement of products from producing regions to consumption areas. Thus, the food processing and marketing infrastructure is as much a process as it is an investment in fixed assets.

Texas claims one of the most integrated food processing and marketing sectors in the country. The seafood processing and marketing sector in Texas is a subset of a larger, food processing and marketing complex. The firms comprising this sector vary from family owned specialty retailers who use locally-harvested indigenous species to publicly-traded, vertically integrated companies within the Fortune 500. Many of these conglomerates procure products from domestic and international sources to satisfy trade area needs. Most participate in the processing and distribution functions as well.

Processing

Seafood processing typically is a stand alone enterprise that is normally not a subsidiary of large food manufacturing conglomerates. Of course exceptions exist, but typically, seafood processing is a family owned, or producer owned enterprise.

Texas is home to numerous capital intensive shrimp processing facilities, most of which can provide numerous products processed through the combination of various market forms, freezing techniques, levels of convenience, and packaging. Shrimp processors currently have excellent capabilities in: a) transporting unprocessed product from farm to plant, b) efficient material handling and c) full line processing. Most Texas shrimp processors have, at one time or another, purchased shrimp from local aquaculturists.

Texas also has substantial capacity in the more labor-intensive processing of molluskan shellfish. Currently, there are about 30 plants which are FDA certified to shuck, repack and/or pack oysters. The molluskan shellfish industry is regulated by the Texas Department of Health with oversight from the U. S. Food and Drug Administration (USFDA). This segment of the seafood processing industry must obtain shellstock from certified, approved water sources. Without this certification, no transaction can legally occur.

Unlike the larger processing facilities for shrimp and oysters, the processing capacity for finfish consists of relatively small inefficient operations diffused throughout the entire production and marketing system (although several isolated exceptions exist). It is common for processing to be accomplished by-hand on a custom basis by either producers, small scale processors of wild-caught, estaurine fishes, or even by firms classified as mid-level handlers; i.e. wholesale distributors. For example, in a 1987 survey of Texas food businesses, it was determined that 75% of the red drum fillets marketed at the wholesale level were converted from gutted market forms by either specialty seafood wholesalers or full line distributors.

Large-scale catfish processing has historically been unavailable in Texas, but a facility capable of processing 100,000 pounds per week recently was completed near Angleton, Texas. This will undoubtedly boost acreage dedicated to channel catfish production in that area. However, finfish processing capability in other areas of the state is, for the most part, limited to small hand operations.

Dedicated crawfish processing does not exist in Texas. This is becoming a more acute limitation to industry growth since more and more users who purchase live crawfish for whole, boiled presentations are requiring larger sized organisms as a condition of sale. Therefore, with periodic trapping providing a distribution of sizes, some type of processing is required to convert the smaller but higher yielding crawfish into marketable forms such as picked tail meat.

Distribution

Food distribution practically defies concise description since there are so many approaches currently used. For example, some shrimp processors may provide store door delivery to retail interests almost on a demand basis within a certain radius of the processing facility, but beyond that radius ship larger quantities to wholesale distributors which then deliver to retail accounts.

Another source of variability is the manner in which procurement is conducted. Some firms may rely on long-standing relationships with vendors for many of the standardized items such as block frozen shrimp, but may have to participate in open market procurement for fresh products.

Distribution of food products is completed by a number of different business types ranging from producers who distribute their own output to full line wholesale distributors who utilize sophisticated technologies for managing order picking, inventory levels, route development and scheduling, and transportation costs.

Specialty Wholesale Operations

The specialty wholesaler focuses on only the seafood product line. These firms are noted for their sourcing expertise, and are judged successful based on how well they can procure the product mix requested by their accounts. Typically, the specialty wholesaler is not a subsidiary of a larger conglomerate, although there are exceptions. Specialty wholesalers in Texas usually focus on assembling fresh products from various sources and distributing them. These firms may establish purchasing arrangements with producers which may also include post-harvest services such as farm pick-up. As mentioned above, some specialty wholesalers may custom process a number of finfish items into the market forms demanded by their clientele base.

Full-Line Distributors

In contrast to the specialty wholesaler, the full-line distributor generally handles numerous product lines in addition to seafoods. This is particularly true of those distributors which target the food service sector as their primary market. Since the full-line distributor may inventory several thousand unrelated items required by food service operators, specialization of corporate skills has focused on automation and development of management systems designed to facilitate order picking, overall inventory management and cost minimization. As such, most full-line distributors prefer to purchase products in market forms usable to the trading area(s). As such, processors are the full-line distributors' major suppliers.

OPERATIONS

Versatility

Operationally, the seafood utilization system (including processing, wholesale and retail interests) contains a lot of versatility as to which functional entities process and distribute seafood products. Processing may be completed by any of the entities within the marketing system ranging from producers themselves to retail establishments.

This situation exists partly because of less restrictive regulations for processing of seafood than for either red meat or poultry, with exceptions being the processing of molluskan shellfish and blue crab. While this relaxed regulatory posture will change within the next 5 years, most seafoods currently can be processed with little oversight from regulatory agencies. Furthermore, most seafoods require less processing prior to consumption than other meats. In fact, some products, such as oysters, may receive no processing prior to retail sale. Thus, many in the distribution business do process seafoods, either continuously or on a custom basis, depending upon customer needs, the quantity and/or species in question, and specific merchandising approaches used by retail interests.

Flexibility also exists in the distribution function. In some cases, producers may develop their own retail account bases, and provide distribution services to these accounts on a periodic basis. This most often occurs when the product is distributed live (as in the case of crawfish) or when there is no workable system for the product; i.e. distribution through traditional marketing channels would result in high death loss. Thus, within the seafood sector, there are many options for getting raw materials converted into consumer market forms and for moving products from production to demand centers.

Product Procurement and Distribution

The seafood processing and marketing infrastructure has evolved into its current configuration by attempting to balance the goal of customer satisfaction with the reality of a somewhat erratic supply base. Consumers are typically unaware of production variations. Essentially, consumers demand products year round, even though certain species may be unavailable or quite expensive at certain times of the year. As a result, many in the processing and marketing sector utilize two to three sources for high-demand products to reduce out-of-stock risk and improve consistency and quality of the product line.

Detailed, timely information about production outlooks, harvests, etc. is required in order to make purchase decisions. Typically, products are selected based on price and adherence to pre-defined criteria. Thus, the decision to purchase farm-raised catfish fillets from either Mississippi or Texas will be based on incoming price plus transport costs and adherence to specifications. Products meeting specifications but priced above the market will not move through customary distribution channels, regardless of origin.

Industrial buyers often source for products worldwide. Country of origin is sometimes an important concern, particularly since FDA scrutinizes shipments from those countries which have been, or are just coming off the "blocklist".

Mid-level handlers (including processors who serve a retail account base, full line distributors and specialty wholesalers) typically maintain an account base by providing timely deliveries of the correct mix of competitively priced products. Owing to the extremely competitive nature of the business, all wholesale distributors must be sensitive to any conditions which provide an account with a reason to switch to another vendor. One such reason may be products which are inconsistent in quality and/or availability.

Many distributors considering long term purchasing arrangements will begin by scrutinizing financial well being of the supplier. Financial conditions which could influence the vendor's ability to obtain raw materials because of a poor credit history, or remain a going concern are of extreme importance since suppliers directly influence the product line offered and concomitantly, the distributor's ability to provide service. Thus, firms being considered as potential suppliers must have an identifiable history which can be accessed by firms such as Dun & Bradstreet. Without such references, negotiations for a purchasing contract may not proceed.

For firms which compete on the basis of common product lines, the use of long term arrangements with large-sized vendors is paramount. Secondary suppliers are used to avoid being out of stock on a particular item. Conversely, those firms which provide customers with a mix of seasonal products in addition to a standard set of choices typically are more flexible in their procurement strategies. These businesses often purchase products on more of an open market arrangement from numerous vendors for shorter contract durations with less scrutiny of historic financial condition.

ISSUES

Key industry leaders within the Texas food processing, distribution and retailing complex were contacted for their thoughts about the future of Texas aquaculture, and processing and marketing limitations thought to impede industry development. These leaders represent the various functional areas within the overall marketing system including: processors, wholesale interests (both full-line and specialty distributors) and retail interests (retail food firms, food service establishments and their state trade associations).

Overall, processors and marketers are upbeat about aquaculture. Many recognize that further increases in demand will be supplied through aquaculture since commercial access to wild caught fishery resources is questionable.

Industry-wide Quality Assurance Concerns

As a production system, aquaculture was praised for the ability to deliver consistent quality product to the market. However, several respondents cautioned that production of food fish through aquaculture usually required the application of various compounds to promote growth, treat diseases, etc. They were emphatic that producers need to implement standard procedures for the use of approved chemicals. Likewise, processors and marketers need to adopt aggressive quality assurance principles similar to those used in other food product lines so that batches of throughput have a traceable history once they enter marketing channels.

One means of creating quality assurance programs is to establish voluntary industry sponsored programs which are overseen by objective third parties. This type of voluntary, species-specific quality assurance program has been instituted for numerous aquaculture products including the Mississippi catfish industry, Scottish pen-raised salmon, and Long Island, New York hard clams (*Mercenaria mercenaria*).

Product credentialing is a logical option when the industry's product line is not standardized via mandated criteria, as is the case currently with the seafood industry. It is also appropriate when the industry desires to set standards which surpass existing ones. This was done by the Florida Department of Citrus which recently established quality and identity standards for citrus juices. Juices which meet the more strict Florida standards are now able to carry a unique, copyrighted logo which is protected under statute.

All credentialing programs have three major components. First, the agreement to generate a promotional budget to support market development activities via checkoffs, either at the producer or first handler level. Second, the development of enforceable product quality standards which are "market driven"; i.e. those parameters which the market has suggested must be controlled, achieved, etc. Third, the development and implementation of a promotional strategy to communicate product quality standards to various segments within the overall market system.

In lieu of proprietary consumer advertising (which is generally beyond the means of most processors) this concept provides for consumer recall of those products which have been credentialed; i.e. those which have passed voluntary inspection. Through such a procedure, participating firms benefit in direct proportion to their market share. Participants in other credentialing programs have indicated favorable results being achieved from such efforts.

Currently, a voluntary quality assurance program exists for Texas farm-raised crawfish. However, no funds are collected at the producer level to support promotional activities. Respondents indicated that credentialing programs which incorporate promotional activities for other Texas aquacultured products would be beneficial.

Linkages Between Producers And Marketers

According to most respondents, Texas aquaculture is a well kept secret. Many indicated that the first step in purchasing local aquacultured products was to know "who produces what, where". All agreed that some type of a periodic directory would help fill the current information void. Because most aquacultural production is an annual crop, it is important to provide marketers with current production data about each species being cultured.

Since all fish farmers must purchase an annual license from the Texas Department of Agriculture, such a production directory would be relatively simple to compile. By designing the licensing form to include a question about whether the licensee would like to be included in a directory, each individual's wishes could be easily accommodated.

Other types of information seem appropriate for establishing linkages between production and utilization interests. Specifically, producers should know more about the species and market forms preferred by various market segments. Similarly, producers should know more about specific processing capabilities and requirements of processors, distributors and retail interests; i.e. minimum quantities required by utilization/marketing firms, availability of farm pick-up, lead time required to execute a procurement arrangement, required product testing prior to purchase, etc. These data could be obtained via mail survey.

Critical Mass

Aquaculture in Texas is currently a small industry. In most of the state, it has not reached the minimum size or "critical mass" required to support major markets or important services such as dedicated processing facilities, feed mills, by-product recovery systems. Finfish processing in most of Texas is currently accomplished by hand on a custom basis. This is appropriate for small local markets, but it represents a competitive disadvantage on a larger scale. Shrimp producers are fortunate in having access to existing coastal processing plants which were built to handle wild catch.

Many buyers simply require larger quantities of raw materials per order than are currently available from Texas culturists. For example, one respondent who typically operates under contractual arrangements with suppliers indicated that 50% of his firm's outlets would be interested in red drum products *if* supply could be insured. Entry into these markets may require pooling of output from several producers.

Pooling arrangements enhance contract negotiations by: a) reducing out-of-stock risk since output from more than one production facility is used; b) reducing distribution cost through economies of scale and specialization of skills; c) providing for some excess procurement capacity if the market responds very favorably to the product. Such arrangements are in effect with Texas farm raised crawfish and have been successful at both maintaining a higher than normal annual, weighted average farm-gate selling price and making inroads with live crawfish sales in retail food chains.

Seasonality

In North America, stocking and harvesting of many warm-water organisms must be timed to coincide with the beginning and end of the warm season. For example, penaeid shrimp must be harvested within the fourth quarter of each year. Seasonal harvests of other species such as crawfish are timed to coincide with their natural life history.

The inability to purchase aquaculture products year round for the fresh market was considered a liability by some respondents. However, for others, seasonality of harvest was not problematic. As noted in the section addressing processing and marketing operations, some issues which are of paramount importance to one business type may be inconsequential to others. Seasonality appears to be one such issue. Firms which require a consistently available product line corporate-wide generally enter into long term purchasing arrangements with suppliers who can provide a constant supply of consistent quality. Thus, sporadic production is of little value to these types of firms. Some indicated that only the proportion of seasonal production which matches current demand at that time period should enter the fresh market. The balance should be placed in frozen storage. Conversely, there are marketing interests which want to avail themselves to all procurement opportunities, regardless of seasonality.

Waste Disposal

Most finfish yield about 30% of total weight when converted to 100% edible, skin-off fillets. Thus, 70% of incoming raw material, by weight, represents offal which has inherent value, but is often burdensome to processors. As a high protein waste product, putrification creates odor problems which may adversely affect the surrounding area. Since processing of finfish is currently done by distributors who are located in light industrial areas of cities, evaluating the availability of periodic pick ups by rendering or reuse firms is the short term solution until dedicated processing comes on line and ancillary services such as by-product recapture systems are employed. While offal is not an insurmountable issue, it needs to be considered when doing pro forma development work.

Pricing

Buying decisions are made based on product supply, quality, price, consistency, and availability of substitute items. This mix of attributes varies in importance depending upon species.

At the farm level, Mississippi farm-raised catfish are perfect substitutes for Texas farm-raised production. Thus, Texas producers must accept the current price for catfish if they compete in similar markets. On the other hand, marketing a product such as red drum requires less sensitivity to pricing since there are few available substitutes.

To avoid this competition from large integrated operations, small-scale Texas catfish growers must continue to sell to local markets. The present lack of supporting infrastructure, considered a "growing pain" in developing industries, can be corrected over time if growth occurs.

RECOMMENDATIONS

- A detailed list of producers and their products should be developed and annually distributed to appropriate market segments. That is, buyers within the processing, distribution, and retailing complex should receive data about cultured seafood products, while the recreational fishing infrastructure should receive a directory about bait, forage, and sportfish.
- Producers should explore the feasiblity and efficacy of output pooling arrangements to gain a competitive advantage in contract negotiations and to reduce the impact of seasonal price declines as production increases.
- Aquaculturists should ensure that only safe, wholesome food products enter marketing channels. Not only will this send a powerful message to consumers, it will also help build credibility with the food processing and marketing complex. This may require self-imposed routine evaluation of products for compliance with generally accepted production practices (i.e., minimal residuals of therapeutic compounds, maximal nutritional value, shelf life, etc.).
- A critical mass of production is required to justify construction of efficient processing facilities and to gain access to desireable markets. The small Texas industry largely lacks this critical mass and will face difficulty as it expands and competes with established aquaculture infrastructure in other states and countries. Initial economic development assistance is recommended to build needed infrastructure in appropriate areas.

FINANCING

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As is true of any developing industry, financing for aquaculture has been limited by the lack of experience on the part of both lenders and producers, as well as by the rate at which the industry infrastructure has developed. Despite the obstacles that must still be overcome, the prospects are brighter today than they have ever been. Among the most significant factors encouraging growth in the industry has been a shift in the political environment toward an emphasis on diversifying the state's economy.

This paper will focus on the following areas: 1) current changes occurring in financing requirements, 2) financing issues specific to aquaculture, 3) sources of financing, and 4) recommendations regarding things that need to be done.

CHANGING FINANCING ENVIRONMENT

Although there are a number of specific concerns related to the availability of financing for aquaculture, the most significant changes in lending practices and policies are not unique to aquaculture, but are applicable to all agricultural borrowers. These changes are primarily the result of the significant loan losses, the number of financial institution failures and tighter regulatory requirements that have occurred during the 1980's. Most of the changes borrowers are experiencing fall into the following five areas:

1. The requirement by lenders for more and better information.

2. More thorough analysis and verification of the information provided.

3. Greater emphasis on both repayment ability and risk management.

4. Increased requirements for monitoring business performance after loans are made.

5. Stricter adherence to the lending institution's policy guidelines, i.e. fewer exceptions to the rules.

What these changes mean is that agricultural producers (including aquaculture) are beginning to be treated like any other commercial borrowers. They will be required to develop detailed business plans which incorporate both general economic and specific enterprise outlook analysis in addition to relying on trends and past performance. Borrowing will become increasingly complex whenever operations are vertically integrated or involve multiple ownership. Loan analysis will also require more time evaluating contractual arrangements between entities and financial statement consolidations in those cases where ownership interests involve a variety of businesses. While many borrowers have a tendency to view much of the information that lenders are requesting as just more red tape, the fact is that things a lender needs to know in the way of financial, marketing or production information are even more important to the borrower if he is going to successfully manage his business.

In preparing a loan request and a business plan, prospective borrowers need to recognize and address the following questions:

- How much is to be borrowed over the planning period?
- When will the money be needed?
- What is it going to be used for?
- How will it affect the borrower's financial position?
- How will the loan be secured?
- When will it be repaid?
- How will it be repaid?
- How will alternative possible outcomes in terms of both prices and quantities affect repayment ability?
- How will the loan be repaid if the first repayment plan fails?
- How much can the borrower afford to lose and still maintain a viable business?

In addition to the changes discussed previously, a more subtle but significant shift in lending practices is occurring in response to legislation providing for additional borrowers' rights, more liberalized bankruptcy laws and the threat of lender liability lawsuits. Lenders are being forced to pull back and be more selective in terms of who they finance. Because litigation usually arises from situations where the borrower is highly leveraged or in financial trouble, it will become increasingly difficult for marginal and higher risk borrowers to qualify for credit. In much the same manner that malpractice lawsuits are changing the practice of medicine, the fear of legal action is changing the lending environment and causing lenders to be more cautious and conservative.

AQUACULTURE FINANCING ISSUES

The previous section briefly overviewed changing lending practices and general factors applicable to all agricultural borrowers. In this section we will focus on some of the broader issues specific to financing aquaculture.

Lack of Aquaculture Experience

Lenders are risk averse by both nature and regulation. Because risk is largely a function of uncertainty, the less a lender understands about a business or an industry, the greater the potential risk he perceives. This risk is compounded if prior experience is lacking on the part of both the lender and the management of the aquaculture operation. While part of the problem is perception, the risk of something going wrong actually is greater until an adequate amount of experience is gained because of the learning process involved and the mistakes that are naturally made as a part of that process.

Early Stage of Development

A second problem is a function of the rate of development of the industry infrastructure and the size of the market. This problem manifests itself in the collateral value of the specialized equipment and improvements required for aquaculture production. If a market is expanding or well established, specialized items tend to have a more ready market. However, the current situation in Texas aquaculture usually requires a large discount from the construction or purchase price in order to protect the lender from a limited or illiquid market.

The marketability of an aquaculture operation can be roughly judged by the number of processors or marketing channels that are bidding for the farm's product. If there is only one processor or marketing channel, the market is subject to less competition or assurance of a continuing market. Therefore, in a market where there is only one processor of the farm's production, improvements may be valued at as little as 10 to 20% of cost or book value, while the existence of three of more processors may increase this value to 40 to 60%. More processors or other marketing channels indicate that the market is more mature and established. Obviously, these valuation factors are also influenced by the size, financial strength and reputation of theprocessors involved. This latter point also extends to the collateral value of contractual arrangements between producers and processors.

Inventory Questions

A third problem which affects the availability of financing for aquaculture is the difficulty in establishing a value for growing products. Despite many jokes about lenders using glass-bottom boats and scuba gear, there are significant limitations on inventorying the growing products, both in terms of quantity and quality.

It should be noted that the problems just discussed differ significantly by type of species. There are both new and established aquaculture products. For example, catfish have been produced successfully on a large commercial scale for years and the market acceptance has been well established. While Texas lenders and producers may lack experience with these products, there is at least information and experience available. Moreover, this experience can be accessed through published materials, the employment of consultants, and by hiring experienced management and/or loan officers. The same situation does not exist, however, for many aquaculture enterprises.

Factors Outside the Business

The importance of a well developed business plan in order to obtain credit has already been mentioned. However, many of the plans developed by aquaculture producers have focused almost entirely on the internal aspects of the business. The concern of many lenders is that the greatest risks may be related to factors outside the business. Thus, prospective borrowers are going to have to address these areas in their plans.

There are two particular areas outside the aquaculture firm that need to be considered: the general environment and the specific industry. The general environment needs to be evaluated in terms of social, cultural, economic, government/legal, technological and international issues. The specific industry needs to be examined in terms of market forces represented by potential new entrants, supplier market power, buyer market power, substitute products and the degree of competition that exists.

Social and cultural issues include general attitudes over farm raised aquaculture products, religious beliefs, education, etc. Economic issues center around the end-users's ability to purchase the product. Disposable income, leisure time, spending priorities, changes in interest rates, the inflation rate and the unemployment rate are some specific economic considerations. Governmental and legal issues can play a major role in an aquaculture project and should be examined carefully. Rights to water, exotic species permits, environmental regulations, and taxing authorities all need to be addressed in the planning process.

Competition

The competitive forces in the industry also require close examination. The ease with which new competitors can enter the industry should be considered. How rapidly will new entrants come in or existing capacity expand in response to favorable price levels? How much will prices fall if production increases significantly? If the aquaculture project relies on outside sources for inputs such as feed, seed stock, etc., particular attention needs to be given to the potential market power of those suppliers. The same issues arise relative to the market power of buyers or processors. How able and likely are suppliers or buyers to squeeze margins if they have or obtain significant market power due either to size or limited numbers? Competitive advantage is also a function of the number of available substitute products. How sensitive is the market to price differences between competitive products?

Market Contracts

In addition to the factors just mentioned and the biological risks involved in production, one of the factors that most affects a lender's willingness to finance an aquaculture project relates to the ability of the borrower to obtain market contracts for his production. In addition to the availability of contracts, other issues relate to contract length, pricing terms, quantity and quality restrictions, as well as the reputation and financial strength of the contracting firm. Currently, only limited contracting opportunities exist for Texas aquaculture producers. However, processing capacity is increasing in Texas, and many of the new entrants are willing and interested in contracting.

SOURCES OF FINANCING

This section offers a brief overview of the major financing alternatives.

Aquaculturists with established operations and/or sufficient financial strength are usually able to qualify for credit from the various types of commercial lending institutions, such as commercial banks, Production Credit Associations, Federal Land Bank Associations and life insurance companies.

Others wishing to enter aquaculture ventures involving products which have a successful track record, e.g. catfish, may be unable to secure loans from the sources listed above because of a lack of borrower management experience, inadequate financial strength or because some lenders are still unwilling to loan for purposes where they have no previous experience. This group may be able to obtain assistance through the Small Business Administration (SBA) or the Farmers Home Administration (FmHA). Although limited in funding, there are also several state programs which can provide some assistance.

A third group of aquaculturists are those interested in high risk, but potentially high profit operations such as shrimp farming. It is possible to obtain support for such ventures from SBA or FmHA, but many of these operations will be forced to seek venture capital or obtain outside guarantors to provide additional financial strength.

Finally, there are aquaculturists who are interested in obtaining funding for the development of commercial operations based on technology which has not been demonstrated outside of the research laboratory. Projects of this nature include artificial upwelling and closed culture of certainspecies. There is little or no credit available for these types of ventures. Funding must be obtained almost entirely through venture capital or by placing the developer's own equity capital at risk.

Non-Government Funding Sources

Commercial Banks

Commercial banks lend primarily for operating expenses and capital improvements. To receive such financing a loan guarantee is sometimes required depending upon the financial strength and previous experience of the borrower, and the riskiness of the project perceived by the bank. Guarantees, which may be personal or through a state or federal program, assure repayment of a certain percentage of the loan. FmHA and SBA, for example, can guarantee loans for up to 90 percent of their value for qualified borrowers.

Two factors which will tend to make commercial banks more interested in diversifying their loan portfolios, but at the same time may make them more risk averse, are the reform of the federal deposit insurance system designed to vary FDIC premium rates according to perceived risks; and the raising of capital requirements for "higher risk" banks. These changes will encourage greater reliance on loan guarantees and further reinforce the need for more education and a better understanding of aquaculture by both lenders and regulators (bank examiners).

Farm Credit System

The banks and associations that comprise the borrower-owned cooperative Farm Credit System provide credit and related services to farmers, ranchers, producers and harvesters of aquatic products, agricultural and aquacultural cooperatives, rural homeowners and certain businesses involved in the processing of agricultural and aquacultural products.

