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 of the 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

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

Texas Aquaculture: Status of the Industry (draft)
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 crucial 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 acre 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 accommodate 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, licenses 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

[Diagram showing relative values of different species]
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 by 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 waterlilies 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 compromise, such as greenhouse-covered overwintering ponds may prove to be the most economical solution. Other issues include the need for additional research on 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 regulation 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 a given 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.
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

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Figure 1
U.S. Foreign Trade of Fishery Products

[Graph showing U.S. Fishery Imports and Exports from 1978 to 1989, with projections for 1989.]

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**

*World Commercial Catch by Leading Countries 1977 - 1987 (live weight)*

![Graph of world commercial catch by leading countries 1977-1987](image)

Source: NMFS 1989

**Figure 3**

*U.S. Supply of Canned Tuna (canned weight)*

![Graph of U.S. supply of canned tuna 1979-1988](image)

Source: NMFS 1989

Texas Aquaculture: Status of the Industry (draft)
Figure 4

U.S. Shrimp Catch (---) and Imports (----)

Millions of Dollars or Pounds


Year

Import ($)

Catch ($)

Import (lb)

Catch (lb)

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


Figure 5

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

Pounds (millions)


Year

Chesapeake

New England/Mid-Atlantic

South Atlantic/Gulf

Pacific

Source: NMFS 1989

Texas Aquaculture: Status of the Industry (draft)
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.

![Image of Figure 6: U.S. Supply of Edible Fishery Products (round weight) 1979 - 1988]

![Image of 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 fished 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, i.e., imitation crab, lobster, scallops, and shrimp.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>40 Million Pounds</td>
</tr>
<tr>
<td>1988</td>
<td>126 Million Pounds</td>
</tr>
<tr>
<td>1989 (projected)</td>
<td>344 Million Pounds</td>
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</table>

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 constitute 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 coastalwide 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
(incuding shrimp, crab, 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 least 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).

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 farmed-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 worldwide 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

<table>
<thead>
<tr>
<th>FAO Regions</th>
<th>Finfish</th>
<th>Mollusca</th>
<th>Crustacea</th>
<th>Seaweeds</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa¹</td>
<td>11,790</td>
<td>202</td>
<td>70</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>North America</td>
<td>236,137</td>
<td>174,473</td>
<td>64,148</td>
<td>230</td>
<td>37</td>
</tr>
<tr>
<td>Latin America</td>
<td>53,774</td>
<td>7143</td>
<td>4309</td>
<td>4924</td>
<td>-</td>
</tr>
<tr>
<td>Asia/Oceania</td>
<td>3,795,503</td>
<td>2,299,748</td>
<td>258,292</td>
<td>2,818,248</td>
<td>28,091</td>
</tr>
<tr>
<td>Europe</td>
<td>347,395</td>
<td>650,482</td>
<td>34</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Near East</td>
<td>55,640</td>
<td>224</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>USSR</td>
<td>296,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>4,796,239</td>
<td>3,132,272</td>
<td>326,853</td>
<td>2,823,408</td>
<td>28,178</td>
</tr>
</tbody>
</table>

| 1986        |         |          |           |          |        |
| Africa¹     | 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 | 2,544,196  | 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 |

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 (1969)
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 25.5 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Louisiana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild</td>
<td>17</td>
<td>20</td>
<td>23</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Farm-raised</td>
<td>3</td>
<td>2.5</td>
<td>16.5</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Florida</td>
<td>6</td>
<td>6</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Texas</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>27</td>
<td>29.5</td>
<td>53.5</td>
<td>88</td>
<td>113</td>
</tr>
</tbody>
</table>

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).

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>YEAR</th>
<th>POUNDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catfish</td>
<td>1988</td>
<td>295.0</td>
</tr>
<tr>
<td>Crawfish</td>
<td>1988</td>
<td>200.0</td>
</tr>
<tr>
<td>Pacific Salmon</td>
<td>1986</td>
<td>74.3</td>
</tr>
<tr>
<td>Pen-Raised Salmon</td>
<td>1988</td>
<td>6.0</td>
</tr>
<tr>
<td>Trout</td>
<td>1988</td>
<td>58.9</td>
</tr>
<tr>
<td>Clams and Oysters</td>
<td>1987</td>
<td>26.6</td>
</tr>
<tr>
<td>Tilapia</td>
<td>1988</td>
<td>25.0</td>
</tr>
<tr>
<td>Shrimp</td>
<td>1988</td>
<td>2.2</td>
</tr>
<tr>
<td>Mussels</td>
<td>1987</td>
<td>1.4</td>
</tr>
</tbody>
</table>

