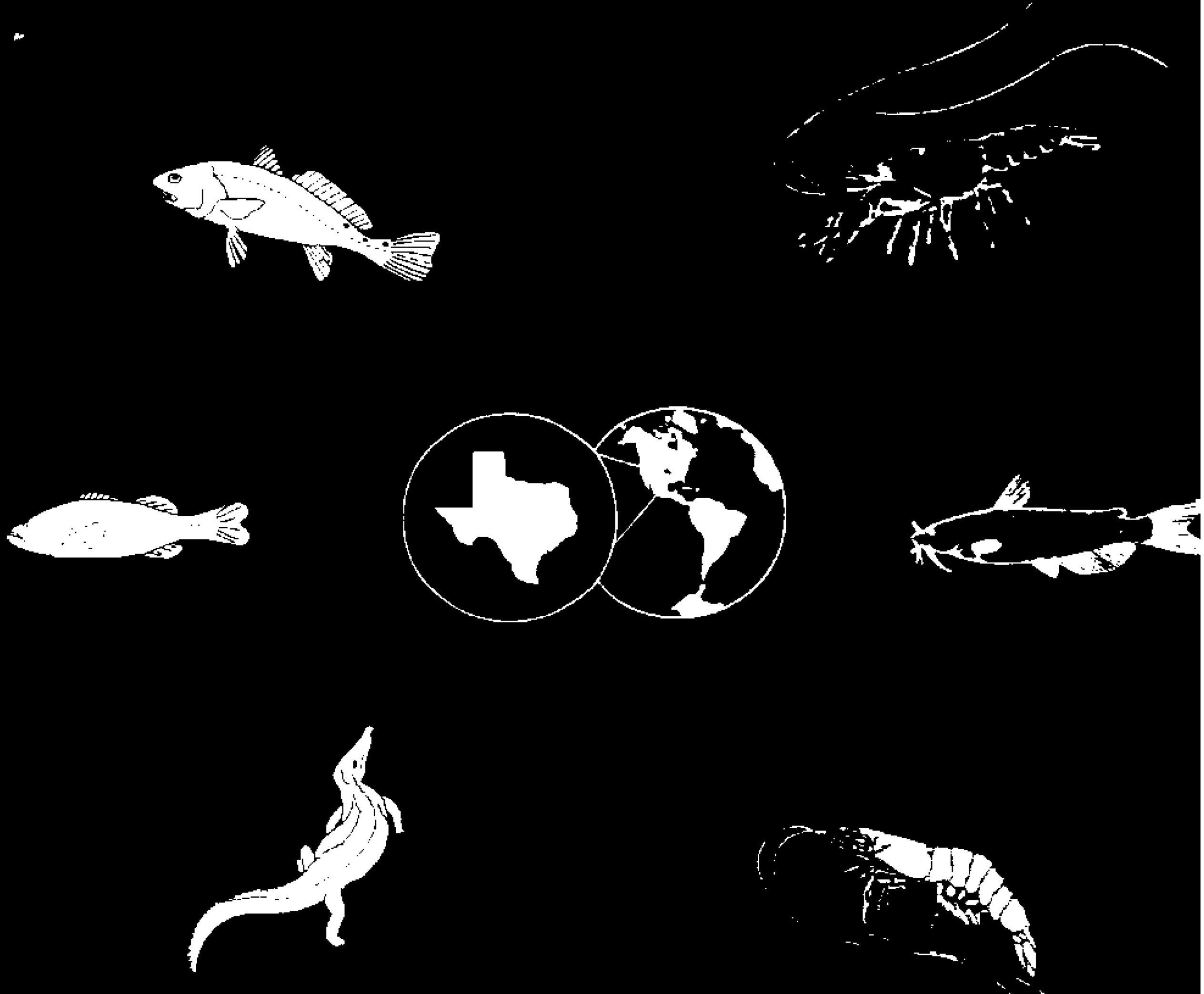
Texas Aquaculture
History and Growth Potential for the 1990s



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Texas Aquaculture: History and Growth Potential for the 1990s

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This report describes the current status of aquaculture in Texas, and its potential for growth. It includes an overview of general aspects of governmental regulation, natural resources, and infrastructure. Also, an evaluation for each species which is currently being cultured is presented with recent developments that are pertinent.