The United States is currently divided into twelve farm credit districts, although based on the outcome of a pending lawsuit the Texas district and the Jackson district (comprised of Alabama, Louisiana and Mississippi) may be merged. The Texas district has already acquired the assets of the former Jackson Federal Land Bank. Except for the Jackson district, which still has a Federal Intermediate Credit Bank, all other districts contain a single Farm Credit Bank (FCB) resulting from the merger of the former Federal Land Bank (FLB) and Federal Intermediate Credit Bank (FICB). The eleven FCB's provide a source of funds as well as supervision and support services to 142 Federal Land Bank Associations (FLBAs), 85 Production Credit Associations (PCAs) and 40 Agricultural Credit Associations (ACAs). As of August, 1989, these 267 associations had approximately 1200 branch office locations throughout the country.

FLBAs make 5 to 40 year term first-mortgage loans for land and capital improvements. Loans may not exceed 85 percent of the market value of the property taken as security unless the loan is guaranteed by a federal agency. PCAs make short and intermediate- term loans for operating expenses, capital purchases and capital improvements. Producers and harvesters of aquatic products may receive terms of up to 15 years. ACAs are associations created by the merger of one or more FLBAs and PCAs. Currently, Texas has only separately managed FLBAs and PCAs.

The Texas aquaculture industry should benefit from the acquisition of the Jackson FLB and the potential merger of the Jackson FICB with the Texas FCB. The Jackson district's extensive experience with the catfish and crawfish industries should bring needed expertise in the financing of aquaculture into Texas.

The other lending arm of the Farm Credit System are the Banks for Cooperatives (BCs). The BCs offer a complete line of credit and leasing services to agricultural cooperatives, rural utility systems and other eligible customers. They require that at least 80 percent of the voting control of the cooperative must be in the hands of farmers, ranchers or producers and harvesters of aquatic products. A cooperative must also do at least 50 percent of its business with or for its members. The BCs may also finance joint ventures between eligible cooperatives and private firms as long as the cooperative has a controlling interest. Three banks, each with a national charter, comprise the BC system. CoBank--the National Bank for Cooperatives is headquartered in Denver, Colorado and maintains ten full-service regional offices, one of which is based in Austin. CoBank also finances agricultural exports and provides international banking services for the benefit of U.S. farmer-owned cooperatives. The two other BCs are the St. Paul Bank for Cooperatives headquartered in St. Paul, Minnesota and the Springfield Bank for Cooperatives based in Springfield, Massachusetts.

Life Insurance Companies

In the past, life insurance companies were primarily real estate mortgage lenders. But recently several companies have broadened their lending activities to cover all phases of agricultural and aquacultural lending activities. The primary limitation for many borrowers is that these companies tend to limit their lending to larger loans, and concentrate on only the most creditworthy borrowers.

Government Funding Sources

The Small Business Administration

The SBA provides both guarantees and direct loans to aquaculture operators. SBA loans may be used for purchase and improvement of land or buildings, construction, machinery and equipment, operating expenses and refinancing of debts. SBA also provides disaster loans in authorized areas.

The Economic Development Administration

The EDA makes loans or grants to the aquaculture industry to provide development and operating capital.

Farmers Home Administration

The FmHA provides both guarantees and direct loans to aquaculture operators. The various types of FmHA loans that can be obtained for aquacultural purposes are as follows:

(a)Farm Ownership Loans and Loan Guarantees are made to help eligible applicants become owner-operators of family farms; to make efficient use of land, labor and other resources; to carry out sound and successful operation on the farms; and to enable farm families to have a reasonable standard of living. These loans can be made for the purchase and development of real estate, including water resources. The loan limit is $200,000 for direct loans and $300,000 for guaranteed loans.

(b)Operating Loans and Loan Guarantees are made to operators for family farms and to applicants wanting to become operators of such farms. These loans can be used for financing and refinancing equipment, for livestock or fish purchases, for family living and farm operating expenses, and for minor land or water improvements. Objectives of the program are to improve living and economic conditions and to help operators become established in a sound system of aquaculture or agriculture. The loan limit is $200,000 for direct loans and $400,000 for guaranteed loans.

(c)Emergency Loans are made in counties where property damage or severe production losses occur as a result of a natural disaster or because of other emergency situations. The funds can be used for major adjustments, operating expenses and other essentials to enable borrowers to continue their operation. This program involves only direct loans and has a loan limit of $500,000 or the amount of loss sustained, whichever is less.

(d)Soil and Water Loans finance land and water developments, drainage of farmland, irrigation, pasture improvement, and related land and water-use adjustments. The loan limits for this program are combined with and limited to those for farm ownership loans.

(e)Business and Industrial Loan Guarantees promote development of business and industry, including aquaculture, in cities and towns with less than country, rural communities and towns of 25,000 or less receive preference. These loans can be made for conservation, development and utilization of water for aquaculture purposes. These loans may also be made for aquaculture related businesses, such as processing plants. Loans of less than $2 million are eligible for a 90% guarantee, those between $2-5 million a 80% guarantee, and those between $5-10 million a 70% guarantee.

Borrowers under the direct farm ownership and operating loan programs may be able to qualify for the special limited resource loan program. Eligible borrowers qualify for initial interest rates which are approximately half of the normal loan rate, but this rate will adjust upward as the borrower's ability to pay improves.

Federal Cost-Sharing Programs

Within the U.S. Department of Agriculture, the Agricultural Stabilization and Conservation Service (ASCS) and the Soil Conservation Service (SCS) in some districts have active cost-sharing programs whereby funds may be provided for conservation measures which could directly or indirectly benefit an aquaculture enterprise. Local ASCS or SCS offices should be contacted for information on eligibility.

State Loan Programs

The state of Texas offers a limited number of financial assistance programs which could be used by producers of aquacultural products. However, the passage of Proposition 3 in the November, 1989 election could expand the number of alternatives. Current state loan programs include:

The Texas Linked Deposit Program. Under this program the state Treasury is authorized to deposit a total of $5 million in state approved commercial lending institutions to stimulate loans for new or expanding non-traditional businesses which use agricultural or aquacultural products. The legislature identified three areas which qualify for Linked Deposit loans: non-traditional alternative crops, including aquaculture; processing facilities for agricultural products; and direct marketing initiatives. Under this program the state accepts a reduced return on its deposit, two points below the current market yield for U.S. Treasury bills or notes. the lender, in turn must pass these reduced rates on to borrowers qualifying for loans under the program. The loan limit is $100,000 for the production of non-traditional crops and $250,000 for processing and marketing loans.

The Veterans Land Board. Thirty-year loans are made to military veterans for purchases of a minimum of 5 acres of land and for a maximum investment of $20,000. While the loan limit is low, interest rates are currently 8.75% and the loans can be used in conjunction with other financing.

Four programs will be created through the recently passed Proposition 3. Two of these programs will be administered by the Texas Department of Agriculture. A rural small business program will establish a $5 million fund to provide loans of under $30,000 to family owned and operated businesses in rural areas. A second program will use a $25 million fund to provide loans and loan guarantees for the purpose of stimulating new food and fiber industries in Texas such as textiles, food processing and aquaculture.

RECOMMENDATIONS

At this juncture there are several things that need to be done to improve the ability of producers of aquaculture products to obtain necessary financing. The first and most important is a coordinated educational effort to educate lenders, producers, potential investors and financial regulators about the industry.The second is the need for SBA, FmHA and city banks handling the overline portion of large loans for rural banks to develop or employ specialists with the experience and ability to review and evaluate both new aquaculture loan proposals and existing loans. This expertise could be used both internally and provided on a fee basis to outside users. Third, the need exists for qualified appraisers with the experience and training to assess the collateral value of equipment and improvements employed in aquaculture. A fourth area is the need for a readily available insurance program to insure producers of established aquaculture products against potential disasters. While commercial insurance can currently be obtained, federal crop insurance does not cover aquaculture enterprises.

Two other areas which merit further study and education involve alternative uses of assets if a venture fails and alternatives to the ownership of land and capital improvements. One obvious example of an alternative use of assets is the use of ponds for water storage for agricultural irrigation or municipal use. Alternatives to land and capital purchases which need exploration include long term renewable leases for land and leasehold improvements. This would include an analysis of the risks to the lessor and the lessee, and studies of alternative lease terms and arrangements.

ACADEMIC PROGRAMS

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There are numerous colleges and universities in Texas offering a broad coverage of course work and degrees in the aquatic sciences. However, the vast majority of these are specific to marine science, aquatic biology and/or fisheries management. Currently only three universities have academic programs in aquaculture or mariculture; only these will be in this section.

UNIVERSITY OF TEXAS

The University of Texas at Austin offers various programs through the Department of Marine Studies at the Marine Science Institute (UTMSI) in Port Aransas, Texas. Mariculture research areas include the spawning of finfishes by manipulation of hormones or temperature and photoperiod, development of intensive raceway culture for year-round production of shrimp and fish, and the establishment of physico-chemical limits in larval fish growth.

Research facilities include the Fisheries and Mariculture Lab (26,000 ft. sq.) containing extensive wet laboratories for spawning, larval development and growout. Core courses on the Austin campus are required in various marine-related subdisciplines with mariculture among the many areas of research available at both the M.S. and Ph.D. degree levels. For further information contact: Dr. Robert Jones, Marine Science Institute, Department of Marine Studies, P. O. 126A, Port Aransas, TX. 78373 (512/749-6711).

TEXAS A&M UNIVERSITY

Texas A&M University (TAMU) offers aquaculture/mariculture academic programs designed to prepare students for scientific investigation and practice of aquatic animal husbandry. Aquacultural research encompasses both basic and applied efforts to solve problems inhibiting the exploitation of captive aquatic organisms for commercial and recreational use.

Red drum and marine shrimp are the species of primary interest although attention is also focused on oysters, crayfish, catfish, hybrid striped bass and largemouth bass. Research areas include nutritional requirements and bioenergetics, environmental requirements and mechanisms of physiological adaption, genetics and genome manipulation, disease control, and culture techniques.

Research facilities include the Aquacultural Research Center and the Fish Genetics Laboratory, both on the main campus at College Station. Research facilities in Corpus Christi and Port Aransas are involved with the maturation, reproduction, larvaculture and grow-out of various penaeid shrimp species.

The academic program includes both undergraduate and graduate degrees. Masters degrees are available either as thesis (M.S.) or non-thesis (M.Agr.) options and are designed to give students broad academic training combined with practical experience in problem solving and management skills. The Ph.D. degree is also available and requires a strong background in the basic sciences and requires extensive research and a thorough knowledge and understanding of the subject chosen. The undergraduate degree allows for a fisheries/aquaculture option and emphasizes the scientific and technological basis of fish farming. Course offerings include culture techniques and systems, nutritional and environmental requirements, diseases, water chemistry, genetics and market economics. For further information contact: Texas A&M University, Attn: Dr. David Schmidly, Department of Wildlife and Fisheries Sciences, Nagle Hall, College Station, TX. 77843 (409-845-5777).

CORPUS CHRISTI STATE UNIVERSITY

Corpus Christi State University (CCSU) is the latest entry into aquaculture education. A proposed M.S. in Mariculture degree has received funding for program development and is awaiting final approval at the state level. This advanced degree is designed to provide the student with a core curriculum in biology, marine science, mariculture, and business. In-lieu of a thesis, it will allow hands-on training at Corpus Christi area mariculture research facilities with various marine fish and shrimp species. Two options will be available to students entering the program; one, as an broad internship and the other as in-depth research.

Currently, mariculture is offered as an emphasis area for the B.S. in Biology degree. The M.S. in Biology degree is also an option for students desiring a thesis degree with research in an approved mariculture topic. For additional information please contact: Corpus Christi State University, Attn: Dr. David McKee, College of Science and Technology, Corpus Christi, TX. 78412 (512-994-2676).

TECHNICAL INFORMATION SOURCES

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Aquaculture information is available from a wide variety of sources. This chapter describes sources and costs of technical information on aquaculture.

AQUACULTURE MAGAZINES

Aquaculture Magazine. General trade magazine for U.S. aquaculture. Bimonthly. $15/yr. P.O. Box 2329, Asheville, NC 28802.

Aquaculture Today. For owners and operators of fish farms. Quarterly. $10/yr. 831 Helmcken St., Vancouver, B.C. V6Z 1B1 Canada.

Bulletin. Variety of information on aquaculture with Canadian emphasis. Quarterly. $35/yr. Aquaculture Assn. of Canada. P.O. Box 1987. St Andrews, New Brunswick, E0G 2X0 Canada.

Canadian Aquaculture. Magazine articles focus on Canadian aquaculture. Bimonthly.$20/yr. 4611 William Head Road, Victoria, B.C. V8X 3W9 Canada.

Catfish/Aquaculture News. Covers the farm raised catfish industry plus some information on general aquaculture. Monthly. $20/yr. P.O. Box 199, Ridgeland, MS 39158.

Crawfish Tales. The official publication of the Louisiana Crawfish Farmers Association. Quarterly. $15/yr. LCFA, P.O. Box 91544, Lafayette, LA 70509.

EAS Quarterly Newsletter. Information bulletin of the European Aquaculture Society, Princes Elisabethlaan 69, B-8401 Bredene, Belgium.

Farm Pond Harvest. General aquaculture in recreational ponds. P.O. Box 736, Mo, IL 60954. Quarterly. $8/yr.

Feed Management. Feed industry information. Monthly. $48/yr. 122 S. Wesley Ave., Mt. Morris, IL 61054-1497.

Fish Farming International. Audit House, 260 Field End Road, Middlesex,HA4 9LT, England. Monthly. $54.

Mollusk Farming USA. Bimonthly. $60/yr. Aquaculture Digest, 9434 Kearny Mesa Road, San Diego, CA 92126.

Naga, the ICLARM Quarterly. International Center for Living Aquatic Resources, MC P.O. Box 1501, Makati, Metro Manila, Philippines. $20/yr.

Pet Age. Pet industry news including ornamental fish. Monthly. $25. 207 S. Wabash Ave., Chicago, IL 60604.

Pet Business. Pet industry news including ornamental fish. Monthly. $24. 5728 Major Blvd., Suite 200, Orlando, FL 32819.

Practical Aquaculture & Lake Management. Fish and shellfish farming and pond management tips. Bimonthly.$18/yr. P.O. Box 1294, Garner, NC 27529-1294. 3 3

Salmonid. Focus on trout and salmon farming. U.S. Trout Farmers Assn. 506 Ferry St. Little Rock, 72202

Seafood Business Magazine. Seafood industry. Bimonthly. $25. P.O. Box 905, Rockland, ME 04841.

Seafood International. General seafood. Monthly. $63/yr. AGB Heighway Ltd., Cloister Court, 22-26 Farringdon Lane, London EC1R 3AU, England.

Seafood Leader. Seafood industry marketing information. Five times per year. $18. Waterfront Press Co., 1115 N.W. 46th St., Seattle, WA 98107.

Texas Shores. General coastal topics which often include aquaculture. Quarterly. $7.50/yr. Sea Grant College Program, Texas A&M University at Galveston, P.O. Box 1675, Galveston, TX 77553.

The Catfish Journal. Publishes catfish industry information. P.O. Box 34, Jackson, MS 39202. (601-353-7916.

Water Farming Journal. Emphasis on U.S. Aquaculture. Monthly. $18/yr. 3400 Neyrey Dr., Metairie, LA 70002.

World Aquaculture. Aquaculture information of world interest. World Aquaculture Society. Quarterly. $30/yr. or with society membership. World Aquaculture Society, 16 East Fraternity Lane, Louisiana State University, Baton Rouge, LA 70803.

World Shrimp Farming. A bimonthly report on shrimp and prawn farming. $60/yr. Aquaculture Digest, 9434 Kearny Mesa Road, San Diego, CA 92126

NEWSLETTERS

AQUAnotes. Quarterly for Texas aquaculturists. $10/yr. Texas Aquaculture Association, 6200 S. Old Hemphill, Ft. Worth, TX 76134.

Coastal Aquaculture. Produced by Texas Agricultural Extension Service and Texas A&M Sea Grant College Program. Irregularly issued. Free to Texas residents. Texas A&M Research and Extension Center, Route 2, Box 589, Corpus Christi, TX 78140.

International Association of Astacology Newsletter. Bimonthly crawfish news of international type. Obtained with membership of $25. P.O. Box 44650, University of Southwestern Louisiana, Lafayette, Louisiana 70504.

New Waves. Research newsletter of the Texas Water Resources Institute. Quarterly. TWRI, Texas A&M University, College Station, TX 77843-2118.

Texas Aquaculture News. Texas Agricultural Extension Service. Monthly. Free to Texas residents. P.O. Box 38, Overton, TX 75684. 3) 3

Texas Shoreline. Texas A&M University Marine Advisory Service Newsletter. Free to Texas residents. Issued irregularly. Sea Grant Program, Texas A&M University at Galveston, P.O. Box 1675, Galveston, TX 77553.

Texas Water Resources. General water information. Quarterly. Texas Water Resources Institute, Texas Agricultural Experiment Station, College Station, TX 77843-2118.

The Texas WaterFront. Information newsletter of the Texas Water Commission. Office of Public Information, P.O. Box 13087 Capitol Station, Austin, TX 78711-3087.

Other Newsletters:

In addition to those listed above, aquaculture newsletters are produced by almost all: Agricultural Extension Services, Sea Grant Marine Advisory Services, and state aquaculture associations.

INFORMATION SYSTEMS

Aquatic Sciences and Fisheries Information System (ASFIS). An international bibliographic service covering the world's literature on aquatic sciences and fisheries, including aquaculture. FAO, Rome. Contact: Aquaculture Development and Coordination Programme (ADCP), FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.

Aquaculture Information System, AQUIS. Global aquaculture information acquired by contacting designated aquaculture centers or Rome. AQUIS is connected to FAO's Aquatic Sciences and Fisheries Information System (ASFIS). Both conventional (bibliographic) and unconventional information are accessible.

Selective Fisheries Information Service. Smaller system containing tropical finfish information. ICLARM MC P.O. Box 1501, Makati, Metro Manila, Philippines.

Texas Natural Resources Information System (TNRIS). Information on water and other natural resources of Texas. Data from state and federal agencies are collected so that one source may be contacted. P.O. Box 13087, Austin, TX 78711. (512) 475-3321.

Other information systems

A number of aquaculture information systems of regional focus have begun in the 1980's. Most are public, because usage is too infrequent for profitability.

ABSTRACTING AIDS

Fisheries Review. Covers broad fisheries field but includes aquaculture. U.S. Fish and Wildlife Service. For current subscription price contact: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. 36 3

ASFA Aquaculture Abstracts. Compilation of aquaculture-related references. Developed from ASFIS (see above). Published five times per year. $255. Cambridge Scientific Abstracts, 7200 Wisconsin Ave., Bethesda, MD 20814. Sea Grant Abstracts. Publications from the nation's Sea Grant Program. Quarterly. Free. P.O. Box 125, Woods Hole, MA 02543.

STATISTICS

Aquaculture Situation and Outlook. Provides U.S. aquaculture statistics and explores industry trends. Published twice a year. $10/yr. U.S. Department of Agriculture, ERS-NASS, P.O. Box 1608, Rockville, MD 20850.

Current Fisheries Statistics, Fisheries of the United States. Published by the National Marine Fisheries Service. Gives statistics for previous year. Government Printing Office. $6.

Catfish Crop Report. A USDA publication. Agricultural Statistics Board Publications, Room 5829 South Building, USDA, Washington, DC 20250.

FAO Yearbook of Fisheries Statistics. Gives world statistics on catches and landings. Aquaculture is included. Publication runs about 18 months after end of year reported. This and other FAO publications are available from: Aquaculture Development and Coordination Programme (ADCP), FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.

LIBRARIES

Aquaculture Information Center. Room 111, National Agricultural Library, Beltsville, MD 20705. This is the national library that services aquaculture.

Texas A&M University/Sterling C. Evans Library. The library which is located on the Texas A&M campus in College Station has an aquaculture database provided by NAL with actual page images (4000+ pages). The pages are not copyrighted and may be downloaded for personal use.

Other libraries with aquaculture listings may be found at nearby universities and field laboratories. Most aquaculture professionals maintain personal libraries and aquaculture professionals housed in groups for public service usually maintain common libraries.

ELECTRONIC MEDIA

Aquaculture: Its time has come. (18 min.) International Center for Aquaculture, Auburn University, Auburn, AL 36849.

Catfish Aquaculture. (19 min.) 3D 3

Redfish Aquaculture. (23 min.)

Crawfish Aquaculture. (22 min.)

Alligator Aquaculture. (19 min)

$30 each on VHS. Make checks payable to Louisiana Cooperative Extension Service and mail to: John Brooks, LSU Cooperative Extension Service, 128 Knapp Hall, LSU. Baton Rouge, LA 70803.

Catfish Farming in the South. (38 min.)

Red Drum Aquaculture. (35 min.)

Southern Regional Aquaculture Center funded these videos. Several others are in preparation. Available for $20 from: Ext. Wildlife and Fisheries, Nagle Hall, Texas A&M Univ., College Station, TX 77843.

MEETINGS AND TRADE SHOWS

Regional, national, and international meetings are excellent opportunities for exchanging aquaculture information. There are many aquaculture meetings promoted these days. The best ones occur annually or semiannually and have a good reputation. Because much information is obtained outside of formal meetings, it is wise to have a good idea of who will be attending.

Trade shows offer the chance to discuss new technological advances with vendors and provides an important opportunity to gain a broad variety of technical information. It is usually possible to obtain an advanced list of exhibitors. Meetings and trade shows are advertised in aquaculture printed media months in advance.

JOURNALS AND BOOKS

Aquaculture-related scientific/technical journals have proliferated in recent years. Only a very wealthy person could afford subscriptions to all of them. The typical reader might be better served by making an occasional visit to a major library to review the journals. Books have become abundant also. Many are quite expensive and should be examined before purchase. Titles often misrepresent content. Helpful are the book reviews sometimes found in journals, magazines and newsletters.

EXTENSION LITERATURE.

Extension literature is available in all Texas County Extension Agent offices. Much of the printed material on inland aquaculture is consolidated in a large three-ring binder entitled "Inland Aquaculture Handbook". Recently published printed materials of regional interest which were funded by the Southern Regional Aquaculture Center also have been included in this handbook. Agents of coastal counties will have printed materials that relate particularly to marine aquaculture. Agents also facilitate the use of videos, slide programs, computer software and many other materials.

HANDBOOKS AND MANUALS.

Technical handbooks and manuals are widely available. The Food and Agricultural Organization of the United Nations (FAO) publishes many such materials which are available from the address mentioned above (see under FAO Yearbook). Locally, several handbooks have recently become available:

Handbook of Texas Water Law:Problems and Needs. This revised (1987) booklet reviews legal status of Texas water resources. Texas Water Resources Institute, Rm 301, Scoates Hall, Texas A&M Univ., College Station, TX 778443.

Inland Aquaculture Handbook. An updated resource book (mentioned above) which is maintained in every Texas A&M University county office. A published version is obtainable from the Texas Aquaculture Association, P.O. Box 2948, College Station, TX 77841. $25.

Laboratory Manual for the Culture of Penaeid Shrimp Larvae. Marine Advisory Service, Sea Grant College Program, Texas A&M University, College Station, TX 77843-4115. $20.

Manual on Red Drum Aquaculture. This manual which was first issued as a conference draft is now in preparation for publication by Texas Sea Grant College Program.

Red Drum Aquaculture. A proceedings of a symposium on the culture of red drum and other warm water fishes. Includes research reports. $15. Marine Science Institute, University of Texas, Port Aransas, TX 78373-1267.

Shrimp Disease Handbook. A 1989 revision of a publication last printed in 1978. Available for $2 from Sea Grant College Program, Texas A&M University at Galveston, P.O. Box 1675, Galveston, TX 77553.

Texas Shrimp Farming Manual. This Manual was produced as part of a workshop held in Corpus Christi, Texas in the fall of 1985. It has been revised and is nearing printing. It will be available from Texas Sea Grant College Program at the above address.

AGENCY REPORTS

Certain state agencies and institutes produce reports that include information which is important to aquaculture. A limited number of copies are produced, but one can usually find a particular issue in major libraries. When focused on local topics, the reports are normally available for examination at county offices. Reports of national agencies are usually deposited in the government section of the larger libraries or are available from the National Agricultural Library. Examples of state reports which could be helpful in aquaculture planning are:

Soil surveys of Texas Counties. The Soil Conservation Service prepares surveys (complete with maps) which characterize soil features of all Texas counties.

Texas Estuary Reports. This report series was produced by the Texas Department of Water Resources in the early 1980's. It provides information on the influence of freshwater inflows and a variety of other information that could be helpful in aquaculture planning.

CONSULTANTS

Consultants are a very important source of technical information. Although some may be specialized in offerings, most are able to provide needed information and services from planning to implementation. There are a number of commercial consultants active in Texas.