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
### Table 2

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

<table>
<thead>
<tr>
<th>State</th>
<th>Total operations</th>
<th>Percent of Total</th>
<th>Water Surface</th>
<th>Percent of Total</th>
<th>Average Size per operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>250</td>
<td>352</td>
<td>18</td>
<td>11</td>
<td>33</td>
</tr>
<tr>
<td>Arkansas</td>
<td>130</td>
<td>194</td>
<td>10</td>
<td>12</td>
<td>72</td>
</tr>
<tr>
<td>California</td>
<td>50</td>
<td>91</td>
<td>4</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>Georgia</td>
<td>30</td>
<td>78</td>
<td>4</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>Louisiana</td>
<td>20</td>
<td>116</td>
<td>6</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Mississippi</td>
<td>280</td>
<td>356</td>
<td>18</td>
<td>67</td>
<td>177</td>
</tr>
<tr>
<td>Missouri</td>
<td>70</td>
<td>200</td>
<td>10</td>
<td>2</td>
<td>16</td>
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<tr>
<td>Tennessee</td>
<td>16</td>
<td>35</td>
<td>2</td>
<td>2/</td>
<td>16</td>
</tr>
<tr>
<td>Texas</td>
<td>115</td>
<td>173</td>
<td>9</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Other 1/</td>
<td>26</td>
<td>408</td>
<td>20</td>
<td>4</td>
<td>29</td>
</tr>
</tbody>
</table>

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\(^1/\)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000 pounds 2/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000 dollars</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Baitfish 3/</td>
<td>22,046</td>
<td>22,046</td>
<td>23,596</td>
<td>24,407</td>
<td>25,247</td>
<td>27,000</td>
<td>44,000</td>
<td>44,000</td>
<td>47,045</td>
<td>51,280</td>
<td>51,522</td>
<td>56,000</td>
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<tr>
<td>Catfish</td>
<td>76,842</td>
<td>220,000</td>
<td>239,800</td>
<td>271,357</td>
<td>326,979</td>
<td>375,000</td>
<td>53,572</td>
<td>132,000</td>
<td>191,840</td>
<td>169,194</td>
<td>226,836</td>
<td>255,000</td>
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<tr>
<td>Clams</td>
<td>561</td>
<td>1689</td>
<td>1689</td>
<td>1588</td>
<td>2506</td>
<td>3500</td>
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<td>9500</td>
<td>4178</td>
<td>4717</td>
<td>8307</td>
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<td>105,000</td>
<td>12,951</td>
<td>30,000</td>
<td>29,700</td>
<td>32,500</td>
<td>48,750</td>
<td>53,000</td>
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<td>Freshwater Prawns</td>
<td>300</td>
<td>275</td>
<td>317</td>
<td>267</td>
<td>178</td>
<td>150</td>
<td>1200</td>
<td>1500</td>
<td>198</td>
<td>1540</td>
<td>893</td>
<td>750</td>
</tr>
<tr>
<td>Mussels</td>
<td>NA</td>
<td>775</td>
<td>917</td>
<td>928</td>
<td>1206</td>
<td>1800</td>
<td>NA</td>
<td>1500</td>
<td>1584</td>
<td>1248</td>
<td>1725</td>
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<td>Oysters</td>
<td>23,755</td>
<td>23,300</td>
<td>24,549</td>
<td>22,473</td>
<td>24,090</td>
<td>26,000</td>
<td>37,085</td>
<td>31,500</td>
<td>38,970</td>
<td>39,977</td>
<td>42,797</td>
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<td>Pacific Salmon</td>
<td>7,618</td>
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<td>45,086</td>
<td>84,305</td>
<td>74,398</td>
<td>80,000</td>
<td>3400</td>
<td>6800</td>
<td>17,252</td>
<td>25,439</td>
<td>32,751</td>
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<tr>
<td>Shrimp</td>
<td>-</td>
<td>255</td>
<td>528</td>
<td>440</td>
<td>1354</td>
<td>1500</td>
<td>-</td>
<td>874</td>
<td>1566</td>
<td>1867</td>
<td>3408</td>
<td>3775</td>
</tr>
<tr>
<td>Trout</td>
<td>48,141</td>
<td>48,400</td>
<td>49,940</td>
<td>50,600</td>
<td>51,000</td>
<td>59,000</td>
<td>37,474</td>
<td>50,000</td>
<td>54,435</td>
<td>55,154</td>
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<td>65,000</td>
</tr>
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<td>14,000</td>
<td>15,500</td>
<td>68,000</td>
<td>NA</td>
<td>7000</td>
<td>9900</td>
<td>20,000</td>
<td>21,700</td>
<td>85,000</td>
</tr>
<tr>
<td>Total</td>
<td>203,178</td>
<td>404,340</td>
<td>455,733</td>
<td>535,764</td>
<td>619,999</td>
<td>746,950</td>
<td>191,977</td>
<td>314,674</td>
<td>398,168</td>
<td>422,736</td>
<td>496,329</td>
<td>645,890</td>
</tr>
</tbody>
</table>

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
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

Source: Chew, 1988
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 comparison to other areas of the U.S. and other areas of the world. The opportunity exists for considerable growth if the appropriate infrastructure, regulatory base, and technological expertise can be assembled.

**LITERATURE CITED**


Texas Aquaculture: Status of the Industry (draft)