AQUACULTURE OUTLOOK AND ECONOMIC IMPACT IN THE U.S.

Aquaculture

Aquaculture in the United States continues to grow because of increased awareness of the health benefits of many fishery products, growing limitations on commercial catches, and technological advancements in production. There has been a rising demand for fishery products in the U.S. in the last decade as per capita consumption rose 19.4 percent (12.5 pounds in 1980 to 15.5 pounds in 1990) (NMFS, 1991). For most of the 1980s, imports of fish and shellfish increased rapidly, while exports grew slowly; however, since 1990, the trend has changed. Export quantities and values were at record highs, while import quantities and values have declined. This is due to the 20 percent annual increase in aquaculture during this decade (USDA, 1991). U.S. aquaculture production for 1991 was 543,770 metric tons, worth 750 million dollars (Aquaculture Magazine, 1992: "Status of World Aquaculture 1991").

United States aquaculture is expected to continue expanding, but different sectors will have varying rates of growth. Aquaculture is not a single industry but rather an association of many independent industries, each with its own opportunities and challenges. Each species is affected by competition from foreign aquaculture, wild harvests, resource limitations, restriction/control of resource management agencies, and marketing strategies.

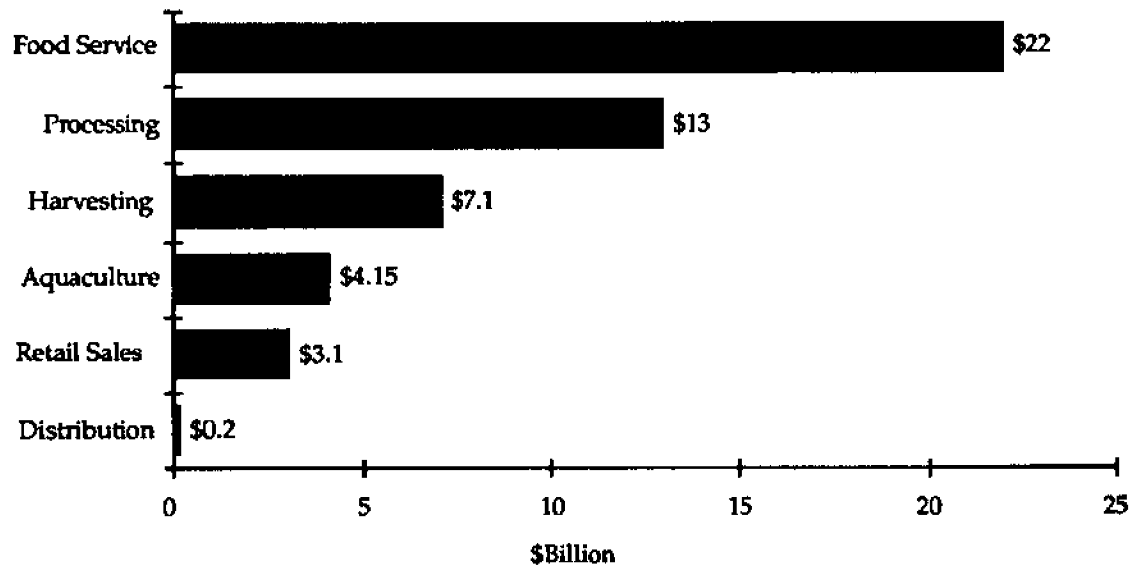
Research for many *agricultural* commodities is well established, and the research network for *aquaculture* as well has been going on in the U.S. since the late 1950s.