AQUACULTURE ASSOCIATIONS

American Fisheries Society. 5410 Grosvenor Lane, Suite 110, Bethesda, Md. 20814. (301) 897-8616. Founded in 1870, 8,000 members. Scientific origination of fisheries and aquatic science professionals. Has 15 sections including a fish culture section (dues $5.00) and a Texas Chapter. Annual meeting, various publications. Annual Dues $43.50.

Aquaculture Association of Canada. Box 1987 St. Andrews, MB EOG 2XO, CANADA (506) 529-8854. 300 members. Purpose: Aquaculture promotion and information exchange in Canada. Quarterly newsletter. Annual Dues $35 regular; $50 corporate: $25 student.

Catfish Farmers of America. P.O. Box 34, Jackson, MS 39205 (601) 353-7916. Founded in 1966, 700 members. Monthly Catfish Journal, monthly newsletter. Annual meeting, Annual Dues $30.

European Aquaculture Society. Dr. N. dePauw, Prinses Elisabethlaan 69, B-8401 Bredene, Belgium 142, +32 59 325127, 900 members. Quarterly bulletin.

International Association of Astacology. P.O. Box 11170, Baton Rouge, La. 70813. (504) 771-2262. Founded in 1972, 300 members. Biennial meeting, quarterly directory. Purpose: To promote scientific study and cultivation of crawfish. Dues: Business $50., Regular $25., Student $12.50.

National Shell Fisheries Association. c/o Tom Soniat, Dept. of Biology, Univ. of New Orleans, Lakefront, New Orleans, LA 70148. (504) 286-6307. Founded in 1909, 900 members. Encourages research on mollusks and associate organisms especially those of economic importance. Annual conference, journal. Dues $30.

Striped Bass and Hybrid Bass Producer's Association. Promotes advancement of the commercial cultivation of striped bass and its hybrids. c/o Ron Hodson, UNC Sea Grant, Box 8605, North Carolina State University, Raleigh, N.C. 27695-8605. With membership.

Texas Aquaculture Association. P.O. Box 2948, College Station, TX. 77841. Purpose: Promotes aquaculture in Texas. Various membership categories with dues from $10 to $50. 150 members.

Texas Crawfish Farmers Association. The Crawfish Farm, OSR Box 127A, El Campo, Tx. 77437 (409) 543-4172. Founded 1984, 52 members, 3 chapters (Mid-Coast, Neches-Trinity, and Sabine - Chapters). Purpose: Promotion of crawfish production and marketing in Texas. Annual meeting. Dues $35.

United States Trout Farmers Association. 515 Rock Street, Little Rock, AR. 72202. (501) 372-3595 Founded 1952, 1,000 members. Promotes trout industry in U.S. Annual meeting, quarterly magazine, monthly newsletter. Annual Dues: Patron $500. Active, Asso-ciate and Foreign $60.

World Aquaculture Society. No. 16 Fraternity Ln. Baton Rouge, La. 70803. (504) 388-3137. Purpose: Aquaculture promotion and information exchange. 2,800 members. Founded 1970. Annual meeting, journal, quarterly magazine, books. Affiliated with European Aquaculture Society, Caribbean Aquaculture Association, Aquaculture Association, Canada, and Japanese Aquaculture Association. Dues $45.

EXTENSION SERVICES

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In this country, the agricultural educational process is usually associated with the Cooperative Extension Service system developed by the Land Grant Colleges and the U.S. Department of Agriculture. This system has great capacity to deliver educational programs. Extension professionals staff offices in nearly all of the nation's 3,150 counties and they are joined by more than 2.5 million volunteers.

TEXAS AGRICULTURAL EXTENSION SERVICE

Cooperative Extension in Texas is represented by the Texas Agricultural Extension Service (TAEX) which is part of the Texas A&M University System. The university linkage provides opportunities for interaction with research. This is an important aspect of the process because Extension's goal is to deliver research-based knowledge to its clientele.

County Offices

A local office within each county attests the partnership of federal-state-local government. Local offices provide for easy access and interaction with people and affirms the mandate to provide education to those people who do not attend the university in a formal manner.

The local office is the place to start when one is seeking technical information. The county extension agent will either provide needed information directly or facilitate contact with appropriate resource persons.

Specialized Support

The county extension agent is supported by subject-matter specialists. There are many specialties represented, including aquaculture. Aquaculture specialists have offices at College Station, Corpus Christi and Overton.

In addition to services provided by agents and specialists, TAEX operates service laboratories that support aquaculture. The Extension Fish Disease Diagnostic Laboratory has served aquaculturists since 1971. The Extension Soil and Water Testing Laboratory has recently expanded its services in water testing to better meet the needs of aquaculturists. Both labs are located at Texas A&M University in College Station.

Aquaculture Activities

Aquaculture and TAEX have grown together. For example, TAEX began to provide aquaculturists with an annual statewide fish conference in the 1960's. This effort helped form the Catfish Farmers of Texas which later developed into the Texas Aquaculture Association. In the early 1980's similar Extension programs helped to facilitate formation of crawfish farmer associations. During those years, a great number of educational programs in the form of demonstrations, media presentations, literature (refer to chapter,"Sources of Technical Information"), meetings, workshops, field days and other methods have been delivered to Texans.

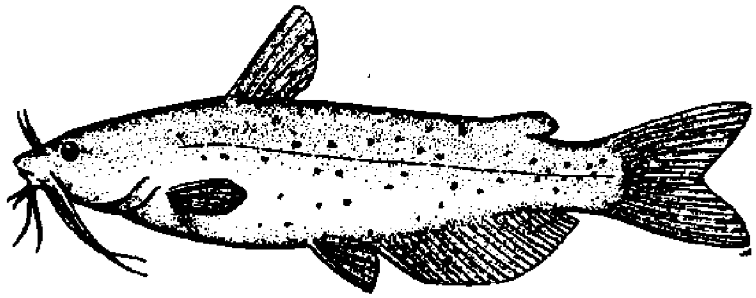
Interaction with Sea Grant

Texas also has extension efforts that developed with the formation of the Sea Grant College Program. Agents that are involved in Sea Grant's Marine Advisory Program have offices in coastal counties. These agents, which have job titles of County Extension Agents - Marine, normally work out of the same office as the County Extension - Agriculture and are supported by Sea Grant, TAEX, and local government.

Sea Grant also employs a mariculture specialist who works out of an office located at Texas A&M University - College Station. Texas Sea Grant projects were the first to demonstrate shrimp farming in the U.S. Recent demonstrations have been focused on shrimps, mollusks and several marine finfish.

OTHER EXTENSION ACTIVITIES

The Fish Farming Experimental Station at Stuttgart, Arkansas, a U.S. Fish and Wildlife Service facility, employs an extension biologist that works with fish farmers. The Soil Conservation Service employs regional biologists who are able to assist in matters relating to aquaculture.



CATFISH

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Production of catfish in the United States reached more than 388 million pounds valued at $321 million in 1988. By far, the most widely produced species is the channel catfish (*Ictalurus punctatus*). Other species are the flathead (*Pylodictis olivaris*), blue (*I. furcatus*), and white catfish (*I. catus*), and the brown (*I. nebulosus*), yellow (*I. natalis*), and black bullhead (*I. melas*).

A recent survey by the USDA indicated that the acreage of catfish ponds is increasing, while the number of producers is decreasing (1,830 growers with 140,392 acres of ponds in 1989 compared to 2,003 growers and 130,252 acres in 1988). This growth in average farm size indicates a trend toward lowering of production costs through economies of scale by large producers who sell a generic product to the processing market.

Four states (Mississippi, Arkansas, Alabama, and Louisiana) account for 91 percent of the U.S. catfish pond acreage. Growers outside the Mississippi delta region generally utilize smaller operations and face higher prices for major items such as fingerlings, feed, and processing. These factors make it difficult for smaller operations to compete in major food fish markets.

TEXAS INDUSTRY STATUS

Compared with such states as Alabama, Arkansas, Louisiana and Mississippi, the industry for farming channel catfish has remained relatively small in Texas. Currently, about 250 fish farming licences are on record in Texas for production of catfish fingerlings or food fish.

Farm Size

The typical Texas catfish operation is a small, "family-farm" which sells product to a local market. The majority of farmers produce fingerlings for sale to private pond and lake owners. Food fish producers sell directly to consumers at the farm or through special arrangements with restaurants, caterers, etc.

Only 10 foodfish producers and an additional 11 fingerling producers advertize their catfish on a state-wide basis in the *Fish Availability List* published by the Texas Aquaculture Association.

Production Methods

Currently all catfish are being cultured in open earthen ponds with mechanical aerators and availability of ample replacement water. This type of facility is expected to dominate production systems in the near future.

Both channel catfish and blue catfish are currently being produced, with the latter generally being sold only as fingerlings for stocking in recreational ponds. There is some demand for flathead catfish stockers, but there is no known production of this species at the present time.

Processing and Marketing

Currently, there is no mechanized processing plant for catfish in Texas. Some producers hand-process fish for sale at the farm. However, at the present time, a catfish processing plant is under construction in southeast Texas by the Naiad Corporation. Operation of this plant will demand 8,000 to 10,000 acres of foodfish production to support full-time operation.

The 1989 farm-gate value of catfish fingerling and food sales by Texas producers was estimated to be $3.5 million.

Future Prospects

During the recent session of the Texas legislature, H.B.1507 was passed. Termed the "Fish Farming Act of 1989" and considerably revised from introduction to passage, it represents the first step by the legislature to foster development of an aquaculture industry and to reduce the number of legal and institutional impediments.

DEVELOPMENT NEEDS

Although the catfish industry is active in Texas and most of the biological problems involved with rearing them efficiently have been overcome, several aspects related to a profitable industry require further development.

The lack of adequate financing to support industry expansion in Texas seems to be the major limiting factor.

Marketing constraints are not viewed as a impediment to further development of the Texas catfish industry. However, entering into the existing market is viewed as a barrier to be overcome. Gaining a market share for fish produced in Texas will be difficult because of the competition from the highly developed integrated industries which already exist in several states.

Other significant development needs include:

- availability of competitively priced nutritional feeds,
- availability of aquaculture equipment and supplies, and
- improved live-hauling services.

While the above items relate to development needs, there are a number of institutional and legal constraints which must be moderated if Texas is to field a competitive and profitable industry.

Among the existing constraints are:

- water availability and usage,
- wetlands legislation as it relates to existing and proposed fish production ponds,
- prohibition of useful exotic fish species,
- unavailability of practically trained and educated personnel, and
- limited number of chemicals that are tested and approved for aquaculture use.

RECOMMENDATIONS

Financing for Catfish Farms

Education of the financial community is suggested as essential to improving the availability of financing for aquaculture ventures. Suggestions for accomplishing improved knowledge of fish farming by investors and lenders include:

- involvement of financial community members in activities of the Texas Aquaculture Association,
- arranging visits between financiers in Texas with those of other states who are currently providing funds for aquaculture development and production,
- state and federal loan guarantees as a means of collateral for the financier, and
- development of financial assistance programs in the Texas Department of Agriculture and the Texas Department of Commerce.

Marketing and Processing

Marketing of Texas produced catfish must develop hand-in-hand with increases in production. Strategically located processing plants will be essential to profitable production, effective marketing and profit. Generally, a single processing plant can serve fish farmers in a 20-30 mile radius from its location.

Research should be initiated on product development to improve the opportunity for use in the home. While the opportunity to sell catfish filets and whole fish has not been exhausted, sales will be enhanced by the availability and promotion of new products, new recipes and convenience packaging. Promotion of Texas products should be a high priority of the Texas Department of Agriculture.

Research and promotion of the human nutritional values of farm raised catfish must be increased.

The persistent problems of off-flavor remains a major marketing problem for the industry. Research on detection and elimination must be continued until this problem is completely alleviated.

Water

Water use in Texas should be prioritized by the Texas Water Commission and Texas Water Development Board with aquaculture receiving a high priority. This high priority can be based upon efficient use in the production of a high quality food product. It should be pointed out that catfish production in ponds and closed systems represent an efficient use of water with evaporation being the major water loss. Good water quality must be maintained in fish farms in order to maintain fish health. Thus, water released from fish farms can be treated and used for domestic purposes. Water released from fish farms is excellent for irrigation, livestock water, etc.

Realistic discharge water quality monitoring procedures must be incorporated into discharge permits.

Wetlands

Jurisdictional wetland legislation must be ameliorated in a manner that allows protection of essential wetlands and the development of a catfish (aquaculture) industry in Texas. It is suggested that a study be done to determine the contribution of catfish ponds to wetland habitats.

Exotic Fish

The ability to compete in U.S. and world markets demands the most efficient production system. Currently, high technology polyculture production systems using exotic species have shown greater returns per acre, reduced incidence of off-flavor and conservation of water resources. Development of well researched criteria to determine the potential for harm when using exotic species in fish culture ponds will be essential. Currently prohibited lists are developed without any input from aquaculturists. Regulation of such species must be made in concert with equal inputs from all concerned. Presently, regulations on the use of exotic species are promulgated by an agency with little, if any, concern for aquaculture and its potential for the Texas economy.

Personnel

It is suggested that a work/study program be initiated at the university level. The program should include basic aquaculture courses and "hands-on" training to better prepare graduates for entry into the job market.

Fish Production

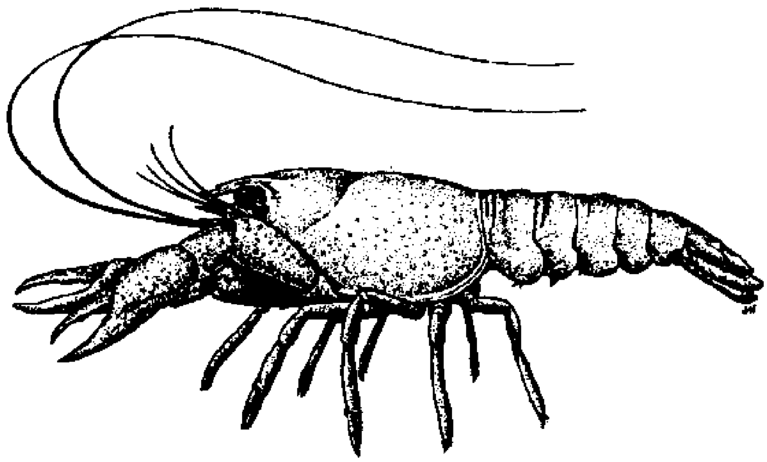
While current production technology will support a profitable industry, there are areas of research that will enhance production and profitability. These include competitively priced nutritional feeds, feeding practices and water quality maintenance. Future research will be needed on catfish genetics to improve growth and health in intensive systems. Genetics research will be needed to develop improved strains particularly adapted to specific environmental conditions.

Research is needed to explore the relationship between fish nutrition, environment, and fish flesh as it's consumption relates to human nutrition and health.

Field testing and demonstrations on the use of exotic species are needed to illustrate efficiency in improving water quality thus eliminating vegetation problems and the use of environmentally adverse chemicals. Polyculture of catfish and various carps is of high interest and potential and should be researched and demonstrated in Texas. For further information on carps, refer to chapter entitled, "Other Freshwater Species".

Therapeutics

While biological control can be used on problems with algae and higher aquatic plants, chemical therapeutics are needed to control, fish disease, and parasites. The therapeutics must be environmentally safe. effective against the target organisms and tolerated by the fish to be treated. Fish farmers need more approved chemicals to enhance fish production in Texas.



CRAWFISH

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INTRODUCTION

Crawfish are found over most of North America. They are fished for bait or food over their entire range. Over 300 species of crawfish have been identified in the United States, but the majority of commercial production is attributed to the red swamp crawfish (*Procambarus clarkii*) and secondarily to the white crawfish (*P. acutus*).

Crawfish culture historically has been confined to south Louisiana. Culture of crawfish for food elsewhere in Louisiana increased markedly in the 1970's and early 1980's in response to demand for an increased and consistent supply. Louisiana continues to produce at least 95 percent of the total U.S. supply of crawfish. Texas, Mississippi, Alabama, Florida, Oklahoma, Oregon, California, Virginia, Missouri, North Carolina, and South Carolina are relatively minor producers of crawfish. However, the president of the Louisiana Crawfish Farmers Association recently reported a distinct decline in crawfish pond acreage in Louisiana to less than 100,000 acres.

A moderately strong, although poorly documented, demand for crawfish as bait and food also exists in Texas. In response to that demand, small scale, commercial production of crawfish was initiated in 1973 in Orange County (Stickney and Davis, 1981). According to a recent survey of producers by Haby and Younger (In Press), 5,000 acres of crawfish ponds are estimated to be in production in Texas.

PRODUCTION METHODS

Crawfish can be farmed in either rice-field ponds in which crawfish/rice polyculture is practiced or in open ponds used exclusively for crawfish. However, rice-field pond production in Texas is extremely rare, if not nonexistent at this time. In both situations, the ponds are managed to make vegetation available to serve as forage for crawfish. Supplementary feeding has traditionally been used only in instances when natural forage is prematurely depleted. However, some farmers are beginning to eliminate the culture of forage vegetation (mainly rice) from their practices and replace it with season-long feeding of commercial crawfish feeds/baits. Preliminary evidence suggests that this practice may produce greater pond yields while easing labor and water quality management requirements.

Because crawfish reproduce in the production pond, only a single stocking is needed. Adults are stocked at a density of 50 to 100 pounds per surface acre of pond. After they are stocked, the adults burrow into the pond bottom. Young produced within the burrow emerge in the fall after flooding. At this stage, the animals feed and grow. Crawfish can be induced to spawn year-round in indoor hatcheries which may allow advances through selective breeding and elimination of seasonal stocking restrictions.

Production rates vary from about 200 pounds per acre in extensive systems to over 2,000 pounds/acre in intensive systems. The use of improved farming techniques results in a higher rate of production per acre in Texas than in Louisiana.

An established crawfish population in a well managed pond provides a seasonal crop with an extended harvest generally lasting from late fall through late spring. However, some farmers have recently begun to carry their harvest into mid-and late-summer with acceptable results.

Harvests of crawfish ponds are conducted by trapping with as many as 30 traps per acre. Harvesting is a labor-intensive operation, but advances in the design of traps and in mechanical harvesting equipment have greatly reduced the amount of time and labor required for harvesting. Additional advances in harvest technology are expected. This will further reduce labor while increasing catch rates and overall profitability.

MARKETING

In Louisiana, an enormous but erratic harvest of wild crawfish from the Atchafalaya basin greatly impacts marketing of pond-reared crops. Undesirable characteristics of the wild crop, include its great variation from year to year and its limited season. The former produces instability in marketing, while the latter causes a depression in prices received by both fishermen and farmers. In recent years, price has dropped to as little as $0.22 per pound. While prices this low are not usually experienced in Texas, the abundance of cheap Louisiana crawfish can and does depress Texas farm-raised crawfish sales and prices.

The purging process, which involves holding the animals in clean water without food for a period of about 24 hours, allowing them to clear their gut, greatly improves the quality and shelf life of this live seafood product. An increased recognition of these benefits by consumers and marketers mildly buffered periodic price declines in Texas due to the influx of both wild caught and farmed Louisiana crawfish, which generally are not purged. If Texas purged crawfish can continue to gain recognition for product quality, they will become more insulated from the influences of the Louisiana harvest. However, the probability that Louisiana fishermen and farmers will adopt this practice is high if the market demands this quality assurance. Thus such a competitive advantage for Texas interests may be short-lived.

CHARACTERISTICS OF TEXAS FARMS

Some general characteristics of the farm, the farmer and his/her customers can be drawn from the survey by Haby and Younger (In Press).

The typical farmer is relatively new to the industry, having been in operation less than 3 years. With little access to the farm credit system or other traditional lending sources, he/she has financed the start-up or expansion of his/her crawfish operation primarily with personal resources.

Over 89% of the state's production is done on farms greater than 30 acres with 81% of the state's production taking place in just four southeastern counties (Chambers, Jefferson, Liberty and Orange). Annual production varies with individual operations, but Haby and Younger calculated average yields of Texas survey respondents to be 409 pounds/acre. Assuming an average farm-gate value of $0.80/pound, the total farm-gate value of Texas crawfish production is estimated to be about $1.6 million.

Farmers marketed 71% of their crop live to three customer types: ultimate consumers (26%), wholesale interests (35%), and food service establishments (20%). Only 12% of Texas farm-raised crawfish went to processors. Since there are no known processors in the state at this time, it is assumed this amount went to Louisiana for processing.

Typically, Texas crawfish farming requires that producers also serve as product distributors which creates additional management and capital demands. Slowly, supportive market services such as cooperative marketing, brokerage and mixed-product distribution have evolved. However, it appears that the majority of the current producers are either unsure of how to access these options or are unwilling to participate for varying reasons at this time.

ISSUES

Overall, those involved in this unique farming enterprise seem optimistic about the industry's potential for future growth, despite indications that recent production cuts have occurred. Indeed, as crawfish farmers face the 1990's, they are beginning to develop strategies to improve their chances for future growth. Recently, in an effort facilitated by the Texas A&M Marine Advisory Service (a component of the Texas A&M University Sea Grant College Program and the Texas Agricultural Extension Service), Texas crawfish aquaculturists developed a listing of critical issues and ranked strategies necessary to promote industry growth. The following are their recommendations (Individual issues within categories are listed in order of producer rankings; however, the broad categories are unranked).

Water Use and Management

1. Find effective ways to deal with the rising costs of water.
2. Identify more effective ways to control water quality.
3. Devise strategies for more effective on-farm water use management.
4. Participate in governmental processes which will determine the regulation and allocation of water resources.

Production Management Practices

1. Develop a better understanding of crawfish nutritional needs.
2. Develop more cost effective harvest technology.
3. Establish effective predator and disease controls.
4. Establish adequate financing for new and expanding farms.
5. Proactively address regulatory issues such as licensing and permitting.
6. Develop adequate supply lines for seed stock and/or brood stock.

Trade Association

1. Develop supply and/or marketing cooperatives.
2. Proactively provide input into research and producer education programs carried out by state and federal agencies and the State's University System.
3. Develop alliances with other relevant trade associations and interest groups.
4. Establish greater, more timely input into governmental policies and regulations that impact aquaculture production.

Marketing by Industry

1. Develop and implement a comprehensive product promotion plan.
2. Develop a set of product standards which are supported by crawfish farmers.
3. Develop a standardized reporting system to assess the current status of the crawfish industry by lenders, policymakers, etc.

Marketing by Individual Farmers

1. Overcome the seasonal oversupply problem.
2. Develop or expand crawfish markets (ie., new product forms and/or new market areas).
3. Expand promotion of crawfish to consumers.
4. Develop processing facilities in Texas.
5. Strengthen the distribution system for crawfish.
6. Develop enforceable quality standards for crawfish and crawfish products.

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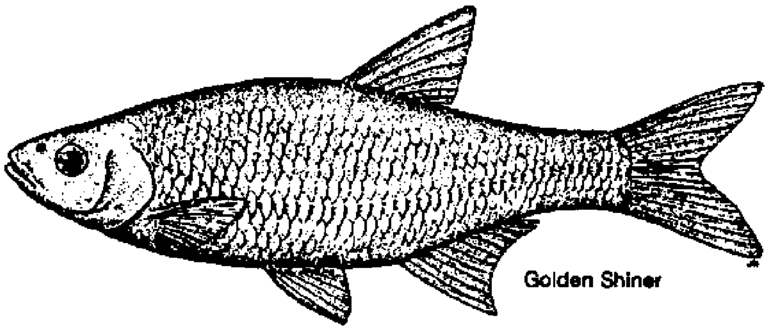

BAITFISH

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STATUS OF THE INDUSTRY

Commercial development of baitfish began as early as 1915 but little progress was made until after World War II. During the 1950's and 1960's rapid expansion occurred, particularly in Arkansas. By 1972, Arkansas had developed 29,091 acres of baitfish ponds of which 91% were devoted to production of golden shiner (*Notemigonus crysoleucas*). In 1987, the U.S. baitfish industry utilized over 40,000 acres and produced 26 million pounds of baitfish. The average farm-gate value of all minnows in 1987 was about $2.75 per pound. Thus, the total value of U.S. baitfish production was $71.5 million. Arkansas still accounts for about 75% of baitfish production and acreage and about 115 of the 165 major producers in the U.S.

Most of the baitfish sold in Texas are trucked in from Arkansas. Although the farm-gate value of the Texas baitfish industry is estimated to be about $10 million, most of this value is associated with temporary holding and distribution of minnows from Arkansas. Fewer than 100 acres are devoted to production of baitfish in Texas, and the value of this aquaculture component is estimated at $250,000.

The largest use of baitfish is for freshwater sportfishing although some minnows are sold to the aquarium industry. Estimated annual per capita usage of baitfish is one half to one pound. Demand is linked to population. Thus, the rapidly growing urban areas in Texas represent obvious markets. Demand also tends to increase in the vicinity of new lakes or impoundments.

Bait Species

Although more than 20 species of fish have been grown for bait, three species clearly dominate U.S. production. These include, in order of importance, the golden shiner, the fathead minnow (*Pimephales promelas*), and the goldfish (*Carassius auratus*). Other species that may prove profitable to bait producers in Texas include common carp (*Cyprinus carpio*), crawfish (*Procambarus* spp.), Mexican tetra (*Astyanax mexicanus*) and various other shiners (*Notropis* spp.).

The killifish (*Fundulus grandis*) is being produced in limited quantities in the Galveston Bay area of the Texas coast. Penaeid shrimp (*Penaeus* spp.) have strong potential as a saltwater sportfishing bait, but no commercial bait shrimp culture facilities exist at this time. This situation may change with the upcoming designation of several productive back-bay areas of the Texas coast as protected nurseries where trawling for bait shrimp is not allowed.

TYPICAL PRODUCTION METHODS

Bait minnow production techniques are well developed. Giudice et al. (1981) provided an excellent summary of methods in the booklet, "Manual for baitfish culture in the South" (publication number EC 550 of the U.S. Fish and Wildlife Service and the University of Arkansas Cooperative Extension Service). In summary, the reproduction and grow-out phases of baitfish production are generally accomplished in outdoor ponds. When the water temperature warms to 65-70 F during late spring and early summer, adult minnows begin spawning on appropriate substrate in the ponds. After spawning, the eggs or fry are generally transferred to separate fertilized ponds where a rich plankton bloom is encouraged. Although baitfish fry are omnivorous and can subsist entirely on natural plankton in the pond, production rates can be doubled by offering supplemental feed. As the fish grow, they are gradually transitioned from a finely ground, high protein starter feed to a coarser, lower protein grower feed.

The golden shiner reaches a size of 25 cm (10 in) when mature. However, most are marketed in smaller sizes. Fatheads are produced on fish farms using intensive culture systems and usually are sold at 6 to 8 cm (2.5 to 4 in.). Many farms raise goldfish both for bait and the aquarium trade. Often the most colorful go to aquarium dealers and the others are baitfish.

Production per acre generally ranges from 250 to 1,000 pounds. The industry average is just over 600 pounds (USDA, 1988). Yields as high as 4,484 kg/ha (4,000 lb/acre) have been produced by goldfish farmers and as high as 1,570 kg/ha (1,400 lb/acre) by golden shiner farmers.

The average baitfish farmer invests more than $2,500/acre before harvesting a single fish. This does not include the price of land, which may be as high as $1,000/acre. Capital costs include land clearing, pond construction, development of adequate water supplies, spawning materials, seines, holding tanks, and hauling trucks. Feed and energy account for about 45% of operating costs. Giudice et al. (1981) estimated that a small family could live comfortably on 40-50 water acres of baitfish ponds if 1,000 pounds per acre of good quality, small bait were produced and marketing did not involve a wholesaler. The industry average for returns to land and management are estimated to be approximately 25 % of sales value (USDA, 1988).

DEVELOPMENT PLAN

U.S. baitfish production increased 3% from 1986 to 1987. Expansion of the industry will depend upon continued growth of sport and commercial fisheries, construction of additional ponds and lakes in the state, and improvement in management techniques. As Arkansas producers face worsening problems with water availability and bird predation, Texas producers may have an opportunity to capture a larger share of the growing market. In order to provide a consistent supply of a variety of minnow sizes, relatively large farms are needed. However, there iis considerable risk in competing with the mature, established industry in Arkansas. A combination of land, water, and climate favors concentration of the baitfish industry in Texas. Close proximity to markets also is a factor.

Resource Requirements

A successful baitfish enterprise requires relatively flat land with good water retention. Rocky, gravelly, or sandy soils and rolling or steep terrain usually are undesirable. Adequate quantities of water that is neither too acidic or too alkaline must be available. Surface waters often contain excessive amounts of silt and pesticides or undesirable fish species with attendant problems of disease and parasites. Therefore, absence of adequate underground water generally restricts development of a baitfish farm. Declining water tables make water reuse programs essential to the future of the industry.

Capital costs represent a major constraint to expansion of the industry. More readily available credit and increased profit margins would ease this limitation.

Research and Technology Needs

Much of the progress in this industry has been made by managers and production specialists, who, by trial and error, have found ways to improve their operations.

Virtually no research on the culture of baitfish is currently being conducted in Texas. Studies should be made on baitfish production potential in Texas where good data are currently unavailable. Such studies would be conducted primarily in ponds and feature various stocking levels of broodfish, fry or finger-lings, depending upon the species of interest.

A survey of the availability and popularity of various baitfish species of potential importance in Texas is of primary importance so that research can be aimed at those which offer the best probability of success for the aquaculturists. This survey should be conducted by an appropriate state government or university agency.

The nutritional requirements of many baitfishes are poorly known. Feeds are currently available for most species, but a great deal of research is required if feeds formulated to meet the nutritional requirements of each species are to be developed. A strong research program in baitfish nutrition should follow or parallel development the baitfish rearing industry in the state.

Environmental requirements of baitfishes are of great concern to producers. Studies aimed at providing information on the requirements for oxygen and susceptibility to high levels of metabolites, along with studies on the interactions of these parameters, are required.

Almost no research has been done in the field of genetics. Selection of brood stock represents a major problem because of the large numbers of fish involved. Baitfish farmers sometimes harvest the fastest growing fish, allowing others to be held over as brood stock. This may prevent improvements in yield. To remedy the paucity of knowledge in this field, the following is recommended: a) a study in which annually-selected and spawned brood fish are compared with those raised in control ponds; b) research to find strains that are resistant to diseases, parasites, stress, viruses, and other production problems; c) research on spawning with the object of defining methods to obtain spawns from brood stock in one season.

Under certain water quality and algae conditions, golden shiners produce only 338 kg/ha l(300 lb/acre) per year. Farmers need to know what kinds of feeds to use before, during, and immediately after spawning. A great deal of knowledge about nutrition and diet has been borrowed from trout research. Specific information related to baitfish is lacking, such as how much dietary protein is needed during various seasons, and how much food to feed. Universities and experiment stations could develop this information.

Environmental requirements concern baitfish farmers more than any other. Oxygen depletion may cause losses amounting to thousands of dollars. Even if catastrophic losses do not occur, low-oxygen stress can predispose the fish to disease and parasitic infection.

Baitfish farmers traditionally use a number of chemicals to prevent oxygen shortages, treat bacterial infections, eradicate undesirable fish, and combat parasites. EPA and FDA have challenged the safety of these chemicals. Many chemical companies do not obtain clearance for their products because of cost involved. Baitfish farmers believe this problem should be addressed by the Federal Government. They also believe that high enough priority has not been given to clearance of chemicals used in the industry and that they should not be under the same restrictions as food producers.

Pond vegetation generates environmental concern. Algae such as *Anabaena*, *Chara*, *Microcystis* and *Pithophora* together with higher aquatic plants such as *Ceratophyllum*, *Elodea*, *Najas* and *Potamogeton* represent major problems. Restrictions by EPA and FDA hamper economical solutions. The few registered chemicals are often impractical or ineffective. Copper sulfates control some algae, but its corrosive qualities make large-scale use difficult.

Dryland vegetation presents another problem. Barnyard grass, smartweeds, and similar plants germinate quickly when farmers partially draw down ponds for harvesting. Disk harrowing controls the plants, but rain or high water tables often prevent use of harrow equipment. The only alternative involves chemicals, most of which are banned.

Vegetation control studies should be funded for several years, with both universities and experiment stations participating. Such research would also be applicable to catfish farming, intensive culture of sport fish, farm pond management and management of ponds on Federal and State Hatcheries. Research is this area is badly needed.

Little research has been done on control of effluents from baitfish farms. Investigators at the USFWS Fish Farming Experimental Station studied the subject briefly and concluded that organic matter discharged from ponds had no significant pollution potential.

More research should be done on the rotation of baitfish and crops, such as grain, rice, sorghum and soybeans. Yields of crops increase dramatically following fish in rotation systems. Studies also are needed on the advantages of using pond water to irrigate crops.

A host of animals prey on baitfish, including otters, diving ducks, egrets, herons, mergansers, bullfrogs, alligators, snakes, snapping turtles, backswimmers, dragonfly nymphs and other aquatic insects. Baitfish farmers wage a constant battle against these predators and research is badly needed to develop methods to control them.

Many baitfish farms are near aerial-spraying operations. The chemicals may be causing fish deaths. Studies are needed to assess this problem.

When fishermen buy baitfish they expect healthy, hardy animals. To produce fish that meet these requirements requires quality control throughout the growing and harvesting process. It is important to grade healthy fish into sizes suitable for different kinds of sport fishing.

No facility specializes in baitfish research. Several universities have made important contributions, but considering the size of the industry, much remains to be accomplished. It is recommended that a 5-year program be developed incorporating the following items:

- establish a program of applied research and demonstrations and
- establish a program of basic research.

Studies should provide solutions to problems of growing baitfish in ponds and on methods for controlled culture systems.

Other Needs

The number one complaint by the Texas baitfish industry is the regulatory ban prohibiting use of tilapia as live bait. Tilapia have much potential as a farm-reared baitfish in Texas. Due to their sensitivity to low temperatures, tilapia can be more readily grown in Texas than in Arkansas, thus providing a competitive edge. Tilapia food-fish operations generally produce excess small fish which could be sold to bait dealers for distribution. Other exotic fish species also might make excellent bait for Texas fishermen, possibly better than those now cultured. An effort should be made to accurately evaluate all species for use as bait under conditions which will not damage the natural fish populations in the State.

More publications, workshops, seminars, field days and short courses are needed to transfer technology from the classroom to the field. The Extension Service can provide assistance in this area. Much of the technology developed for baitfish culture came from the industry itself. However, many problems cannot be solved by in-house technology.

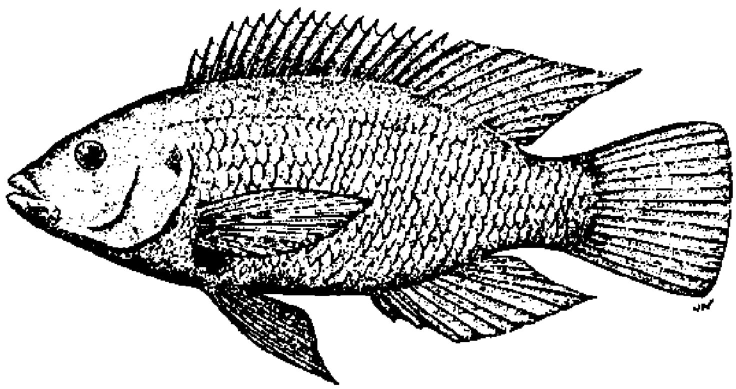
Information on economics is limited. As in the case of technology, much needs to be done to develop and transfer such information to the baitfish industry. Accurate, up-to-date economic information should help baitfish farmers to obtain loans.

A major land use problem involves the spread of urban areas into farming sections. Proper land use planning should solve this problem.

Numerous regulations, particularly those of the EPA, FDA and the TPWD, constrain orderly development of the baitfish industry. Fish health inspections are not standardized.

RECOMMENDED ACTION

1. Develop basic research on life history and biology of potential new species of baitfish. This would include providing information for use by TPWD in setting regulations for use of these is Texas.
2. Conduct research on genetics and reproduction, and through selection, develop superior strains of broodfish resistant to diseases and stress. This is a long-range program.
3. Initiate a study of water quality, including methods of managing algae blooms for maximum production.
4. Continue to develop information on nutritional needs of brood fish, fry, and fingerlings.
5. Continue research on ways to alleviate oxygen shortages.
6. Coordinate efforts by FWS, EPA and FDA to clear chemicals useful to the baitfish industry and for the aquaculture industry at large.
7. Establish research programs aimed at practical control of aquatic and dryland plants that cause problems.
8. Initiate research on better ways of constructing ponds and drain systems, and on the advantages of crop and fish rotations.
9. Continue research on control of disease and parasites.
10. Develop information on practical methods of controlling predators.
11. Upgrade methods of harvesting, grading, and transporting fish.
12. Test other fish species for potential as baitfish.
13. Develop mechanisms to coordinate research and development projects.
14. Develop methods of selectively controlling green sunfish, mosquito fish and tadpoles.
15. Initiate studies on the advantages of using pond water to irrigate crops.



TILAPIA

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PRESENT STATUS

Tilapia (*Oreochromis* and *Tilapia* spp.) are exotic tropical fishes, having been introduced throughout the tropical and subtropical world from Africa and the Middle East . Except for extreme South Texas, tilapia cannot overwinter except during unusually warm winters, in constant temperature springs, or in the discharge canals of electrical generating stations. There is no indication that the lower lethal temperature tolerance of tilapia will increase with time.

From an aquaculture standpoint, tilapia have many advantages. Tilapia are well accepted when tried by consumers, are resistant to most parasites and diseases, grow rapidly, are tolerant to extremes in water quality and are largely herbivorous. High densities of tilapia can be grown with a reduced level of management as compared to channel catfish. Tilapia are important food fish in all tropical regions of the world and are becoming more so.

Tilapia, principally *Oreochromis aureus*, are present as year-round populations in various power plant cooling lakes around Texas and in the Rio Grande. Overwintering populations may occur in farm ponds in south Texas and may also occur as far north as Buffalo during unusually mild winters. In most regions, however, winter kills are common when water temperature falls below about 10 C for a period of several hours.

Although biological and historical data indicate minimal negative impact or, in most cases, positive impact on native fish populations, there is apprehension from sport fishermen about stocking tilapia in Texas waters. Concern about exotics is shared by some regulatory fisheries officials, which has resulted in highly restrictive culture regulations.

About 500,000 pounds of tilapia valued at more than $500,000 are produced annually in Texas. Currently, producers are restricted to the use of two species of tilapia for production. These being *Oreochromis mossambicus* and *O. aureus* and their hybrids. Worldwide research indicates that both *O. niloticus* and *O. homorum* are also valuable species for the production of fast growing, all-male hybrids which increase profitability. Yet neither of these are permitted in Texas because of environmental concerns considered by many in the industry to be ill founded.

If one were to examine the major agricultural breakthroughs of this century, a large proportion would be found to involve hybridization of species. Hybrids have given Texas the 1015 onion, the ruby red grapefruit, a dust resistant chicken in poultry breeding, and the Santa Gertrudis and Hereford cattle, to name a few. Most hybrids command premium market prices.

It is vital that tilapia producers be able to utilize the most effective hybrids of the differing species of tilapia. There are some 50 known species of tilapia worldwide, and over 20 have been cultured. Some of these species are recognized for their shorter growout seasons, some for their unique feeding habits, and others for their higher percentage of fillet yields in processing. Certain hybrids are recognized for producing high percentages of male offspring, which reduce the time required for growout.

Most pond aquaculture sites in Texas are located within floodplains. Texas regulations currently prohibit tilapia culture within flood plains. There are more than 800,000 private impoundments in Texas that could be used for cage and other forms of tilapia culture. Regulations prohibit their use because it is impossible or impractical to filter discharge flood water.

Low-income farmers are unable to take advantage of their existing resources for tilapia production because of regulatory restrictions and comparatively high species certification costs.

Investors are reluctant to invest in Texas because of the seemingly hostile regulatory climate. The multi-billion dollar aquaculture industry is locating in other states more favorable to aquaculture.

POTENTIAL

The potential for rearing tilapia in many parts of Texas appears great, provided regulatory problems can be overcome. Of primary importance is the need to develop reliable and economical overwintering facilities for broodstock and fingerlings. Research has indicated that tilapia fry produced in the spring can be reared to as much as 300 g within a growing season in Central Texas. Whether there is a sufficiently longer growing season in the southern portion of the state to allow growth of 400-g or larger fish within a year has not been thoroughly tested. For many portions of the state, better culture strategy might be to use a system of recirculated, heated water for the cool months combined with outdoor ponds for summer production.

The ultimate potential of tilapia culture in Texas will be dependent upon consumer acceptance. Because Texans and, for that matter, most U.S. residents, are unfamiliar with tilapia, some innovative marketing techniques may be required. Fish, in general, sell well in Texas, and test marketing of tilapia in Texas and other states has indicated that these fish are well received wherever they are offered for sale. Live fish are well received in the urban areas.

Filets are well received but may face severe competition from imports, presently from the Peoples Republic of China.

No processing plants have been developed in Texas for tilapia, but privately owned processing facilities for channel catfish could process tilapia. Small tilapia and filet bones can be run through deboning equipment and the end product formed into fish cakes, sticks and other specialty products. Fast food restaurants might be an appropriate outlet for the deboned product as would the frozen retail grocery market.

From the aquaculturist's standpoint, few fish are more hearty than tilapia, nor easier to rear. Expected production levels per unit area of water far exceed those for channel catfish. Production as high as 40,000 kg/ha/yr has been achieved in ponds in some regions of the world.

DEVELOPMENT NEEDS

Texas tilapia producers were surveyed to prioritize problems and development needs (Table 1). Over regulation by the Texas Parks and Wildlife Department was identified overwhelmingly as the most critical issue. Reducing state restrictions was named in the top two critical needs by 94% of the 18 survey respondents.

Developing economical overwintering systems is a critical need. Energy and infrastructure costs have been prohibitive in many cases. Overwintering facilities which employ artesian warm water, high density confinement in closed systems located in structures heated with low-cost energy, utilization and conservation of natural ground temperature and other possibly more innovative techniques should be developed.

Table 1. Ranking of issues facing Texas tilapia producers (in order of decreasing importance) according to a survey conducted during October, 1989

Mean Score	Rank	Issue
1.4	1	Reducing state restrictions
3.8	2	Developing more efficient overwintering systems
3.9	3	Assessing and developing markets
5.5	4	Expanding supply of all-male fingerlings
5.5	5	Developing more efficient water filtration systems
6.1	6	Feeds and feeding; nutritional requirement
6.4	7	Developing more efficient culture systems
6.5	8	Researching environmental requirements
6.6	9	Researching use of mossambique tilapia as a food fish
7.7	10	Disease and parasite control

Market recognition and development was rated equally important. Tilapia should be positively portrayed as a high value food product. The product should be offered live and in various processed forms for varied Texas consumer preferences.

Water quality limitations need study. More economical and efficient biological and mechanical water filtration systems need to be developed to remove nitrogenous wastes from closed systems. Oxygenation and gas stripping systems should complement filtration systems. Technology for aeration and filtration is available, but applying these techniques in a way to produce a competitively priced product needs further development.

Expanding the supply of male fingerlings would not only increase production and profitability, but also reduce opposition from groups opposing exotics. More reliable and economical production techniques for both pure strains and hybrids need to be developed.

Competitively priced, high-quality feeds need to be available. Stocking tilapia in polyculture systems should improve profitibility by providing a marketable aquaculture product while improving water quality.

Culture systems that optimize the most economical and productive technologies must be developed if tilapia culture is to be competitive in the world market.

Studying the use of alternative strains, species and hybrids for particular types of culture systems is important to development of the industry. Most culturists agree that one of the two species approved in Texas, *O. mossambicus*, is poorly suited for food production.

IMPLEMENTATION PLAN

The most important issue hindering development of the tilapia industry in Texas is over regulation (Table 1). Theoristic regulatory officials have convinced most of the public and the media that tilapia introductions are harmful to native fishes.

Public education conveying historical and biological facts about tilapia followed by effective legislative lobbying is necessary to overcome misconceptions. The Texas Department of Agriculture should promote tilapia as a nutritious and environmentally safe food product. The Texas Agricultural Extension Service should disseminate factual information to the public and media. Educational conferences should be held involving all interested parties to openly discuss the issues. The Texas Aquaculture Association should support educational and research activities related to tilapia environmental issues. If the public were aware of the economic potential and positive sportfishing impact of tilapia, there would not be a regulatory problem.

State and federal resources should support both basic and systems research and development. A partnership of public and industry interests should develop and support a pilot facility or enter into an agreement with an existing facility to solve production problems listed above.

State agencies and universities should support industry marketing efforts with information, promotion, education and research.

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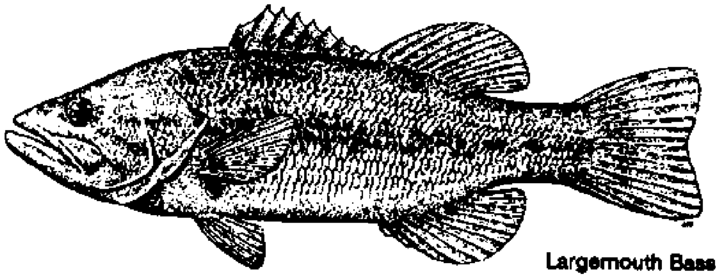

Largemouth Bass

SPORTFISH

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BACKGROUND

A number of freshwater sportfish species (and associated forage species) are cultured for the purpose of stocking private waters for providing sportfishing recreation. Channel and blue catfish are two of the most popular species stocked in private water but these are discussed in more detail in other status reports. Another major species produced is the largemouth bass (the northern and Florida sub-species as well as their intergrades). Other species include bluegill (primarily as forage for largemouth bass), redear sunfish, hybrid sunfish, black and white crappies and hybrid striped bass. Additional forage species stocked into sportfish ponds include tilapia, fathead minnows, golden shiners and threadfin shad.

There is little doubt that the largemouth bass is one of the most important sportfish cultured for stocking private waters. As a result, this report will center on the status of largemouth bass culture in Texas but will also address the various forage species cultured for bass production.

Largemouth bass have been cultured in the United States since about 1890. Historically, a variety of sportfish were available to the pond owner at no cost from Texas Parks and Wildlife. This service was discontinued in the late 1970's and as a result, the private sector assumed the role of producing sportfish for the purpose of private lake stocking.

The introduction and success of Florida bass stockings in the 1970's created considerable interest in the stocking of this sub-species as well as intergrades between the northern and Florida sub-species. Initially, techniques for discerning between sub-species and their intergrades were unreliable. However, advances in electrophoresis techniques the last few years has made specialty marketing of sub-species and their intergrades possible. The ability to determine the genetic background of stocks has the most immediate impact on largemouth bass but could impact the genetic management of a number of other sportfish species in the future.

CURRENT STATUS

Today, the private sector produces sportfish fingerlings almost exclusively through the use of open ponds. State and federal agencies rely on tank and raceway production techniques in addition to ponds, particularly for largemouth bass. Currently, approximately 15 producers advertise sportfish species available for sale at their farms. Unlisted sources of sportfish fingerlings not included on availability lists for stocking public and/or private waters include Texas Parks and Wildlife, the U.S. Fish and Wildlife Service and other private producers not listed on availability lists at the present time.

Acreage in production is estimated at 150 acres by agencies and 250-300 acres by private industry. Production is primarily geared toward producing 1 to 3 inch bass and sunfish. However, some producers provided advanced fingerlings of these species on a limited basis. The major market outlets for these species are private pond owners, club lakes, golf courses and fee fishing lakes. Total value of the sportfish fingerling industry is estimated at 1.5 million dollars annually. Price breakdown for selected species include bass $0.25-$0.35/inch up to 6 inches with large bass costing $10.00-$18.00/lb.; sunfish average $0.15-$0.20/inch; hybrid stripers $1.00-$1.50 for 3-5 inch fish; fathead minnows $12.00/lb.; and threadfin shad $140.00/thousand.

POTENTIAL

The potential for the sportfish fingerling industry in general is favorable. However, the industry is leveling off in both size and production. The ever increasing demand for quality sportfishing will dictate production of sportfish fingerlings and their associated forage species, particularly in small impoundments that are intensively managed.

At this time, development of quality urban fisheries appear to have the greatest potential for future development. Continued drought conditions throughout the southern portion of the state continue to have a negative impact on the industry in that region.

DEVELOPMENT NEEDS

While certain sportfish and related forage species readily accept artificial rations, largemouth bass remain difficult to rear using this technique. Problems cited by industry include ration costs and the intensive labor requirements necessary to train fish to accept the rations. In addition, research on the performance of ration-reared sportfish after stocking should be conducted.

Other needs cited (in no particular order of importance) include:

1. Better pedigree certification procedures for largemouth bass stocks.
2. Development of unisex female bass and crappie.
3. Further research on "catchability" of largemouth bass sub-species and intergrades.
4. Continued strong public educational efforts on proper stocking and management techniques.
5. Increased availability of large bass at reasonable prices.
6. Increased utilization of the private fingerling industry by government.
7. Greater interaction between fish farmers and professional societies (ie., Texas Chapter - American Fisheries Society).
8. Feasibility of on-farm use of electrophoresis techniques.
9. Further research on relative growth rates of largemouth bass sub-species and their intergrades.
10. Improvement of the image of fish farmers.