Advancements in the treatment of diseases and in intensive or high-density culture of fish and shellfish in indoor facilities are especially encouraging. Still, it remains to be seen if these techniques and other developments in hatchery systems, feed formulation, water management, disease control, genetics, and marketing will ultimately enable domestic producers to compete successfully against foreign aquaculture products. The future of aquaculture in the U.S. looks promising, but continued research is essential to lowering the costs of growing, processing, and marketing these products. Other industries-such as the auto industry-face the same challenge daily. As the expansion of the industry continues, most people involved remain cautiously optimistic.

Aquaculture's Economic Impact

The U.S. seafood industry directly and indirectly contributes $49.5 billion per year to the nation's economy; and this is projected to reach $62.9 billion by the turn of the century. Of the $49.5 billion, the food service and processing sector accounted for the largest percentage (77 percent). Harvesting injected 16 percent, with distribution and retail stores contributing only seven percent. (see Figure 1).

Figure 1. U.S. Seafood Industry Economic Impact



Source: National Fisheries Education and Research Foundation

In addition, aquaculture products produced in the U. S. generated $4.15 billion of economic activity. This industry employed 140,000 full-time workers for a value of $1.7 billion annually.

AQUACULTURE IN TEXAS

The aquaculture industry in Texas is relatively small. Other southern states, which account for a majority of U.S. production consistently out-produce Texas in almost every species except marine shrimp. Mississippi, Alabama, Arkansas, and Louisiana, for example, produce over 90 percent of farm-raised catfish, which is the highest volume product for U.S. aquaculture. In 1990 and 1991, Texas accounted for approximately two percent of catfish acreage and produced approximately two percent of total sales. (see Table 1).

TABLE 1. U.S. Catfish: Number Of Operations, Water Surface Area, And Total Sales

	Operations			Water Surface			Total Sales		
	1990	1991	1992	1990	1991	1992	1989	1990	1991
	(Number)			(Acres)			($1,000)		
Alabama	362	350	370	17,550	18,600	19,000	23,811	30,954	29,539
Arkansas	204	206	205	17,900	20,500	20,500	22,752	29,577	19,166
Florida	70	47	61	900	1,200	1,100	1,808	2,474	2,439
Illinois	29	53	1/	450	450	1/	1/	1/	1/
Kentucky	45	45	1/	1/	400	1/	1/	1/	1/
Louisiana	200	200	221	10,000	11,500	10,000	12,531	15,225	8,832
Mississippi	319	308	297	91,000	94,000	95,000	192,804	227,400	207,311
Missouri	150	125	125	2,650	2,700	2,700	2,041	2,576	2,101
North Carolina	54	52	54	1,000	1,100	1,300	883	1,154	1,636
Oklahoma	95	85	80	1,500	1,300	1,100	966	2,235	1,954
South Carolina	1/	29	36	750	1,500	1,800	244	2,381	1,984
Tennessee	34	28	1/	340	380	390	1/	1/	1/
TEXAS	116	145	169	2,300	3,600	3,300	1,136	5,860	2,555
Other	178	147	268	5,350	4,680	5,300	10,740	9,447	7,910
TOTAL	1,856	1,820	1,886	151,690	161,910	161,490	269,716	329,283	285,427

1/ Data not published to avoid disclosing individual operations.
2/ includes California, Georgia, Idaho, and Kansas.

Source: Catfish Growers Survey, National Agricultural Statistics Service, USDA.