IMPEDIMENTS

A number of impediments have been identified as being potentially detrimental to the present and future of the sport- fish fingerling industry. These impediments include:

1. Predation by cormorants - ineffective legal control techniques.
2. Excessive regulation by government.
3. Competition by governmental sources producing sportfish fingerlings.
4. Out-of-state competition - unsound stocking strategies.
5. Water rights and cost of water pumping, etc.
6. Public perception of aquaculture as a detriment to public waters.
7. Drought

IMPLEMENTATION PLAN

The sportfish fingerling industry differs from the food fish industry in several ways. Primarily, sales are based on the desire by a landowner to properly stock and manage a body of water in order to increase recreational opportunities through sportfishing. If proper management techniques are employed, that landowner may not purchase additional sportfish or forage species for several years. In contrast, the food fish industry relies heavily on establishing repeat business with expansion into new market areas.

This unique characteristic of the sportfish industry requires strong educational efforts on the part of governmental agencies and the industry itself. Landowners need factual information concerning the benefits and techniques associated with sportfish management. Further support should be generated for research in critical areas by educational agencies, industry and landowners. The Texas Agricultural Extension Service should play an active role in this process by assisting both industry (through improved culture techniques) as well as landowners (through educational programs).

OTHER FRESHWATER SPECIES

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Many other freshwater forms have potential for culture in Texas or are currently being produced and sold. It is not possible to provide complete status reports for all of these. This review is intended to focus attention on additional opportunities for the expansion of aquaculture.

Most of these groups have not been investigated thoroughly enough to determine their eventual potential. Because much of the future of aquaculture lies in the use of species not presently cultured, efforts should continue to research and conduct pilot scale testing of new species and/or new approaches to production. This includes but is not limited to utilizing polyculture rather than the traditional monoculture methods presently in use.

ALLIGATORS

Hides of the alligator (*Alligator mississippiensis*) have rapidly increased in value over the past ten years. The impetus for this was the banning of alligator hunting during the late 1960's. At that time it was feared that the alligator population in the United States might become extinct without protection. Subsequently an open season for hunting and capture of wild alligators was reinstituted in Texas as well as Louisiana and Florida. Nonetheless this resumption of the wild harvest has not been a detriment to the production of alligators on farms in Texas, Louisiana, Florida and Georgia.

The most recent figures from sales in the United States (1988) indicates that farm raised alligator hides sold for $21.00 per foot to $46.00 per foot. This resulted in total hide sales values in excess of $4.1 million in the United States from farm produced animals during 1988. The percentage of this from Texas producers is quite small though it has been reported that there are 16 active alligators farms in the State. The farm gate value of alligators produced in Texas during 1989 was estimated as $52,000. Sales of alligator meat are reported to be excellent but the extent of the market is poorly documented and is considered to be mostly a novelty item.

Most farm raised alligators that are sold on the hide market are about 6 feet in length and three years of age. Larger alligators are sometimes found on the market and these tend to command premium prices. Alligators can be raised extensively in fenced outdoor earthen ponds. Their growth rate is dependent on temperature and for that reason some growers have gone to a more sophisticated indoor temperature controlled environment. Though more expensive to operate these do have the advantage of a longer growing season because alligators grow very slowly at temperatures below 70 degrees F.

Brood stock are normally secured from domesticated stocks as wild-caught alligators tend to be overly aggressive. Because there is a shortage of high quality domesticated broodstock some growers are forced to rely on wild-caught animals. Brood enclosures vary in size but are a minimum of four acres in size surrounded with welded wire fencing and treated posts. Because alligators are excellent climbers there is usually a section of fencing angled inward from the top of the fence to discourage escapes. In addition the fencing is buried about six inches below ground or boards are used to prevent escapes from under the fencing. Females are allowed to build nests and lay their eggs wherever they desire inside the enclosure. There are problems with predation on the eggs from birds, raccoons and other small mammals. Most growers remove the eggs from the nests and hatch them artificially. Care must be taken to place the eggs in the incubator in the same position as when found in the nest. Young animals are retained in the incubator area until they reach a length of 2-3 feet when they are released into outdoor pens for rearing.

During the growing period alligators are segregated by size to reduce predation by larger alligators. There are few other predators on the sub-adult alligators. Feeds used are fresh or frozen fish and fresh or fresh-frozen meat. This is usually ground up for the smaller animals but can be chunked for the adults. There is a need for research on low-cost diets using artificial feeds and a better understanding of the basic physiology of alligators which should result in increased growth rates as well as increased viability of the young. This will require an improvement in diets for adults, development of treatment methods for disease control and a better understanding of environmental condition required during the initial growth stages. Market promotion will become a necessity in the near future to compete with the growing wild crop industry as well as sales from foreign competitors.

AQUATIC PLANTS

Production and sales of aquatic plants across the United States are poorly documented. There is a sizable market in some areas for plants to be used in reclaiming wetland areas and also for landscaping of selected areas. In Florida it has been reported that this is the fastest growing segment of the aquaculture industry.

In Texas the six major growers produce mainly ornamental waterlilies and plants for the aquarium trade. In the past most of the latter were harvested from the wild but concerns about environmental degradation and the possible contamination of aquariums with undesirable animals has curtailed this effort. Some plants are sold for use in pilot scale waste and sewage treatment facilities. The use of plants for this purpose holds great potential across the entire nation.

Though Texas and Florida enjoy a reputation as the largest producers of aquatic plants for sale there is very little market information available. Best estimates placed the 1988 farm-gate value in Texas at $2.4 million.

The broad potential for the use of aquatic plants for food, energy, water reclamation, chemicals, pigments and other special products makes them deserving of further research. Basic physiology, reproduction, nutrition, and environmental requirements all need further study. In addition the lifting of restrictive regulations concerning utilization of plants in private bodies of water is a necessity. The natural aquatic environment can be protected while still allowing private growers to use the most efficacious species available.

BUFFALO

Though buffalo was one of the first types of fishes cultured in ponds for food in the Southern United States, it is not produced except in isolated instances in Texas. The major reason is that buffalo commands a very low market price and is perceived as less than desirable as a table fish by most householders. The three native species of buffalo are bigmouth buffalo(*Ictiobus cyprinellus*), smallmouth buffalo *(I. bubalus*) and black buffalo (*I. niger*). Methods for extensive production of these fish are well documented and growers in the State will not increase production without additional financial incentives.

The farm-gate value of buffalo in Texas is estimated as only $10,000. To increase production of these species, studies on marketing acceptance by region will need to be conducted as well as improved product forms and improved diets for the fish.

CHINESE AND INDIAN CARP

Grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*) are all utilized in aquaculture to some extent at this time. The black carp (*Mylopharyngodon piceus*) and the mud carp (*Cirrhinus molitorellus*) are also being studied for possible use in the Texas. These fish occupy separate portions of the aquatic ecosystem and have been grown in polyculture operations with good success.

The major use of these fishes is for control of nutrients in waste waters though the grass carp and the bighead carp are marketed for food in the major metropolitan areas of the state. Bighead carp are also used for trotline bait in selected areas.

All of these species have a demonstrated potential for intensive culture. They grow rapidly, utilize feed of a low trophic level, are quite hardy, and extremely high yields have been reported.

Chinese and Indian carps are under intense regulatory pressure because of the possibility that they might reproduce in public waters of Texas and disrupt the ecological balance of native species. Whether or not this possibility is realistic is highly debateable. Nevertheless, carp are considered to be a threat to the environment in the minds of many in the public sector.

All of these fish are easily spawned under controlled hatchery conditions with the use of hormones. Procedures for production of functionally sterile triploid grass carp has helped to relieve some of the pressure against release of these fish into private water systems in the state. Production of economical quantities of these fish is quite possible in the state if regulatory requirements are satisfied. The procedures for intensive production do not differ significantly from those used for other omnivorous fish.

The farm-gate value of Chinese and Indian carps in Texas is estimated as $80,000 during 1989. The major constraint on production at this time is the regulatory environment, as production techniques and marketing channels are fairly well established.

COMMON CARP

Common carp (*Cypinus carpio*) have been cultured for over 3,000 years in the Orient, 600 years in Europe, and 100 years in the United States. The numbers or poundage produced for food is quite small (1989 Texas farm-gate value less than $10,000), but a market does exist in areas with certain ethnic populations. The fish are in demand as bait, primarily for trotlines, in many areas. Certain varieties are cultured for ornamentals in aquariums and garden pools.

The common carp is easy to spawn in captivity, very hardy and will eat most plant and animal matter. Because of this fact, they are widely cultured throughout the world and are generally considered to be the species with the greatest tonnage sold each year on the world markets. Though this international market exists, there has been little interest in developing it in Texas.

FRESHWATER SHRIMP

Although several species of freshwater shrimp (also called prawns) are native to Texas, problems with canabalism and small size have caused culturists to select the Malaysian prawn (*Macrobrachium rosenbergii*). Culture of these animals has been promoted because of the desire by many Americans for a large tasty shellfish similar to the lobster or salt water shrimp. Production in Texas is limited by optimum temperature requirements of 80-85 degrees and a minimum of 60 degrees.

Prawn farmers generally buy their seed stock from a commercial hatchery. Most of these hatcheries are located in tropical climates (Hawaii, Puerto Rico, Guadelupe), but there is at least one hatchery currently operating in Texas. Though this is a freshwater species it requires brackish water for the first 3-6 weeks of its life.

Prawns have a relatively long larval development (25-45 days) as compared with saltwater shrimp larvae (20 days). Newly hatched brine shrimp are the staple diet used in the hatchery, however, thisi is frequently supplemented with cheaper sources of animal protein such as minced fish, egg curd, etc. Gradually, the larvae are shifted to prepared feed sources.

Postlarvae or head-started juveniles are usually stocked into fertilized freshwater ponds. Culture methods vary from low-density (1000 - 5000/acre) polyculture with catfish to moderate-density (20,000 - 30,000/acre) monoculture. Commercially available feed is added to the pond as the shrimp get larger when high stocking rates are used. The growing period from postlarvae to harvest varies from 120-150 days. Because these shrimp have widely varying growth rates, initial grading or selective harvesting is recommended. The largest males are usually harvested first. This serves two purposes: 1) the larger animals command the best price and 2) this removes the more aggressive and canabalistic individuals.

Marketing and product handling have been major constraints on this animal. To capture the best prices and avoid competition with saltwater shrimp, producers usually attempt to grow prawns to a large size and market them head-on as a distinct, high-value product. Undersized *Macrobrachium* may be sold as ornamental shellfish for aquariums.

At this time the farm gate value of this species in Texas is estimated to be less than $25,000 annually.

FROGS

Though frog legs are on the menus of many restaurants, procedures for economically viable production in captive situations have not yet been proven. Eleven producers in the state indicate that they have bullfrogs (*Rana catesbeiana*) or tadpoles available for stocking, but these are all as sidelines to a viable fish production facility. The farm-gate value of this species is assumed to be negligible in Texas. At the same time, it is reported that the demand for frog legs far exceeds the supply and that there continues to be a demand for frogs for biological research.

General procedures for frog production start with collection of the egg masses from brood ponds. The eggs are usually hatched in troughs under closely monitored environmental conditions inside a building. After hatching the tadpoles are fed in these same troughs until they metamorphose and then they are moved to pens or troughs with a small amount of standing water. At this stage, they are fed living foods such as small minnows. Flies and worms are also used after frogs are trained to accept them. Food size and quantities must be increased often and grading of the frogs is essential as they tend to be highly cannibalistic.

Probably the greatest requirement for frog culture is an effective sanitation program. Bacterial diseases are the biggest problem and must be avoided or controlled. Temperatures need to be between 68 and 80 degrees F at all times for best growth. Under optimum conditions a saleable frog can be produced from an egg in about 8 months.

Additional research needs include better methods of disease control, improved diets and improved genetic strains. Marketing surveys have indicated that more frogs could be sold, but present prices are too low to make this an attractive industry.

GOLDFISH

The market for goldfish (*Carassius auratus*) has continued to expand in recent years. The market for the ornamental varieties has remained steady, but the demand for feeder-fish (live feed for aquarium fishes) has increased steadily. At this time there are very few records available on the extent of production or sales in the state. Most of the goldfish sold are bought from out of state suppliers and then sold to retailers direct or held in growth facilities until marketed. The producers who do spawn and grow their own fish report that they cannot meet the demand, especially for the smaller sizes though they are often growing three crops per year in a single pond. Markets are usually to wholesalers, but gold fish are sold directly to retailers for trotline bait.

Brood fish are carefully selected for the desired colors and shapes. Near spawning time, goldfish are easily sexed and then placed into spawning ponds. Stocking rates for open pond spawning are from 40-80 pounds per acre. If the egg transfer methods are used, up to 1,000 pounds (2,500 fish) are often stocked. Spawning usually occurs within 24 hours after stocking when water temperatures are above 70 degrees F. Hatching occurs within 96 hours at this temperature. Finely ground feed is then offered within 48 hours. Feeding rates after the first month are adjusted to insure that fish reach saleable size at the desired time for marketing.

The 1989 farm-gate value of goldfish (excluding those used as bait) is estimated as $150,000. To increase production and sales of goldfish in the state, improved feeds and a better understanding of the selection criteria for brood stock to secure better egg production and improved animal health measures are needed. In selected areas a more complete understanding of the effects of water quality on growth rates and handling qualities is also needed.

ORNAMENTAL FISHES

The demand for ornamental fishes continues to grow throughout the United States. Production of these fish in Texas is rather limited but has expanded in each of the last five years. Exact figures are not available on the actual extent of locally pro- duced fish because many of the species are cultured primarily inside buildings in tanks and aquariums. Pond production is limited to the warmer months of the year because most of the species in demand are natives of tropical or subtropical regions. It is expected that Texas production will continue to increase because of unpredictable wild stock supplies and increasingly complex import restrictions.

Most of the ornamental fish produced in the state are freshwater species. Production of marine ornamental fishes is difficult and there is a general lack of knowledge of culture techniques. There is considerable potential for development in this area. Nonetheless the wholesale and retail arms of the ornamental fish industry have continued to grow utilizing fish caught in the wild in Asia, South America and Africa. Again the extent of these portions of the industry are poorly documented but it has been reported that the retail sales in the aquarium industry in Texas exceeded $4 billion in 1988. Of this approximately 10 percent was for livestock and the remainder for aquariums, feed and supplies. Assuming that 25% of the retail sales value represents the wholesale value, then the wholesale value of hte ornamental fish business in Texas during 1988 was about $1.5 billion. Verification of these figures is not possible at this time but studies to document the extent of the industry should be initiated.

Ornamental fish producers in Texas grow a wide variety of species with a variety of life cycles, nutritional and environmental requirements. Some fish are egg-layers and others are live bearers. Some are nest builders and others do not tend their young at all. Some eat only fish, others eat plankton and others readily eat prepared diets. Because all of these fish are sold live, delivery to markets of a high quality fish in good health is mandatory. This requirement needs further testing and research effort. Plastic bags are the most common shipping container. These are placed in styrofoam containers and then into cardboard boxes. Recently airlines have become increasingly reluctant to accept such containers and new methods need to be developed.

There is no standard price for ornamental fish. Bulk shipments of commoner varieties may be sold at the producer level for 25 cents each, while rarer species may be priced at $25 or more for single animals. Much of the price differential is directly dependent on the brilliance of the colors of the fish. Color is to some extent dependent on the nutrients available to the fish. Therefore producers need more and better information on the nutrient re- quirements of all of the species of fish that they culture.

Other problems that plague producers of aquarium fish include predation, environmental requirements for spawning and growth and handling requirements for broodstock and eggs. Predation by birds is a major concern and regulations generally prohibit destruction of fish-eating birds even though relief from losses is available to more traditional agricultural crops. Fish produced indoors are not susceptible to this problem, but adjustment of the production system to the desired environmental requirements is costly.

Major constraints on the ornamental fish industry in the state include the following:

1. It is necessary to change the belief that only fish actually produced in the state contribute to aquaculture. In fact, the wholesale/retail part of the industry is the largest segment of the industry in Texas.

2. Regulations governing ornamental fish production need clarification and consistency. It is questionable whether to start a production installation without some assurance that regulations will not be a detriment in the immediate future.

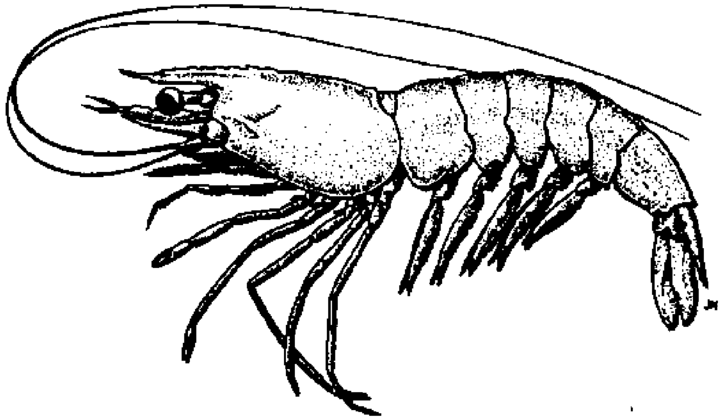
3. Research on nutritional requirements is of immediate concern.

4. Marketing and promotion needs are varied depending on the fish being produced. Collection of reliable data in this area is essential for this industry to grow.

5. Methods for adapting the technology being used in other fields of aquaculture should be delineated.

MISCELLANEOUS SPECIES

Another potential aquaculture species for Texas is the American eel which is being produced in at least five other states. Sturgeon and paddlefish may also have potential as either food fish or stock enhancement species.



PENAEID SHRIMP

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HISTORY

Shrimp farming began in Texas with the research of Harry Cook and coworkers at the National Marine Fisheries Service (NMFS) Laboratory in Galveston in the early 1960's. Through their efforts, laboratory-scale spawning and larval rearing techniques were developed for a variety of indigenous penaeids, including the white, brown, and pink shrimp (*Penaeus setiferus*, *P. aztecus*, and *P. duorarum*, respectively).

This success in larval rearing stimulated a number of grow- out trials in ponds during the late 1960's and 1970's). The Dow Chemical Company attempted to commercially produce shrimp near Freeport, but that effort proved to be premature. One of the most significant findings of grow- out trials was that two non-indigenous species, *P. vannamei* and *P. stylirostris*, yielded higher production than native species. In order to utilize non-indigenous species, it became necessary to control reproduction in captivity.

During the late 1970's and early 1980's, methods for inducing reproduction of penaeids were implemented by researchers at the NMFS Laboratory and at Texas A&M University. Soon afterwards, commercial development efforts began.

Laguna Madre Shrimp Farms began constructing hatchery and pond facilities in 1981. A brackish water impoundment near Anahuac was stocked in 1984 and 1985. Several 30-70 acre intensive pond systems were built during the period from 1985 to present. In addition, two semi-intensive pond systems of 120 and 230 acres were developed by King Ranch and Mariquest respectively. Most Texas shrimp farms are located on the coast, but several small-scale, intensive farms have developed in West Texas using saline ground water.

CURRENT STATUS

Principal Species

Virtually all penaeid shrimp currently farmed in Texas are *P. vannamei*, a Pacific white shrimp native to the region between northern Peru and southern Mexico. There is interest in testing the performance of other species such as *P. monodon* because of its large size and fast growth and *P. chinensis* because of its cold tolerance and potential as a second crop. In addition, the indigenous white, brown, and pink shrimp may receive new consideration as researchers begin to question whether early disqualification of those species remains justified considering nutrition and management advancements that have been made.

Typical Production Methods

Hatchery

The hatchery process begins by either collecting brood stock from their natural spawning grounds or raising juveniles to adulthood in ponds. Adult shrimp are induced to mature indoors by simulating natural offshore conditions through control of temperature, salinity, lighting, and nutrition. Eyestalk ablation is often used to stimulate maturation.

Individual females generally release 200,000-300,000 eggs/spawn. Fertilization occurs externally as the eggs discharge past the spermataphore attached to the ventral side of the female by the male.

Eggs hatch about 12-15 hours after spawning. Hatching rates generally average about 50%. The first larval stage, nauplius, subsists on yolk and requires about 36 hours to pass through 5-6 substages and metamorphose to the protozoea stage. At this point, the larvae filter feed on unicellular phytoplankton, particularly diatoms. After 3 substages, protozoea transform to mysis and become more predatory and are generally fed newly hatched brine shrimp (*Artemia*) nauplii. After 3 substages, mysis transform to postlarvae (PL's) which resemble miniature adult shrimp and are gradually weaned off live foods onto prepared dried diets.

Postlarvae are generally held in the hatchery 5-8 days beyond postlarval metamorphosis before transferring them to ponds for grow-out. The entire hatchery duration from egg to $PL_{5\text{-}8}$ is about 3 weeks. The above feeding regime is modified in some cases to include microparticulate or microencapsulated diets as supplements and partial replacements of algae and Artemia nauplii.

Growout

Management procedures for grow-out vary according to the stocking density utilized. Extensive management utilizes low density (,000/acre) fertilization but little or no feeding, and minimal water quality control. Yields from extensively managed ponds or impoundments generally range from 50 to 500 pounds/acre.

Semi intensive management utilizes moderate stocking densities (40,000-60,000/acre), fertilization, feeding, and water quality control through daily water exchange. Yields from intensively managed ponds generally range from 500 to 1500 pounds per acre.

Intensive management utilizes high stocking densities (100,000-200,000/acre), high quality feeds, aeration, and water exchange. Yields from intensively managed ponds generally range from 2500 to 4000 pounds per acre.

Closed system, indoor facilities are also being tried on a pilot scale. These systems plan to use environmental control to produce a fresh, high value crop year round. Target yields are projected to be about 1 pound per square foot.

Status of Industry

Hatcheries

Currently, demand for postlarvae in Texas exceeds the capacity of the single Texas hatchery. The Laguna Madre Shrimp Farms hatchery has a production capacity of about 25 million postlarvae/month, but demand during the 2.5 month spring stocking period is about 90 million PL's. However, plans have been announced by Lone Star Aquaculture for construction of a small (3-4 million PL's/month) hatchery on Matagorda Bay. Also, several farms are considering the possibility of developing a coop hatchery.

Grow-out

The Texas shrimp farming industry is centered along the Gulf coast between Brownsville and Freeport. A few small farms have also developed in the Trans Pecos area of West Texas. Of the 1100 acres which have been utilized for shrimp production at some time during the 1980's, only about 478 acres (10 farms) are expected to be in production during 1990. Most of the producing acreage is under intensive pond management. Unutilized acreage is largely attributed to extensive impoundments or semi-intensive ponds that are being modified for intensive management.

Average pond yields are about 2500 pounds/acre with one crop per year.

Product Form and Markets

Marketing methods tend to vary with the size of the farm. Small farms often utilize pond bank and direct retail sales. Intermediate sized farms generally sell directly to processors. Large farms arrange to have their shrimp processed on contract and then market their own product.

Market price varies widely, depending upon the product size, product form (e.g., head-on fresh versus frozen tails), and market level (e.g., wholesale versus retail). Prices received for unprocessed, head-on shrimp at the farm generally range between $2.00 and $3.00 per pound. Of course, retail sales can be substantially higher, but this presently represents a small portion of total sales.

Associated Infrastructure

Several large shrimp processing plants which have traditionally processed wild-caught shrimp have accepted farm- raised shrimp for processing. This has not been a perfect adjustment because farm-raised shrimp, unlike wild catch, are not headless when they arrive at the processing plant. Special arrangements must be made to have shrimp deheaded or markets developed for head-on shrimp.

CURRENT AND PROJECTED VALUE

Based on the estimated 1990 production area of 478 acres, the estimated yield of 2500 pounds per acre, and an average farm-gate value of $2.50/pound, the shrimp farming industry in Texas is expected to have a 1990 farm-gate value of about $3 million.

If current development plans are successfully implemented, the Texas shrimp farming industry is expected to steadily grow both in acreage and in yield over the next five years. Acreage will probably double and average yield increase to 3,000 pounds per acre, causing industry farm-gate value to reach $5-6 million.

IMPEDIMENTS

South Carolina has less coastal area suitable for shrimp farming than Texas, and temperatures there are less favorable for the raising of tropical shrimp. Yet, even though the shrimp industry in South Carolina got started later than the industry in Texas, it is growing at a faster rate. At a recent meeting, commercial producers indicated concern about seven major issues impeding development. In a subsequent mail survey to shrimp farming producers and researchers the seven issues were ranked (Table 1).

Table 1. Ranking of issues facing the Texas shrimp farming industry (in order of decreasing importance) according to a survey (n = 11) during October 1989.

Rank	Mean Score	Issue
1	6.3	Regulations
2	5.2	Postlarval shortage
3	4.5	Technology gaps
4	3.4	Industry unity
5	3.3	Marketing
6	3.1	Feed cost
7	2.0	Critical mass

Regulations

Several regulatory issues are of concern to shrimp farmers:

Shrimp Baculovirus

Two commercial shrimp ponds near Collegeport, Texas, were recently shutdown by Texas Parks and Wildlife Department (TP&WD) for the entire growing season and mandated to be disinfected due to detection of *Baculovirus penaei* in a sample of *P.vannamei* postlarvae. This virus is widely distributed in penaeid shrimp worldwide, and it is known to be indigenous to native shrimp in the Gulf of Mexico. However, since it was imported in an exotic species, it was considered a potential threat. In South Carolina, where this virus was also identified in imported shrimp, there was no regulatory action was judged necessary.

Intake Water Screening

Recommendations are currently placed on applications for Army Corps of Engineers section 10 or section 404 permits for water pumping stations to require fine-mesh screening systems to reduce possible mortality of planktonic estuarine organisms, including eggs and larvae. These recommendations require that water be prescreened through a mesh of 0.5 mm to prevent entrainment of eggs and larvae. Such regulations are unprecedented in other states and among other major Texas water users such as coastal power plants.

Compliance with this regulation is difficult and expensive from an engineering point of view, because fine mesh screens tend to clog very quickly in turbid estuarine water. Fortunately, the regulatory agencies are cooperating with a private producer to test a relatively inexpensive, after-the-pump, self-cleaning screen which is designed to return small organisms to the bay with minimal damage.

Exotic Species Regulations

According to a new TP&W ruling, a cultured exotic species can be placed on the prohibited list without allowance for public comment if that species is found in state waters. This makes the entire industry liable for a single incident. There is concern among farmers and potential investors that new regulations such as this can be enacted which cannot be dealt with economically by ventures which have already invested substantial amounts of money.

Bivalve Inspection

Several shrimp farms have expressed an interest in polyculture of shellfish such as clams or oysters with shrimp to reduce algal densities in ponds and provide a secondary source of revenue. According to current regulations of the Texas Department of Health, private waters of the state of Texas are not approved for shellfish culture, because they haven't been sampled to evaluate water quality. However, due to budgetary constraints, the Health Department is unable to implement a program to allow sampling of private waters. Also current statutes prevent private laboratories from being certified to provide appropriate testing. Thus, current regulations effectively prevent polyculture of shrimp and oysters in Texas.

Post Larval Shortage

The shrimp farming industry needs a reliable, source of high quality, reasonably-priced post larvae for pond stocking. During 1989, shrimp farms in Texas and South Carolina suffered economic hardship due to lack of sufficient postlarvae. Many of the farms either were not stocked at full capacity or were stocked late. This situation arose, because most farms had relied on a single hatchery in Central America, but that hatchery experienced disease problems and was unable to meet demands. Another problem is that large variations in quality and health of postlarvae occur among hatcheries.

Research

There is concern among commercial shrimp farmers that publicly funded research may not reflect the needs of the industry. Research is not always well coordinated with the commercial sector to prioritize objectives and with research interests in other states to avoid duplication. Furthermore, the results of research trials often are not made available to the industry as quickly as possible.

Marketing

The U. S. currently imports approximately 75% of the total shrimp consumed. To be competitive, the Texas shrimp farmer must maintain a technological edge in production efficiency and be able to sell to high value portions of the shrimp market. It is critical that "Texas raised" be distinct from the large volumes of low-priced imports.

Feed Cost

The most expensive part of any shrimp farming operation is feed. The availability of quality feed is essential to a successful operation. At this time there is no source of high quality shrimp feed in Texas. Most Texas shrimp farmers presently rely on a feed mill in Idaho for high quality shrimp feeds. The shipping cost associated with that distance adds about 10% to the cost of feeds. This also bypasses Texas feed mills for the job and income related to shrimp feed production.
Industry Organization

We need an effective means of communicating problems and solutions between farms, government and research institutions. Industry Size

Several of the problems listed above would be much easier to solve if the overall size of the shrimp farming industry in Texas were larger. It is difficult to get feed mills, processors or marketers interested in spending money on program development unless they perceive a reasonable return on their investment. Better operating techniques will be developed sooner if more farms are operating.

RECOMMENDED ACTION

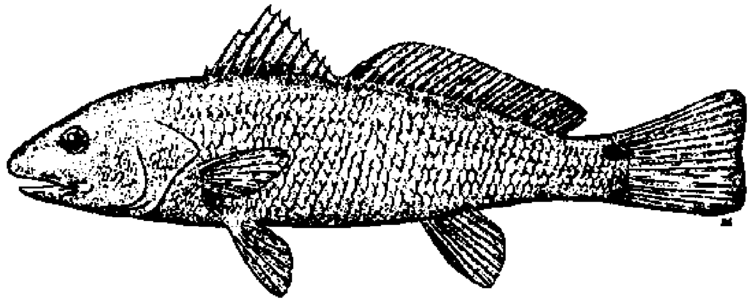
- A forum is needed where problems regarding proposed regulations or the execution or interpretation of an existing regulation can be discussed. Hopefully, this will be provided through the newly created position of Aquaculture Liaison Officer.
- Shrimp farming should be given the full status of an agricultural operation in Texas. This would make available federal crop insurance, eligibility for disaster relief and loan assistance.
- To ensure a reliable, high-quality, and reasonably priced source of postlarvae, several hatcheries should be located within Texas. Thus, technical problems in any one hatchery would not result in lack of supply. These problems are already moving toward solution. Texas shrimp farmers met in September 1989 and estimated their postlarval requirement would be about 66

million during 1990. Most of the required post larvae will probably be supplied by one hatchery, Laguna Madre Shrimp Farms. Granada Corporation also intends to begin operation of a commercial hatchery in College Station.

- Commercial enterprises should be involved in setting research goals and priorities. The state's aquaculture research should be directed toward the development and promotion of a commercial aquaculture industry. Basic research goals should be set jointly with input from commercial interests. Execution of the research should be carried out by the research institutions. Results would be reviewed with commercial enterprises. Applied research objectives, execution and results analysis should be done jointly. To avoid duplication of effort, continue to coordinate shrimp farming research through the five-state research consortium.
- The Texas shrimp farming industry should seek a marketing edge for its product by stressing product quality and promoting "Texas raised" status.
- If the industry is to develop, quality feeds will have to be manufactured locally. Several Texas mills are currently trying to develop a quality feed. This effort should be supported through research assistance in developing and evaluating feed formulations.
- Profitability can be increased through appropriate technology. Examples of areas that deserve attention include: head starting techniques, feeding methods, aeration and circulation methods, bivalve polyculture possibilities, and potential winter crop species. In order to address these topics, a suitable public-sector salt-water pond facility should be developed in Texas for the purpose of implementing practical pond production trials.
- Shrimp farmers are in the process of organizing in a loose association. An Industrial Advisory Committee is being formed to communicate between commercial interests and various research institutions. Hopefully the Aquaculture Liaison Officer can provide some overall coordination as well as interaction with the Aquaculture Executive Committee.

SUMMARY

There are approximately 10 shrimp farming enterprises currently operating in Texas. The short-term expansion of this industry in Texas will depend to a large extent on the success or failure of these companies. Very few if any of these operations can afford to wait years to attain profitability. Therefore emphasis should be placed on those areas which can be expected to aid the current investments as quickly as possible. This means granting full agricultural status, concentrating on applied research which can be tested now in a commercial environment and work with the commercial interests in the regulatory areas to minimize the risk of an economic disaster for the farmer while maintaining a rational protection of the environment.



RED DRUM

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INTRODUCTION

Interest in commercial red drum (*Sciaenops ocellatus*) culture emerged only about 10 years ago, primarily as a result of changes in the market value of this species. Historically, red drum have been considered a popular recreational species with commercial sales occurring primarily in the Gulf and South Atlantic states. Its relatively low U.S. commercial demand (3-4 million pounds per year) was met by the traditional inshore gill net fishery concentrated in Texas and Louisiana. However, when cajun chef Paul Prudhomme introduced his blackened redfish recipe in 1981, the national demand for red drum dramatically increased.

Conflicts between recreational and commercial fishing interests had resulted in bans on commercial fishing for red drum in several states including Texas. consequently, the traditional inshore gill net fishery was unable to supply the increasing market demand. As red drum supplies tightened and prices rose, the formerly undesireable adult ("bull") red drum were targeted to fill the market gap. Efficient offshore purse seining vessels began locating offshore schools by spotter plane and capturing large of the 20-40 pound fish. This strong fishing pressure on red drum broodstock alarmed fishery workers and conservationists and ultimately resulted in a ban on purse seining of red drum in federal waters of the Gulf of Mexico in 1986. Most of the noncommitted Gulf states also banned commercial fishing of red drum in state waters during this period. By the late 1980's, nearly all avenues for commercial fishing of red drum in the United States were closed. Legislation passed by the 1989 Texas legislature culminates this process by prohibiting sale of red drum in Texas unless they are farm raised.

Commercial interest in red drum aquaculture began during the early 1980's as demand and price were rapily rising.

TECHNOLOGY DEVELOPMENT

Although researchers first reported growing captive red drum in ponds over 30 years ago, red drum aquaculture did not significantly advance until 1975 when Connie Arnold (at that time with the National Marine Fisheries Service Laboratory in Port Aransas, Texas) succeeded in spawning them using temperature and photoperiod control.

Control of Reproduction

The temperature/photoperiod method of spawning involves holding red drum adults in indoor tanks for several months while simulating the passage of seasons through programmed changes in water temperature and photperiod (hours of light each day). When such conditioned red drum arrive at the simulated Fall season (temperature of 24-26 C and photoperiod of 10-12 hours), they begin courtship behavior, mating, and spawning automatically - just as they do in nature. Unlike many species which are capable of only one spawn per year, red drum are capable of repeated spawning at regular intervals over extended periods of time. This prolific egg production capability of red drum is a major advantage.

Egg Collection and Hatching

Fertilized red drum eggs contain an oil globule which makes them buoyant at salinities of at least 25 ppt. This characteristic has simplified egg collection from the large broodstock tanks. Typically, a water drainpipe is positioned to draw water from the surface of the broodstock tank, thereby skimming the buoyant eggs from the large tank and transporting them to an appropriate collection area. Using this technique, the water hardened eggs automatically accumulate in the collection basket during the night following spawning. The following morning,the eggs are removed with a soft net, and transferred into a graduated cylinder where the floating egg mass is enumerated (1 ml of displacement = 1,000 eggs). The eggs are then placed in a tank of gently aerating water until hatching (about 24-30 hours after fertilization) and larval development. When the larval yolk sac is absorbed and mouth parts develop, they are capable of feeding (approx. 3 days after hatching).

Fingerling Production

Two methods were developed during the late 1970's for rearing the sensitive first-feeding larvae to fingerling size. The laboratory method, first developed by Connie Arnold, involves rearing larvae indoors and feeding them live rotifers (which are in turn sustained by live algae cultures) and brine shrimp. This method requires considerable equipment and expertise for maintenance of cultures. Survival rates are often poor, but this is an excellent method of producing small quantities of fingerlings on demand year-round.

The fertilized pond method was developed by Bob Colura at the Texas Parks and Wildlife Department Marine Fisheries Research facility near Palacios. This method, which is similar to one which earlier had proven successful for production of striped bass fingerlings, involves release of first-feeding larvae into fertilized ponds. It is critical that the ponds be properly prepared in advance to develop a rich complement of the appropriate-sized plankton. The fertilized-pond method has proven to be relatively consistent and amenable to mass culture applications. It was adopted for the red drum population enhancement program (10 million fingerlings/year) sponsored by the Texas Parks and Wildlife Department and the Gulf Coast Conservation Association. This joint program is designed to increase depleted coastal populations of red drum by producing and releasing fingerlings into various Texas estuaries.

As a result of the above research and mass production efforts, technology for spawning, hatching, and larval rearing of red drum was well developed by the early 1980's, when commercial interest began. However, at that time, little was known about techniques of raising red drum from fingerling size (enhancement program typically released fish 1-2 inches long) to marketable size (2-4 pounds).

COMMERCIAL DEVELOPMENT

During the initial stages of commercial development in the early 1980's, industry growth was stymied by lack of a consistent supply of fingerlings for grow-out trials (fingerlings produced for stock enhancement were unavailable for commercial use). Fortunately, the existing research and stock-enhancement facilities provided models for industry development of commercial hatcheries. Several hatcheries were built in Texas to satisfy projected fingerling demands for anticipated commercial growout. After a relatively brief learning period, all of the hatcheries were successful to varying degrees in inducing spawning and producing fingerlings.

Initial grow-out attempts utilized a wide variety of culture systems and locations, because opinions differed about appropriate methods of rearing fingerlings to market size. Small scale grow-out trials were conducted at pre-existing coastal pond systems ranging from Beaumont to Port Isabel, and at inland sites utilizing both fresh and brackish ground water. A number of production trials experienced nearly complete loss of stocks in outdoor ponds in a severe freeze during the winter of 1983-1984. Experimental trials in South Carolina during the mid 1980's apparently were spared exposure to those severe winter temperatures. Intermittent winter mortality has continued to plague Texas pond grow-out efforts,

Some trials have been successful at producing and marketing one and two-year-old fish. These attempts demonstrated that red drum were capable of reaching 1-2 pounds in 1 year and 3-4 pounds in 2 years. Yields in South Carolina reached as high as 20,000 pounds per acre in small intensively managed ponds.

Laboratory research during the 1980's has substantially advanced our knowledge about red drum culture. Continuing nutrition studies at Texas A&M University are resulting in feed formulations tailored to the protein, lipid, mineral, and salt requirements of red drum. Physiological studies have contributed information about the tolerance of red drum to combinations of salinity, water hardness, and temperature.

Interest in red drum culture was high by 1987 when the Texas Agricultural Extension Service and the University of Texas marine Science Institute offerred a 3-day educational conference on red drum aquaculture. Over 300 participants attended.

STATUS OF THE INDUSTRY

Hatchery

Four red drum hatchery facilities presently exist in Texas. These are estimated to have a total production capacity of approximately five million eggs and three million fingerlings per year. However, at this time, only one red drum hatchery is producing significant quantities of fingerlings for outside sales. Current selling price for 2-4 inch fingerlings is $0.25 each.

Growout Ponds

A total of 154 acres of ponds have been used for red drum grow-out in Texas. However, only 48 acres are currently in use. Pond production trials have utilized various facilities along the entire length of the Texas coast and as far inland as West Texas. Production methods vary from extensive to semi-intensive. At least one extensive pond is being used for fee fishing. Targeted semi-intensive production rates are 4000 - 9000 lbs/acre with one crop per year. The primary problem facing red drum producers continues to be low temperature mortality. Some producers have reported that loses due to cormorant predation also can be severe during the winter. A variety of approaches have been used to maintain red drum through the winter. These include:

- transferring fish from outdoor ponds to indoor facilities during the winter. This arrangement is most feasible for overwintering/headstarting small fingerlings that require a minimum water volume.
- using a continual flow of well water or heated ambient water to maintain a warm zone within the pond during the winter. This method has been utilized by many producers with mixed results.
- using greenhouse covered pond. This is a relatively expensive but effective approach.

Of these approaches, only the greenhouse and indoor methods were successful during the record-breaking freeze of December, 1989.

Indoor Systems

In order to avoid the danger of winter mortality and to sustain rapid growth rates year-round, several producers are attempting to raise red drum in indoor tanks equipped with recirculating water systems. At present, the industry is operating eight 10,000-30,000 gallon raceways and several smaller recirculating systems (500-4200 gallons) for fingerling production and growout. The primary problem with indoor systems has been their relatively high capital and operating costs. Given the present high market value of red drum, intensive systems may have the luxury of improving their efficiency over time before prices fall to lower levels.

Processing and Marketing

No processing plants have been constructed specifically for red drum in Texas. The relatively small quantities of fish that are presently produced are generally processed by hand and sold to restaurants and wholesalers. Market forms include whole, gilled and gutted, and filleted. Most fish are marketed fresh rather than frozen. Current prices for whole fish range from $1.75 to $3.00 per pound.

Value of Texas Industry

The annual farm-gate value for Texas red drum production was estimated at $250,000 during fall, 1989. However, it is unlikely that this estimate will apply to 1990 production, because heavy losses were sustained as a result of the record cold temperatures which occurred during December, 1989.

IMPEDIMENTS

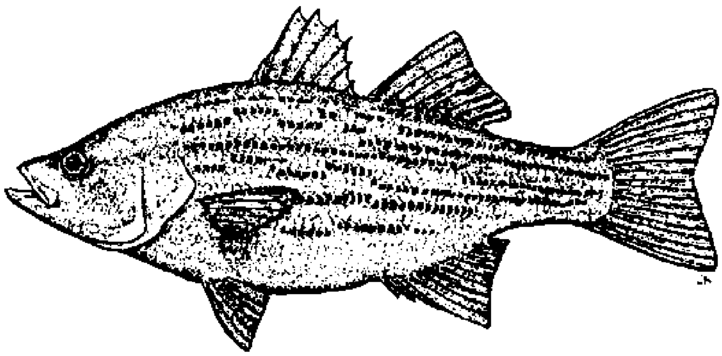
Low temperature mortality has been and continues to be the primary impediment limiting development of red drum aquaculture in Texas. An engineering and cost analysis of various alternatives for maintaining minimum safe temperatures in ponds is badly needed by the industry.

Another problem identified by red drum producers is disease control. The parasite *Amyloodinium ocellatum* is difficult to control with conventional FDA-approved treatments. Research is needed to screen alternative treatment chemicals or methods.

Information is needed concerning the relationship between water quality changes in intensive culture systems and the susceptibility of red drum to disease.

Other issues of concern to red drum producers include:

- need for cooperative feed purchasing to reduce transportation costs
- need for cooperative processing and marketing to reduce costs and provide a more consistent supply
- need for sources of financing
- need for depredation permits to reduce losses due to cormorant predation during the winter
- need for more competitively priced fingerlings (producers felt that fingerling prices would decline as the industry grows and evolves)



HYBRID STRIPED BASS

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The potential for farming striped bass and their hybrids as recreational and foodfish appears very promising. Wild-harvested striped bass landings from the east-coast fishery declined from a peak level of over 14 million pounds in 1973 to less than 1 million pounds in 1988. Most east coast states have instituted strong restrictions on wild harvests. Prices have risen, making striped bass and their hybrids attractive candidates for aquaculture.

Hybrid striped bass generally refers to a cross between striped bass (*Morone saxatilis*) and white bass (*M. chrysops*). Hybrids of these two species exhibit better characteristics for aquaculture than either parental species. The first hybrid cross, sometimes called the "original cross" was produced in South Carolina in the mid-1960s using eggs from striped bass and sperm from white bass. A "reciprocal" cross using white bass females and striped bass males has also been produced.

The original range of striped bass was on the Atlantic Coast from New Brunswick Nova Scotia through the Gulf Coast to Mexico. It was introduced on the west coast in the late 1800's. Populations became established and presently occur from British Columbia to Mexico. Landlocked populations have become established in many reservoirs throughout the United States. Where no natural reproduction occurs, they are maintained through regular stocking programs.

White bass originally occurred throughout most of the Mississippi basin and along the Gulf Coast. They have been introduced widely in recent times for recreational fishing, especially in large reservoirs.

CHARACTERISTICS OF HYBRIDS

Hybrid striped bass are intermediate in appearance to the parental species. The body is slightly compressed in cross-section. Lateral stripes similar to those of the striped bass are present, but the strips are generally broken in the area behind the pectoral fin and below the lateral line.

Water Quality Requirements

Hybrid striped bass thrive in a variety of water types. They do well in slow moving streams, large reservoirs, lakes and ponds. Because they are pelagic in nature, they are generally found in open water areas. They are most active around dawn during periods of low light. In late winter, they usually congregate in deeper waters near inflowing streams. In spring, they may make upstream spawning runs, and successful reproduction in a few reservoirs has been reported.

Hybrids thrive under a wide range of environmental conditions. Optimum growth occurs in the temperature range of 25-30° C and in the dissolved oxygen range of 6-12 mg/l.

Salinities of 0 to 25 ppt are acceptable; hardness and alkalinity values greater than 100 mg/l are suitable, and a pH range of 7.0 - 8.5 is optimum.

Feeding Habits

Hybrid striped bass are voracious feeders. Fish less than 50 mm in length feed primarily on crustacean zooplankton such as cladocerans and copepods. Insects of various types and zooplankton continue to be a major part of the diet until the fish are 100-125 mm long. Hybrids may be switched to prepared diets at a very small size. However, this transition usually occurs when the hybrids are larger than 100 mm.

Growth Rates

Hybrids grow rapidly during their first two years of life. Growth to 275-375 mm in length and 225-350 grams in the first year and 450-550 mm in length and 1-1.5 kg in the second year is common. Growth rate declines rapidly with increasing age. Maximum reported weight for a hybrid striped bass is approximately 20 pounds and the typical size caught by fishermen is from 2-5 lbs. Individuals weighing from 10 to 15 pounds are not uncommon. The life span of hybrids is around 5-6 years, which more resembles the lifespan of white bass than the 30 to 40 years that striped bass may attain. Growth rates of hybrids in production ponds are influenced by several factors: Water temperature, water quality, quantity of food, palatability of food, frequency of feeding.

Reproduction

Hybrid striped bass, unlike most hybrids, are generally fertile. Like the parental species, they produce eggs and sperm in the spring when temperatures are 15 to 20° C. Some males mature at the age of one year and all are mature at two years of age. Some females mature at 2 years of age, and all are mature by 3 years of age. Females produce an average of 160,000 eggs per pound of body weight and spawn once a year. Males on the other hand are usually multiple spawners.

Natural spawning of hybrids has been verified in a few instances. They may participate in spawning runs with striped bass or white bass. Therey are also confirmed cases of reproduction in reservoirs that contain only hybrid striped bass. Hybrid striped bass produce sperm and eggs during the spring when water temperature is between 55 to 70° F. Temperatures of 65 to 68° are, as with the parent species, suitable for spawning hybrids. Spawning usually lasts 4 to 5 weeks depending on location.

Since domesticated stock have been developed only on a research basis, the only source of broodstock at present are those collected from the wild. Striped bass spawning runs occur from late March to late May, depending on location. The spawning grounds for striped bass are usually found near deep, swift and turbulent sections of rivers, well upstream from lakes, reservoirs and estuaries. Males begin their spawning run one to three weeks before the females.

White bass spawning migrations are made from lakes and reservoirs to inflowing streams. They generally spawn in rocky areas where water flow is turbulent. Their peak spawning season usually occurs from late March to late May depending on location. Male white bass usually arrive at the spawning grounds before the females. There is usually more than one period of activity for a given population and these occur when water temperatures are 18-19° C.

TYPICAL PRODUCTION METHODS

Broodstock Collection

Methods of collecting broodstock vary depending upon the species. The most commonly used methods for collecting striped bass and white bass are hook and line, various types of nets,3 and electrofishing. Hook and line collections work well for white bass males and females. They are relatively small fish and easy to catch as they make their spring migration toward their spawning grounds. Hook and line is a suitable means of capture since relatively few fish are needed and stress of capture is less likely to affect their ability to produce viable gametes. This method is also effective for collecting striped bass males. It is least desirable however, for striped bass females as they are larger fish and must be played to near exhaustion during the capture process. This results in a high mortality rate. Those that do survive are often difficult to ovulate. However, hook and line collections is frequently the only means of collection available to private culturists since other more effective methods are prohibited to them by law.

Electrofishing is the most efficient and least stressful method for collecting white bass and striped bass broodstock. This method is seldom used because it is generally impossible for private culturists to obtain electrofishing permits.

Broodstock should be handled carefully and stress should be kept to a minimum, especially in the case of striped bass females. Frequent handling of broodstock or unnecessary roughness increases mortality due to stress and may inhibit ovulation. Fish are transported in saline water (0.3-1.0% NaCl or reconstituted sea water). Typically, quinaldine (2.0 mg/l) or MS-222 (21 mg/l) is used to sedate the fish. Ice may be added to reduce water temperature.

Hormone Injections

Human chorionic gonadotrophin (HCG) hormone is used to induce final maturation and ovulation and sperm production in striped bass and white bass. The hormone is injected intramuscularly below the dorsal fin. Injection of striped bass is made soon after capture to improve chances of successful spawning. Egg samples are taken 20-28 hours after injection with a small glass or plastic catheter. The tube is inserted through the urogenital opening into the ovary, so a small sample of eggs may be taken. The eggs are examined under a microscope to determine when ovulation will occur. Ovulation usually occurs in 25-50 hours after injection depending upon water temperature and stage of gonadal maturation.

White bass females are injected with quantities of hormone that are well over the threshold level needed to induce ovulation. Because studies have not been performed to determine the appropriate levels for white bass females culturists tend to inject excess hormone. Sexually mature female white bass, depending on water temperature, will usually ovulate within 25-50 hours after injection. Egg samples are generally not taken from white bass because the fish are small. If egg samples are taken, a 1.5 mm diameter catheter should be used and and eggs staged under a microscope in the same manner as striped bass.

Ovulation in striped bass and white bass females is verified by applying slight pressure to the abdomen of the fish. Freely flowing eggs indicate that at least partial ovulation has occurred. There is considerable "art" to determining when complete ovulation has occurred, particularly in striped bass. And, accurate prediction of ovulation is critical to obtaining viable eggs. Eggs detach from the ovarian tissue during ovulation and the effects of anoxia begin within a short time. Ideally, eggs should be stripped immediately after ovulation, but in practice, it is difficult to determine whether the female is fully or only partially ovulated. Optimum time for stripping eggs is 15-30 minutes after the first indication of ovulation. If the eggs are not stripped within an hour after ovulation, anoxia occurs and the eggs become overripe.

To reduce stress, female and male broodstock should be anesthetized with MS-222 or quinaldine whenever they are to be handled. However, during spawning, care must be taken to prevent water containing these drugs from contacting eggs and sperm. Generally, the fish are wiped dry with a towel before they are held over the spawning container.

Spawning

Striped bass females can be spawned by using one of two methods. The tank spawning method can only be used to produce pure-line striped bass because female striped bass will not ovulate in the presence of white bass males. When this method is used, the fish spawn "naturally" in tanks. The fish are injected with hormone and placed in the tanks 12-15 hours before the female is expected to spawn. Usually two females and four males are placed in a circular tank and left undisturbed. The tanks are generally 1.2 to 2.4 m in diameter and about 1.2 m deep. Water is supplied at a rate sufficient to create a circular velocity of 10 to 15 cm per second at the perimeter. The center standpipe must be screened and a bubble curtain used to prevent loss and impingement of eggs. When males have participated in spawning, the water will appear milky. The broodfish are removed after spawning and the eggs are incubated in the tank. Some culturists install a device to collect the eggs after they are water-hardened. The eggs are transferred for incubation to McDonald jars.

The production of hybrid striped bass must be accomplished by manually stripping the eggs and sperm from the ripe fish into a container. Sperm from two or more white bass or striped bass males is used to ensure fertilization of the eggs.

Fertilization

Fertilization of striped bass eggs is accomplished by using either a wet or a dry method. In practice, there appears to be little difference in the percent fertilization from the two methods. Wet fertilization is accomplished by stripping the eggs from the female into a small amount of water. Sperm is added periodically as the eggs are being stripped, because sperm are motile for only 1-2 minutes, and the eggs begin to water-harden as soon as they come in contact with water. Water-hardening may prevent the sperm from entering the egg. This technique is best accomplished with 2-3 workers to efficiently remove eggs and mix in sperm at the same time. The main advantage of this method is that urine and drugs may be diluted before contact with eggs, minimizing deleterious effects.

The dry method of spawning striped bass females is accomplished by manually stripping the eggs into a dry, clean container. Care is taken to keep water from the container until after sperm has been added. Sperm from several males is mixed in thoroughly. Water is then added to mobilize sperm and fertilization is completed within two minutes.

The dry method is used when stripping eggs from white bass females. However after sperm and water are added and fertilization is complete the fertilized eggs are added to a tannic acid solution (150 mg/l) and aerated vigorously for 7-12 minutes. White bass eggs are adhesive and unless they are treated, it is difficult to incubate them successfully. The actual amount of time eggs must be kept in tannic acid depends upon the alkalinity and hardness of the water.

Incubation

The most common method of incubating striped bass and white bass eggs is in a modified McDonald hatching jar. The jar is a tube-within-a-tube designed to allow circulating water to keep the eggs in motion and air bubbles to escape without lifting the eggs out of the jar. One jar holds 100,000-200,000 eggs. Optimum flow rate is 0.1-0.3 gallons per minute but will vary according to fluctuations in egg buoyancy during the incubation period. Egg buoyancy increases with water hardening during the first two hours of incubation. Water flow must be monitored closely to avoid flushing eggs from the jar. Newly hatched fry are carried out of the jars by the water and into aquaria.

Water temperature for egg incubation should be similar to the broodstock holding tanks, ranging from 16-20° C. Aerated well water is preferred because temperature variation is minimal. The incubation period varies inversely with water temperature. At 16-18° C the incubation period is between 40 and 48 hours. Two hours after fertilization, rate of fertilization should be determined by counting the number of eggs within dividing cells. At 4 hours, an estimate of total number of eggs should be determined volumetrically by letting the eggs settle to the bottom of the jar. The number of eggs per milliliter must be determined by counting a small subsample.

Fry Hatching

A hatch rate of 50% is acceptable and 60-80% is considered good. The fry are held in aquaria (30-75 gallon capacity) or cones before they are stocked in ponds. Water exchange in these containers should be continuous. Newly-hatched hybrids have no mouth opening, an enlarged yolk sac, and a large oil globule projecting beyond the head. At 4-8 days post-hatch, the yolk sac and oil globule are assimilated, the mouthparts developed, and fry begin to feed. Fry are stocked into fertilized ponds at 2-10 days post-hatch, depending on the culturist's preference and experience. Fry that are held more than 5 days must be provided with live food such as brine shrimp nauplii or wild-caught copepod nauplii or cladocerans. Fry should be fed frequently (at least every three hours) during the early rearing period.

Fry may be transported when they are one to two days of age. Mortality at the age of 1-2 days is less than if the fry are transported at 4-5 days of age. Larvae are concentrated in the aquarium and then dipped from the aquarium into plastic bags. The bags are placed in styrofoam containers with approximately two gallons of water. All the air is expelled from the bag and oxygen is added to fill the bag. Larvae can survive well in these containers for 48 hours. Direct sunlight on the container should be avoided and water temperature maintained at 16-18° C. Ice may be added to the container to help maintain acceptable temperatures.

Fry should be transferred into fertilized ponds during periods of low sunlight, because exposure to ultraviolet light may kill them. The bags of fry should be floated in the pond for about 30 minutes to allow the temperature to equilibrate. After the bags have been opened small amounts of pond water should be added periodically for the next 10 to 20 minutes to allow the fry a chance to adjust to any differences in water quality.

Fingerling Production

Production of hybrid striped bass fingerlings is geared towards maximizing both the number and the size of fish during their first 30-45 days of life. This phase of production is done by stocking 2-10 day old fry into fertilized ponds.

Survival and production of fingerlings depends upon the culturist's ability to supply the young fish with live food of good quality and quantity. Original cross hybrid fry prefer large crustacean zooplankton, such as cladocerans and copepod nauplii, as their first food. Reciprocal cross fry must have an adequate supply of small zooplankters such as rotifers since fry from white bass eggs are smaller than fry from striped bass eggs.

Pond Preparation

Nursery ponds should be filled approximately two weeks prior to stocking fry. Ponds filled too early will develop large populations of predaceous insects that will prey upon the hybrid fry. Most hatcheries use freshwater although brackish water up to 5 mg/liter (ppt) is used in some areas. Generally, hatcheries that use brackish water or hard freshwater (more than 100 ppm Ca hardness) are more successful than those that rely on soft freshwater. The ponds should be dried and disked prior to filling to promote the breakdown of nutrients in the pond bottom. Agricultural limestone may also be applied to the bottom at this time if necessary.

Fertilization

Success in rearing hybrid striped bass depends on the presence of adequate populations of zooplankton. Nursery ponds are usually fertilized with a combination of organic and inorganic fertilizers to enhance the natural production of zooplankters. New ponds or ponds that are filled with well water may be inoculated with phytoplankton and zooplankton to foster development of the desired zooplankton populations.

Approximately two weeks before the ponds are to be stocked with fry they should be fertilized with an organic fertilizer. Organic materials such as manure and meat scraps are sometimes useful but are not generally recommended, because they can create dissolved oxygen problems and other management problems. Organic fertilizers such as cottonseed meal, bermuda hay and alfalfa pellets decay slowly and provide a more sustained production of zooplankton. These fertilizers provide essential nutrients, such as carbon, nitrogen and phosphorus, for primary production of phytoplankton and secondary production of zooplankton. Fertilizers should have a low carbon to nitrogen ratio for rapid decomposition. They should also provide an adequate amount of nitrogen and phosphorus in usable forms and be small enough to allow fast colonization by bacteria, algae and protozoans. This enables quicker decomposition and solubilization of key nutrients.

Inorganic fertilizers commonly used include ammonium nitrate (52% N) and phosphoric acid (32% P_2O_5). These fertilizers are available in liquid and granular form, but liquid forms are preferred, because they are easier to apply and work more rapidly. Inorganic fertilizers should contain nitrogen to enhance bacterial growth, which subsequently increases decomposition of the organic fertilizers. They should also contain adequate amounts of phosphorus in soluble form to allow rapid uptake by phytoplankton, and minimize sediment absorption or chelation into unusable inorganic complexes. Fertilizers should be well mixed with water and dispersed evenly over the pond surface to maximize distribution of nitrogen and phosphorus.

Application rates for fertilizers vary depending on the type and structure. Generally, organic fertilizers are initially applied 1-2 weeks before and twice weekly after stocking fish. Prior to stocking, 200-500 pounds of fertilizer per acre is applied depending upon specific pond conditions. Two weeks after stocking, fertilizer is applied at a rate of 25 pounds per acre. Inorganic fertilizers are applied three times per week before and twice weekly for three weeks after stocking. Application rates vary depending on water conditions, but are generally around 25 pounds per acre.

Stocking

Fry are generally stocked at a rate of 250,000-500,000 fry/hectare at 2-10 days of age. Food supply, dissolved oxygen and other water quality factors are especially important to fish survival. Aeration and circulation of pond water help moderate daily water quality shifts, improve dissolved oxygen levels and increase plankton production. As zooplankters are subjected to fish predation, the number of cladocerans and copepods decrease and the number of rotifers and protozoans increase.

Forty to fifty percent survival to fingerlings is common for original cross fry. Ten to twenty-five percent survival is more typical for reciproical cross fry because of difficulty in maintaining a rotifer bloom.

Survival of larval fish is affected by rapid changes in temperature, pH or hardness and insufficient dissolved oxygen levels and can be enhanced by slightly saline waters. Constant monitoring of water quality and food supply, and remedying problems quickly will help improve fish survival.

Initial Feeding

At a size of 25 mm, fish are introduced to prepared food. The transition to pelleted feed is begun when fish are around 14-21 days old. Particle size of prepared food is critical to successful transition. It should be a size that the fish is readily capable of consuming (mash or #1 crumble to start). By 28 days old, fish should be sustained on prepared feed and fed increasing amounts according to growth. Food particle size is increased as fish grow. Food should be offered daily with the frequency depending on the amount of natural zooplankton in the pond.

During this stage, survival rates are extremely variable and may range from 0-80%. The nursery period lasts from 30 to 45 days. It is necessary to train fingerlings to take prepared feeds. Training the fish to take prepared food is easier if it has been presented to them in the rearing ponds. Prepared food should contain at least 45-50% protein primarily derived from fish meal and be of a size that is readily consumed by the fish. No. 1 or 2 crumble is usually satisfactory for fingerlings at this stage. Salmon or trout feed (40-48% protein) is commonly used.

Grading

To prevent cannibalism, grading (or sorting by size), is very important at this stage. Losses of 50% or more can occur in one to two weeks if fingerlings are not frequently graded.Once trained to take pelleted food, fish are ready to be stocked into ponds.

Grow-out to Yearling

Fingerlings are generally available from producers in the southeastern U.S. from May to July depending on location. They are stocked at a rate of 8,000-12,000 fish per acre to complete their first year of growth. Two to four acre ponds are recommended for commercial production. Large ponds are more difficult to manage whereas small ponds are expensive to build. Initially fish are fed three times a day at a rate of 25-30% of body weight per day. After several weeks, feeding is reduced to twice a day, and gradually, the amount of feed is reduced to 1-3% of body weight per day by the end of the growing season. A commercial salmon or trout feed (38-50% protein) provides adequate nutrition. Protein requirements decrease as fish grow.

Hybrid striped bass survive and grow well in a wide range of water quality variables, however, maintaining good water quality is a major part of all phases of production. Temperature and dissolved oxygen levels should be monitored daily, morning and evening, and aerators used to keep dissolved oxygen levels above 4 mg/l. Maximum growth occurs around 25-27° C, although hybrids survive a temperature range of 4-32° C in culture systems. Below 15° C, feed consumption is reduced and growth slowed.

Dissolved oxygen is important in any culture operation, and especially for hybrid striped bass. Hybrids may survive dissolved oxygen levels as low as 1 mg/l for a short time, but these levels are very stressful. Dissolved oxygen levels below 4 mg/l reduce food consumption and growth, increase amount of energy needed for respiration, and increase mortality.

Ammonia, the principal excretory product of fish, should also be monitored regularly in ponds. Concentrations should not exceed 1 mg/L. Hybrid striped bass generally become more tolerant of water quality with age, however water quality management is a most important factor in successful foodfish production.

By the end of the first growing season, individual fish may weigh an average of 225 grams (0.5 lbs). Any fish from 110 grams should reach marketable size (1.24 lbs) in the second year. Survival rates of 85% are common at the end of the first growing season. Fish are harvested after the growing season ends, usually beginning in December when pond temperatures drop below 12° C and continuing through March. Handling fish at 12° C or above increases the likelihood of fungus and disease problems. The pond is seined, and the fish are herded through an opening in the seine into a holding net. The number and weight of fish is estimated by weighing several samples of a known number of fish and taking a total weight of fish. The fish should be weighed in water to reduce stress.

Grow-out to Market Size

Advanced fingerlings should be graded before they are stocked for grow-out to reduce the size variation in each pond. Feeding problems will be reduced and all the fish in one pond will reach market size at about the same time. A commonly accepted grading technique for advanced fingerlings does not exist at this time.

Fingerlings (110-225 grams) are stocked into grow-out ponds at a rate of 3,000-4,000 fish per acre depending on the experience of the culturist. With proper management, these fish will reach marketable size by October or November. Survival rates for the second growing season are generally 90% or better.

Fish are fed commercial feed at a rate of 1-3% of body weight per day. While temperatures are low and dissolved oxygen levels are high, fish can be fed at a rate of 3% of body weight per day. However, as temperatures and biomass increases, dissolved oxygen levels become more difficult to manage. The feeding rate should be around 1% of body weight per day. Food conversion ratios of 2 to 1 or less are expected.

Water quality requirements for second-year fish are similar to first-year fish. Daily monitoring is important because of the increased biomass of fish in the ponds. Low dissolved oxygen levels can become a major problem at this stage. Aeration techniques are standard procedure. Paddlewheels are the most efficient aeration method in production ponds. Typically, the aerator is off during the day and turned on at night to maintain dissolved oxygen levels above 4 mg/L. Location of the paddlewheel is important to adequate aeration in the pond.

Optimum growth occurs at 25-27° C and dissolved oxygen levels above 6 mg/l. Growth slows as dissolved oxygen levels approach 4 mg/L. Some mortality may occur at 1-2 mg/l and all fish will die if dissolved oxygen levels remain lower than 1 mg/l for very long. Disease problems are more prevalent when fish are stressed by low dissolved oxygen levels. Fish should be observed regularly for fungus, disease and any other problems and treated quickly when problems arise.

REGULATORY LIMITATIONS

According to an official interpretation of the Texas Parks and Wildlife Department (TPWD) on March 22, 1989:

"Striped bass, white bass, or their hybrids raised by a licenced fish farmer in Texas may be sold only to another licensed fish farmer or to a person for the purpose of stocking the waters of this state. None of the fish may be marketed for human consumption. Licensed fish farmers may possess any of these fish that he has raised or obtained legally in any numbers and at any size.

TPWD has no authority to issue permits to take either striped bass or white bass from Texas public waters to be used as broodfish. Licensed fish farmers may obtain broodfish from any legal source including other licensed fish farmers and legitimate out-of-state suppliers. Any of these fish shiped into this state must be accompanied by a bill of lading stating:

- number of fish
- pounds (estimated live weight)
- species
- place of origin of the fish
- name and address of receiver
- date of shipment

The receiver of these out-of-state shipments must keep the bill of lading on file for not less than one year from the date of shipment, but these records must be retained for as long as any of the fish are possessed by the receiver."

Ironically, it is legal for out-of-state producers to ship hybrid bass into Texas for human consumption. Thus, Texas law presently encourages aquaculture of hybrid bass in other states, but prohibits it in Texas. Obviously, there is a need to change this legislation. Analogous changes have occurred recently in other states in response to the interest in hybrid bass aquaculture.

The primary concerns expressed by conservation and recreational fishing interests concerning legalizing the sale of hybrid bass for human consumption are:

- this might complicate enforcement because of the potential claim that illegally harvested wild stocks are farm raised, and
- hatchery requirements for broodstock could deplete wild populations of adult striped and white bass.

These concerns are legitimate, but they can be addressed in much the same manner as exemptions for farm-raised red drum were addressed. Proof that fish are farm-raised can be documented through bills of lading, and excessive harvest of wild adults can be prevented through use of broodstock collecting permits. Senator Ken Armbrister (D-Victoria) introduced an amendment to this effect during the regular session of the 1989 Texas Legislature. The amendment passed the senate, but did not clear the House. The exact reason for the problems in the House are unclear, but a better educational effort is probably needed with recreational fishing groups such as the Gulf Coast Conservation Association and Texas Black Bass Unlimited. Until amendments to existing legislation are passed, the development of hybrid striped bass aquaculture cannot progress.

STATUS OF INDUSTRY

Despite the inability to sell hybrid bass for human consumption, several producers are growing hybrid bass for sale to recreational pond owners or simply to gain experience, assuming that legislative changes in marketing restrictions are imminent.

Grow-out Trials

Grow-out trials are being conducted in at least the following counties: Brazoria,Calhoun, Goliad, Guadalupe, and Karnes. Average production is 2,500 pounds per acre. Marketable fish (1.25-2.0 pounds) can be produced from one-inch fingerlings in about 1.5 years in outdoor ponds. Reports indicate that hybrids have survived and grown well in Texas ponds with salinities ranging from 0 to 45 ppt.

Several producers who experienced disappointing results with winter survival of red drum are now trying hybrid bass on a pilot scale. The recent record-breaking freeze of December 1989, which caused disasterous losses of pond-raised red drum, has not affected survival of pond raised hybrids.

At least one producer attempted to reduce the cost of fingerlings by producing his own from first-feeding larvae purchased from an out-of-state hatchery. However, this first attempt was unsuccessful due to avoidable problems with aquatic insect predation. Presently about 4 acres of ponds are available for fingerling production. This is expected to expand to 15 acres during 1990.

Hybrid striped bass are also being tested in indoor recirculating systems. Presently two 10,000 gallon raceways and several small recirculation systems (500-1,000 gallon tanks) are devoted to indoor fingerling production and grow out.

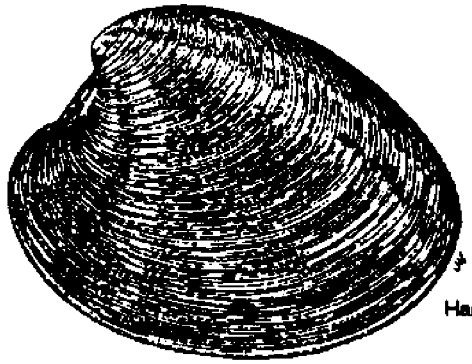
Economic Projections

Insufficient data are available from Texas trials to generate economic information based on Texas experiences. However, recent economic analyses performed in North Carolina indicate that production costs range between $1.31 and $1.72 per pound depending on the size of the farm and the pond configuration (Brown ,J W., J. E. Easley, Jr., and R.G. Hodson. 1988. Investment and production costs for the hybrid striped bass x white bass in North Carolina, UNC Sea Grant Publication UNC-SG-WP-88-2). According to industry observers, recent sales prices have ranged from about $2.25 to $3.00 per pound. However, there is uncertainty about price response to anticipated increasing supplies from aquaculture.

RECOMMENDATIONS

The major development need for expanding hybrid striped bass aquaculture in Texas is a legal provision whereby broodstock can be collected from public waters of Texas and farm-raised hybrids can be sold either as recreational or food fish. Other matters of concern to producers interested in hybrid striped bass are:

- need for grants, low-interest loans or other financial incentives to get farms started.
- need for cooperative feed, processing, marketing arrangements
- need for bird predation permits to control cormorants
- need for practical research on production techniques for hybrid striped bass, as well as nutritional requirements, and water quality tolerances.



BIVALVE MOLLUSCS

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HISTORY

Although a variety of bivalve molluscs are found in Texas coastal waters, the American Oyster (*Crassostrea virginica*) is the only one that has sustained a viable commercial fishery.

Hard Clams

The native hard clam (*Merceneria texana*) is widely distributed in Texas bays, but not in great abundance. In the few areas of dense populations, the average size of individuals is relatively large. Indications are that stock recruitment is poor and the resource could readily be over harvested.

The consistent high market demand for the hard clam and improved aquaculture techniques developed on the east coast has prompted some attempts at clam culture in South Texas. These primarily were designed as test or demonstration projects, the results of which have not yet been fully determined.

Bay Scallops

The bay scallop (*Argopecten irradians*) also offers potential for cultivation. Like the oyster, it has the capacity for rapid growth. Furthermore, scallops, which are marketed as adductor muscle destined to be cooked, avoid the health problems associated with consumption of raw oysters. Unfortunately, little research on scallop culture has been conducted in Texas.

American Oysters

The oyster industry in Texas has developed slowly over the years amid a myriad of problems both within and outside the industry. Historically, the industry was fragmented, composed of individual oyster luggers, owner/operators who "oystered" to supplement their primary income from shrimping and netting finfish. Harvesting of oysters prior to 1950 was accomplished largely by tonging, which is labor intensive. By the 1960's, most oysters were harvested with dredges.

Early on, some of the resource management policies and practices were not conducive to oyster industry growth and development. In the 1950's, the demand for oyster shell as a road building material and as a source for limestone cement was quite high. Years of oyster shell dredging in Galveston and other Texas bays began to seriously jeopardize the health and survival of living oyster reefs.

It was during this time that a few oystermen began efforts to obtain private oyster leases not only for oyster production purposes but as a means to prevent further destruction of public oyster reefs by commercial shell dredgers. The development of private oyster leases has changed the character of the Texas oyster industry from a collection of part-time oyster fishermen producing an unpredictable harvest to a year round business pursing market development.

CURRENT STATUS

Dramatic declines in oyster harvests have occurred on the East coast of the United States due to pollution and diseases referred to as "dermo" (caused by the protozoan, *Perkinsus marinus*) and "MSX" (caused by the parasite *Minchinia nelsoni*). The U. S. oyster market is facing decreasing natural stocks and an inconsistent supply of the resource. Thus, some feel that the stage has been set for potential growth of bivalve mollusc aquaculture in Texas.

Texas, with its typically warm coastal climate, offers the potential for fast grow-out. Texas bays and estuaries have a wide range of substrate types and hydrographic conditions - many of which are favorable for bivalve culture. Texas also has ample undeveloped shoreline suitable for pond and raceway culture of oysters.

Private Leases

Until recently, the culture of the American oyster in Texas has been limited to transplanting from closed areas to private leases. The concept of private oyster leases administered through the Texas Parks and Wildlife Department developed as a means to allow individuals an opportunity to cultivate suitable but presently non-productive bay bottom for oyster production. Industry members attempted to select areas with the most suitable substrate and hydographic conditions for their private leases. During the formative years, lease holders had access neither to seed oysters nor the technology to produce them; therefore, they were limited to utilizing oysters within closed areas of the bay. Oyster "mariculture" developed in Texas much as it has throughout the Gulf and South Atlantic region as a combination of private leasing, relaying, and reef development.

The oyster lease and transplant program is logical from a number of standpoints. It is agreeable to the state management agency in that it allows public access to an otherwise unavailable resource. The Texas Department of Health Shellfish Sanitation Control Division favors the program because it reduces the abundance of polluted oysters within closed areas, thereby decreasing the incentive for poaching. The benefits to lease holders are obvious.

Private lease holders operate their transplant program under the scrutiny of the Texas Parks and Wildlfe Department and Texas Department of Health. Most recently, transplanters have been allowed to operate during closed oyster season (late spring and summer). They are also permitted to harvest and sell oysters from their private leases during closed season, but not from the same area where transplanting is being conducted.

Problems

The methods employed in transplanting are highly efficient (95% oyster recovery is expected) and generally successful; however, there are economic risks involved.

Problems and sometimes considerable expense occur in keeping the boundaries of the leases correctly identified and marked with buoys.

A two-week minimum time period is required for transplanted oysters to complete the purging process. In the interim, the reefs may be subjected to disease, predators, and silting. Also floods may occur which could kill the oysters outright or render them "unharvestable" due to poor water quality conditions.

Oyster farmers can reduce their risks by selecting healthy oysters for transplanting, carefully monitoring their lease sites, and transplanting to only those sites with the best water conditions.

Area Leased

Presently, all private oyster leases are located within the Galveston Bay Complex. During the past 10 years, the private lease program has shown little change in the number of leases or the total leased acreage. The number of leases in Texas ranged from 44 in 1979 to 48 in 1983. Total leases in 1988 were 43. Total acres leased remains rather constant at around

2,368 acres. The 2,510.2 acres leased in 1983 was a record high. It is estimated that up to 80% of the leased area is actively cultivated.

Production Levels

Production levels during the last 10 years have been inconsistent. They ranged from a low of 40,900 pounds of meat in 1979 (due to flooding and three consecutive years of bad sets in Galveston Bay) to a high of 1,652,600 pounds in 1986. In 1987, total Texas oyster production equaled 2,843,600 pounds. Of that amount, 1,165,700 pounds or 40% were produced from private leases. The ex-vessel value of the 1987 private lease crop was $2,774,300.

Hatcheries

Oyster mariculture in some areas such as the Pacific coast ofthe United States relies heavily on hatcheries to produce seed. Although that requirement initially was considered a disadvantage, it has led to the several advancements which are major benefits to that industry. These include a controlled supply of oysters, selective breeding for desireable traits, production of cultchless seed for the halfshell trade, and production of polyploid animals which are suitable for harvest yearround.

A needed step in the growth of the bivalve aquaculture industry in Texas is the development of a private or cooperatively owned hatchery that could offer a ready supply of seed. Presently in Texas, there are two oyster hatcheries. One is designed primarily for research and development and is located at Texas A&M Univeristy at Galveston. The other is a private hatchery located at Palacios, Texas. Its present production capacity is 100 million eyed larvae annually.

It may not be economically feasible to use hatchery produced seed in all types of aquaculture systems. Their application may be profitable only in situations where water conditions can be controlled and high survival and harvest rate is ensured.

Pond Grow-out

Pond culture of oysters in Texas has been limited to one facility utilizing the grow-out of oysters in polyculture with shrimp. The seed oysters were obtained from an east coast hatchery. The project met with limited success and the business is going through a change of ownership.

Presently under construction is an oyster grow-out facility located on Matagorda Bay near Palacios. It is a flow-through, semi-raceway pond system designed to produce 10,000 bushels beginning in 1990. Its source of seed oysters will be the Palacios-based hatchery previously mentioned.

Processing

Oysters produced on private leases are harvested by the most economical means possible (2 dredges per boat) and are processed and handled in the same manner as the "wild stock". Most lease holders are among the group of 90 or so shellfish plant operators that are certified to operate in the State of Texas.

The extent of handling and processing required depends upon how the oyster is to be marketed. Half-shell trade (shipped live and in-the-shell) may require shell cleaning, washing, sizing and packing in shipping boxes. Others require shucking and packing in gallon containers. The handling procedure may simply involve transfer of oysters from the boat to a waiting truck to be shipped out.

Processing quite often requires specialized equipment and a sizable work force. One company in Dickinson utilizes a CO_2 tunnel to produce Individually Quick Frozen (IQF) oyster singles of uniform size. Value added to the ex-vessel price may range from 30% to several hundred percent depending on the market form. The greatest value added occurs when oysters are prepared for the half-shell trade.

Pricing

The ex-vessel price per barrel of oysters has increased substantially over the last few years. In the early 70s the price was around $20 a barrel. In 1987 and 1988, it went over $60 a barrel. A barrel yields about 17.5 pounds of meats. At $60 a barrel, this would place the dockside value of oyster meats at $3.43 per pound. The highest value oysters are those sold to the half-shell market. This is a logical target market for high-quality cultured oysters.

IMPEDIMENTS

Food Safety Issues

An ever-growing issue of great concern to oyster producers and public health agencies is the need to produce a wholesome safe product. The trophic level and bottom habitat of oysters make them prone to concentrate a variety of toxins and undesireable microbes, if they are exposed to poor water quality.

Oysters are non-selective filter feeders which ingest large quantities of detritus and plankton. This characteristic which normally results in production of a nutritious food product, can be a serious problem if they are exposed to sewage effluent, red tide, or other pollutants. They live on or in the substrate where water quality problems tend to be the worst. Unlike scallops, oysters are non-mobile as adults, so they cannot escape deteriorating environmental conditions. Also the viscera of oysters is consumed with the rest of the body, often in the raw form. Consequently, there is a defiinite need to ensure oyster quality from a public health standpoint.

Regulatory Issues

The need for a reliable system which ensures that a consistently wholesome product enters the marketplace has resulted in some rather strict and numerous guidelines for oyster lease holders and depuration plants. Compliance with these guidelines is quite costly and, in the case of oyster depuration plants, may presently be cost prohibitive. Some restrictions on harvesting conditions from private leases are set to provide a wide margin of safely for the consumer, because the Health Department has limited manpower and resources to provide more detailed monitoring.

Presently, there is a moratorium placed on the issuance of new private oyster leases in Texas. There is some question about the abundance and future availability of oysters within closed waters. Oyster levels in some closed areas are quickly reduced soon after transplanting begins.

Another consideration is the emergence of shoreside depuration plants that are designed to utilize the same resources as the private lease holders.

Off-bottom culture and depuration in public waters appear to be biologically sound approachs to bivalve aquaculture. However, obtaining permits to use the water column in public waters seems very doubtful.

Biological Issues

Diseases, predation, and fouling problems are major concerns of bivalve aquaculturists. High salinity and temperature exacerbate diseases, predation, and fouling. This is especially true if they are carried to extremes for abnormally long periods of time. Man's activities that result in interruption of the fresh water flow and resuspension of sediments can seriously reduce oyster survival in private oyster reefs.

If salinity remains high for extended periods, the oyster disease, "dermo", can cause high oyster mortality. Oyster drills (*Thais haemastoma*) also move in and become established on the reef. Other predators, such as blue crabs (*Callinectes sapidus*) stone crabs (*Menippe mercenaria*), and black drum (*Pogonias cromis*) can cause serious harm to young oyster populations.

A major concern of both the industry and state management agencies is the possible introduction of MSX, a disease which has devastated the Chesapeake bay oyster fishery.

Technology Issues

Much of the technology used for growing, planting, and processing oysters today is the same as that used 100 years ago. New methods are needed to reduce costs and improve production.

Fortunately, many intensive aquaculture techniques are well known and in commercial use in other areas. For example, hatchery methods for producing seed on command and for generating cultchless and polyploid individuals are in routine use on the Pacific coast with *C. gigas*. Intensive grow-out techniques such as the "belt technique" being utilized by watermen in the Appalacacola Bay area of Florida and the "tray technique" being utilized in the Chesapeake Bay area appear appropriate and promising for Texas. However, each of these existing technologies must be adapted to the unique conditions in Texas and evaluated for economic feasibility before it can be widely implemented.

Certain problems are not adequately addressed by existing technology. Consequently, new lines of research are required in such areas as:

- correlating flow rates with appropriate stocking densities
- testing grow-out of oysters in raceways and ponds including polyculture trials with shrimp and fish.
- developing closed culture systems and efficient artificial diets.
- selective breeding for disease resistance and rapid-growth, and improved shell quality.
- evaluating alternate bivalves such as clams and scallops.

RECOMMENDATIONS

The stage has been set for growth of the bivalve aquaculture industry in Texas. The present situation is characterized by high product demand and decreasing natural production of the resource. Bivalve aquaculture technology has come of age, and the will of industry members is strong. This combination of factors creates an optimistic outlook for bivalve aquaculture in Texas, provided regulatory agencies create an atmosphere that will encourage investments for research and development in this fledgling seafood industry. The passage of the "Fish Farming Act of 1989" by the Texas Legislature is well timed to establish needed programs to support private aquaculture enterprises.

Regulations

Governmental agencies should be responsive to the entrepreneurial activities of a budding aquaculture industry by creating opportunities for growth while protecting the environment. There needs to be better inter-agency cooperation and coordination in streamlining the permitting process. This is especially needed where multiple permit requirements must be met. Permitting for transplant purposes requires a streamlined regulatory system which encourages rather than hampers hatchery development and seed production.

Clarification of definitions or nomenclature, such as "exotics" are needed to avoid misunderstandings and perhaps unnecessary impediments.

There needs to be better industry/management agency cooperation in responding to mutual needs or providing services within a reasonable time frame.

Before new growth in the private lease program can be realized, several questions may need to be resolved:

- User groups need to be identified and an equitable resource allocation system devised.
- It may be necessary for the General Land Office to review its easement rights policy toward leasing bay bottom.
- Many good prospective lease areas are thought to exist in Texas bays, but further work is needed to identify them. The private lease program could benefit from a survey for the purpose of substrate mapping. If substrate parameters were known, aquaculturists could employ compatible culture methods to maximize production.
- Another approach would be to seek out new areas for leasing. Galveston West Bay, Matagorda Bay and San Antonio Bay have been suggested as suitable locales for new private leases.

Before much growth can be expected in the area of off-bottom culture and depuration plants, questions concerning public versus private ownership of the resources must be resolved.

Food Safety

Industry members must continue to be constantly vigilant about product quality. In order to make maximum use of the oyster resources available within state and private waters without jeopardizing public safety, the industry should seek increased funding for the Shellfish Sanitation Control Division and perhaps establish a fee structure for sanitary survey requirements.

An increase in Health Department personnel and funding would enable monitoring of guidelines which optimize the efficiency of the bivalve culture business and provide a wholesome product with a good margin of safety for the consumer. Funds could also be used for an improved sampling program to fill gaps in the date base.

Additional research is also needed for food safety research concerning:

- identification of other indicator organisms more closely related to pollution
- and the characteristics of harmful non-depurated bacteria such as *Vibrio vulnificus* and *V. damsela.*

Biological Issues

In order for the Texas bivalve aquaculture industry to grow and develop, it will be necessary to:

- avoid careless transplanting and seed production practices to prevent introduction of MSX and other non-indigenous diseases.
- adapt appropriate aquaculture technology from other areas to Texas for pilot scale testing and economic evaluation
- Initiate research on genetics, predator and disease control, polyculture and alternate species as described above.

Development Incentives

There is a need to establish business incentives and insurance programs for new aquaculture products. Continue and expand agricultural diversification programs, such as those now offered by the Texas Department of Agriculture. Provide assistance for small business innovations handled through the Small Business Administration. The General Land Office should continue its role in establishing incentives for aquaculture research and development. There may also be a need to increase the number of public/private sector aquaculture business agreements. The Texas aquaculture industry should be recognized as a food producing entity and be eligible for the same federal financial assistance and disaster programs as farmers and ranchers.

Finally, the Texas bivalve aquaculture industry needs to direct its attention to developing a streamlined and sophisticated processing and marketing program. This can be accomplished in part through education within the industry and consumer public toward aquaculture products. Streamline product identity methods through an improved system of labeling and recordkeeping. The formation of associations and cooperatives should be explored for marketing and promotional purposes.

OTHER MARINE SPECIES

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FINFISH

Commercial culture of marine finfish, other than red drum, has not developed in Texas. One of the reasons for this has been the lack of technical information regarding the culture of marine finfish. Such information is developed only when the need is perceived to be great enough to warrant comprehensive research programs. Such was the case in Texas with red drum, although the impetus came as much from a desire to restock the bays as to produce an aquaculture commodity.

Since the Texas Aquaculture Development Plan was published in 1981, worldwide aquaculture production has increased over one thousand percent, due primarily to shrimp and salmon production, but with many new species now being routinely cultured. Texas has the opportunity to produce a variety of native finfish species, either for food or for restocking programs. However, some of the overriding problems common to culture of marine finfish must first be addressed. These include:

- Improving broodstock acquisition and maintenance procedures.
- Developing natural (versus strip) spawning techniques.
- Determining dietary requirements of larvae and fry during the relatively protracted larval rearing period in order to improve survival.
- Engineering grow-out systems to consider the temperature sensitivity of warmwater species which require more than one year to reach market size (i.e. overwintering).
- Developing a marketing strategy which positions cultured marine finfish products in the specialty item category in order to bring prices which will make the venture profitable.

The following are some of the marine finfish species native to the Texas coast which have been considered for commercial aquaculture production.

Pompano

Pompano (*Trachinotus carolinus*) exhibit several attributes which make them an ideal candidate for culture. Pompano have consistently had a high market value relative to other finfish species. They are considered a limited gourmet item whose supply from the wild fishery has never met the market demand.

Pompano are hardy fish, readily adapting to confinement and high densities, and capable of tolerating a variety of environmental stresses. For example, while the optimal salinity for growth is between 30-35 ppt, they will tolerate salinities from 9 to 50 ppt and can be acclimated to waters less than 1 ppt. Likewise, while the preferred temperature is between 28 and 32C, pompano will tolerate water temperatures between 12 and 34C. High turbidity, rapid pH changes, and oxygen concentrations as low as 3.0 ppm do not adversly affect captive fish.

Pompano can be spawned naturally through temperature/photoperiod manipulation or induced to spawn through hormone injection. Larvae and fry can be raised on cultured (vs. wild) zooplankton such as rotifers and brine shrimp, and easily weaned onto a prepared food.

With all of these aquaculture "assets", numerous pompano ventures in Florida, Alabama, and the Dominican Republic failed during the 1960's and early 70's. Various factors contributed to their demise, including a reliance on juveniles captured in the surf for grow-out stock (since a reliable supply of hatchery reared juveniles were not available). Likewise, information on the larval and fry diets was lacking due to problems with spawning and subsequent lack of larval fish. And finally, most ventures made an unrealistic assumption that pompano could achieve economically favorable food conversion ratios using commercial fish foods available at that time.

Pompano and other carangid fishes mentioned as candidates for aquaculture (such as permits and palometas) have no swim bladders and therefore must swim constantly. This activity consumes up to 20% of their body weight per day in dry feed. However, they grow rapidly, achieving market size of about three pounds in a year and a half under optimal conditions.

The following are areas of research that are important to development of commercial pompano culture:

- Improvements in natural spawning and larval rearing techniques.
- Development of cost effective feeds - especially for grow-out of fish above one and one-half pounds.
- Engineering of high intensity systems for this species which has extraordinarily high oxygen requirements.
- Hybridization of pompano with permits or palometas to improve growth rate and food conversion while retaining the marketing qualities of pompano.
- Control of *Vibrio sp.* outbreaks in high density cultures.
- Polyculture of pompano with other finfish as well as molluscan and crustacean shellfish.

Dolphin

Similar to pompano, dolphin fish (*Coryphaena hippurus*, commonly called mahi-mahi) would appear to be an excellent candidate for coastal aquaculture. They have an established market which exceeds the wild caught supply. Broodstock have an extended spontaneous spawning season thus providing a steady supply of eggs. The fish can be trained to take pelleted food within a month after hatching. Most importantly, dolphin have been grown from 1.6 grams to over 1300 grams (almost 4 pounds) in 85 days at a food conversion ratio of 3:1.

Although dolphin are normally found offshore, a North Carolina study reported dolphin to thrive in estuarine pens with salinities fluctuating between 16 and 26 parts per thousand. In these studies the best growth was achieved at temperatures between 24-29C, slowing considerably as temperatures dropped to 18C, at which time they ceased feeding.

Recently there has been renewed interest in dolphin culture, with excellent work adressing larval nutrition (including "encapsulation" of micronutrients into live zooplankton), hatchery design to improve survival (with emphasis on aeration, stocking density, and cannibalism) and cost effective grow out diets (giving special attention to fatty acid as well as amino acid requirements). A Norwegian salmon aquaculture company, Noraqua, has recently established a pilot facilities in Vero Beach, Florida and in Grand Bahama and plans to have a commercial dolphin farm in Costa Rica operational in early 1992. A commercial dolphin farm is also being developed in Australia.

Red Snapper

Red snapper (*Lutjanus campechanus*) have been suggested as a potential aquaculture species for many of the same reasons previously mentioned for other species, i.e. name recognition, an established high value market, and a demand which historically has exceeded supply. In addition, rapidly declining wild stocks have led to severe restrictions on commercial fishing quotas in the Gulf of Mexico.

Although red snapper have been spawned in captivity via temperature and photoperiod manipulation, little work has been carried out regarding optimal hatchery conditions, suitable larvae diets, grow out systems, or economical feeds for this offshore species.

In one study juvenile red snapper collected offshore readily accepted feed in captivity and grew at about 0.5 percent body weight per day when maintained at optimal temperatures near 30C.

Unlike pompano or dolphin which swim constantly, red snapper are a more sedentary species, often remaining near a particular underwater obstruction for months at a time. Thus it has been suggested that offshore populations could be enhanced through a stocking program utilizing hatchery reared fingerlings or juveniles.

Black Drum

Black drum (*Pogonias cromis*) has not received the aquaculture production attention as has red drum due to the relatively low price paid for black drum and the lack of a state stocking program. Although the meat quality is comparable to that of red drum, the fish has large tough scales, as well as a broad body with a big head which reduce the fillet yield.

Should the market for black drum improve, much of the same technology developed for red drum production could be used to raise this species, i.e. temperature and photoperiod manipulation to induce spawning, zooplankton culture to feed fry, and utilization of commercial feeds for grow out.

Hybrid drum (female black x male red) have been produced in order to assess the more desireable aquaculture traits in each species as they are manifested in the hybrid.

Southern Flounder

Flounder (*Paralichthys lethostigma*), being a sedentary benthic organism with excellent quality and yield of meat would seem to be an ideal aquaculture candidate. However, work related to the culture of flounder has been limited. Early studies showed that fish could be strip spawned. However, both the percent fertilization and hatching success were low. Most of the work involved capturing gravid females from the wild, a practice which would not lend itself to profitable aquaculture production.

However, interest in flounder production may be renewed as several European countries continue to improve their production techniques for flat fish such as plaice and turbot.

Baitfish

The Gulf killifish (*Fundulus grandis*), commonly known as the mud minnow or bull minnow, is a popular live bait for marine fish, particularly flounder. Research efforts at the Claude Peteet Aquaculture Facility in Alabama and at Texas A&M University have demonstrated methods for rearing mudminnows (refer to "Raising Mudminnows", Texas A&M University Sea Grant publication, , TAMU-SG 86-506R). At least one commercial facility is in operation in the Galveston Bay area near Anahuac. Interest has been expressed by several groups in establishing mudminnow farms, particularly as a means of producing a substitute bait for the late summer and fall when live shrimp become scarce.

CRUSTACEANS

Crabs

As a complement to the blue crab fishery for hard shelled or "Jimmy" crabs, a small industry exists in Texas and other Gulf and South Atlantic states to produce high-value soft-shell crabs. This is accomplished by buying "peelers" (those crabs showing signs of imminent molting) from fishermen and holding them in shallow trays of water until molting occurs.

Some holding systems are designed as simple flow through systems receving a constant flow of bay water, while others are engineered with recirculating water systems to provide more environmental control. The softshelled crabs are removed and processed immediately after shedding to prevent the new shell from hardening, which reduces value.

The estimated farm gate value of the soft shell crab business in Texas is $150 thousand. This industry is limited by the unpredictable supply of peelers as well as the high labor costs of monitoring relatively small shedding operations on a 24-hour basis. The potential exists to reduce labor costs through research on maintenance of crabs in water with low mineral content, which slows the shell hardening process. However, the most important areas of research include means of inducing molting and providing a more reliable supply of peelers.

Brine Shrimp

Brine shrimp (*Artemia* sp.) are an indispensible live feed for hatchery production of many marine finfish and crustaceans as well as for feeding of pet organisms in the aquarium industry. They are utilized primarily as newly hatched larvae by aquaculturists and as live or frozen adults by the aquarium industry.

A unique feature of the brine shrimp is it's ability to produce a dessicated and dormant egg stage, called a cyst, during conditions of extremely high salinity or low oxygen. When exposed to favorable conditions, the tiny cysts hatch into brine shrimp larvae within about 24 hours. Thus, live brine shrimp nauplii can be hatched easily from cysts as they are needed as food for hatchery production of other organisms. This feature has made brine shrimp the feed of choice in marine hatcheries worldwide. The demand for brine shrimp cysts is expected to continue to grow in step with the marine shrimp and finfish industry.

Brine shrimp occur naturally worldwide in a variety of saline environments such as the Great Salt Lake and San Francisco Bay. Natural salt lakes in South Texas also support brine shrimp, some of which have already been harvested and marketed on a pilot scale. Areas near the Laguna Madre and upper Baffin Bay may be suitable for production of *Artemia* in fertilized ponds under controlled conditions. Recent studies have shown the nutritional quality of *Artemia* to vary widely. Of particular concern is the fatty acid profile of *Artemia* (a result of their algal diet) which is critical to the growth and survival of larvae marine finfish and crustaceans.

Research needs related to *Artemia* production in Texas should focus on the following:

- An evaluation of potential *Artemia* culture sites where salinities can be maintained above 90ppt, which is sufficient to eliminate most predators.
- Development of inoculation and fertilization regimes necessary to produce quality *Artemia* under conditions ranging from coastal hypersaline ponds to certain west Texas groundwaters.
- Refinement of harvesting , processing, and shipping methods for each of the *Artemia* market forms including live adults, frozen adults, and vacuum-packaged cysts.

Bait Shrimp

The chapter on penaeid shrimp describes the status of salt-water food-shrimp production, which relies largely on a non-indigenous species of shrimp, *Penaeus vannamei*. However, regulations prevent the use of nonindigenous species as live bait. It is worth noting that there is potential to raise indigenous white, brown, or pink shrimp (*P. setiferus, P. aztecus,* or *P. duorarum*) for the Texas live bait market. The Ralston Purina shrimp farming research laboratory in Crystal River, Florida, was relatively successful at attempts to raise these indigenous species during the mid 1970's. However, research efforts to raise brown shrimp in Corpus Christi during the early 1980's suffered very poor growth and survival. In retrospect, the Texas researchers suspect that their feed was simply too low in animal protein, because brown shrimp are relatively carnivorous. Additional research trials are needed. The potential market for live bait shrimp in Texas looks very attractive. The value of a 100 count per pound bait shrimp is similar to that of a 20 count food shrimp, yet the production costs and the production time would be considerably less.

CEPHALOPODS

Squid , cuttlefish, and octopus have been cultured in captivity for biomedical purposes for about 15 years. These animals are used as experimental models because of their unique organ systems. The giant axon of squid (Order Teuthoidea) provides an excellent tool for neural research. The brain of octopuses (Family Octopodidae) is valuable for research on blood-brain barriers, neurotransmitters, and a wide variety of other topics because of its lobed structure, capacity for both short and long term memory, and its adaptability to operative procedures.

In the process of developing procedures for maintaining and culturing cephalopods for biomedical research, the staff of the Marine Biomedical Institute at the University of Texas Medical Branch at Galveston has noted several characteristics of cephalopods which indicate commercial culture potential. These traits include: rapid growth (to one pound in less than a year), excellent food conversion (1.6 to 3.0 FCR on a wet weight basis), tolerance of high ammonia and nitrite levels, reproduction in captivity, and, in some cases, production of large eggs which hatch directly into non-planktonic, adult-like young.

The primary factor hindering commercial culture of cephalopods is the current inability to raise them effectively without live feeds. Furthermore, cephalopods cannot tolerate low salinity, low dissolved oxygen, or pH below 7.6.

Market-size cephalopods are about 95% protein on a dry-weight basis and about 85% edible. Although the catch fishery has generally been able to meet market demand, the market for a high-value cultured product has not been explored. The potential for producing cephalopods for the aquarium industry also should not be overlooked.

SEA TURTLES

The breeding population of female Kemp's ridley turtles (*Lepidochelys kempii*)has declined from an estimated 40,000 in 1947 to 400 in 1986. The endangered status of this species has led to efforts by the National Marine Fisheries Service to headstart hatchlings from Mexico to improve their chances of survival during their first year.

The headstart program which is centered in Galveston began in 1978. It utilizes greenhouse covered raceways housing plasic holding basins which are used to raise the aggressive turtles individually. During its 11 year history, the program has received approximately 20,000 hatchlings and released about 15,000 yearlings into the Gulf of Mexico. This is a long-term project, because the estimated age to maturity of this species is 7 years. Although the yearlings are tagged before release and have been recovered from as far away as Morocco, none are known to have returned to Padre Island or Mexico to breed yet.

FUTURE DIRECTION

With the worldwide demand for seafood projected to continue its dramatic annual increase through the turn of the century, various countries will accelerate their research programs to develop the technology necessary to make aquaculture a profitable enterprise. For example, the French continue to improve on production of sea bream and sea bass. Grouper and sea bass research in the Philippines and other southeast Asian countries is providing the basis for a new industry there. Norway, England, and Spain continue to improve on the economics of salmon, plaice and turbot production.

Such information will continue to be in the public domain, and should be evaluated as to its applicability to the culture of similar Gulf of Mexico species.

Several international groups have developed net pens for culture of salmon in exposed ocean locations. There is interest in the potential application of this technology to warm water marine fishes in the Gulf of Mexico. Nonproducing petroleum platforms could serve as excellent feed storage, housing, and service headquarters for such operations.

Texas has the coastal resources to develop marine finfish aquaculture. However, certain technological problems unique to marine finfish species must be overcome before economically successful ventures can become a reality. Included among these are the following:

- Suitable diets and environmental conditions to encourage sexual maturation and natural spawning in captivity.
- Development of larvae diets which not only improve survival, but are cost effective.
- Grow-out studies which concentrate on facility design, stocking densities, and feed.

Presently, there are two marine laboratories in Texas which are best equipped to address these concerns as they relate to spawning and larval rearing of certain species. However, there are no facilities which can address commercial grow out issues. Grow-out questions must be answered to determine whether various species can be raised profitably. A grow-out facility, linking the research community with the aquaculturists while addressing water quality, nutrition, disease, and the economics of grow out would seem a logical step toward the development of a marine finfish aquaculture industry in Texas.