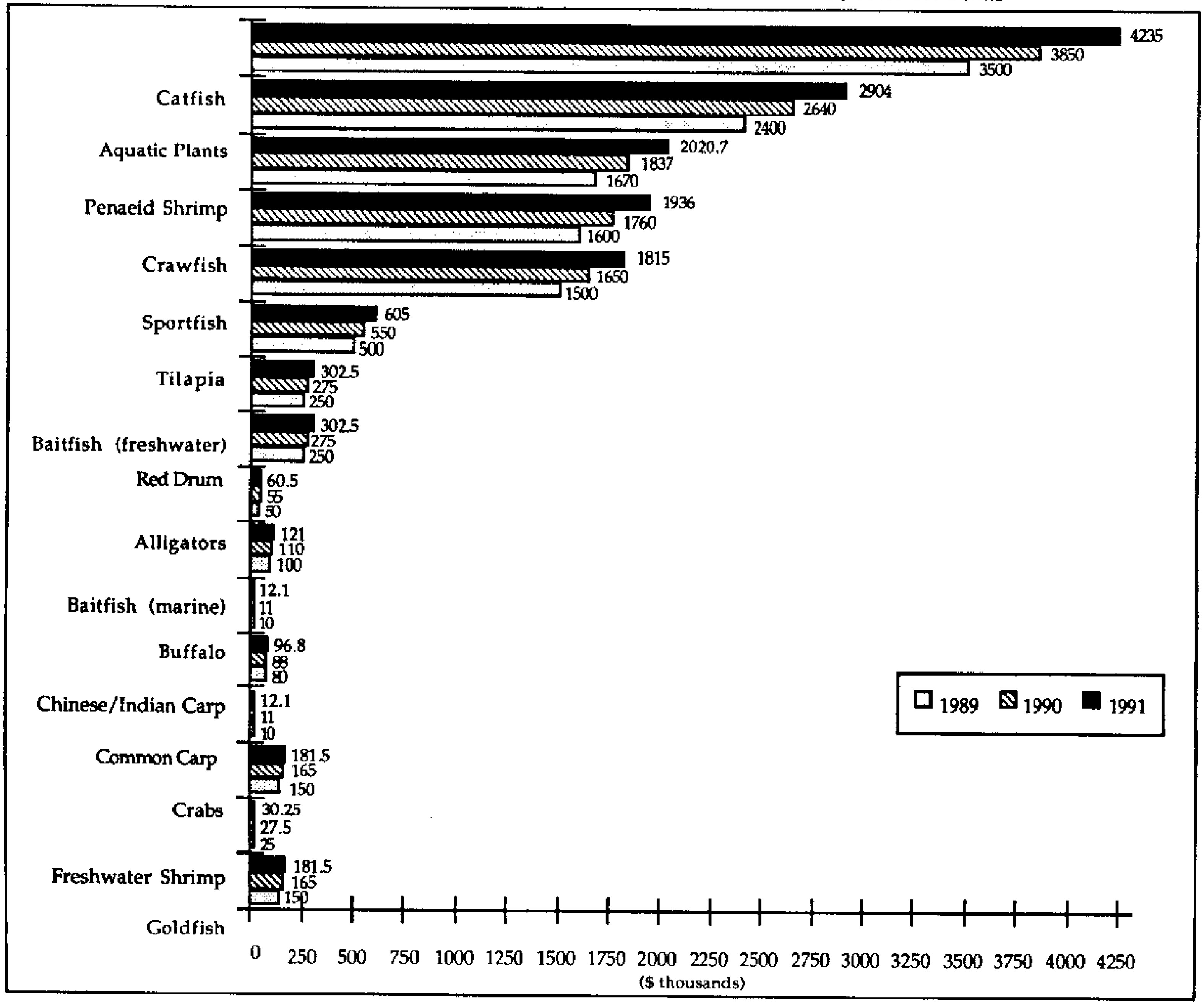
Louisiana accounts for about 80 percent of the crawfish and 70 percent of the alligators produced in the U.S. Arkansas dominates the baitfish industry with 75 percent of the production, while Florida contributes 95 percent of the total tropical fish output in the U.S.. These states produce more of certain types of aquaculture products, but Texas produces more salt-water shrimp than any other state.

According to the Texas Department of Agriculture (TDA), the total value of the Texas aquaculture industry in 1989 was $12.2 million. Based on an annual increase of ten percent, by the year 2000 this industry would be valued at $34.9 million.

Texas aquaculture is good for other industries as well; for example, every ton of a typical catfish feed will use the following: 160 pounds of menhaden fish meal, 965 pounds of soybean meal, 582 pounds of corn, 200 pounds of rice bran or wheat shorts, 40 pounds of binder, 30 pounds of fat sprayed on finished feed, 20 pounds of dicalcium phosphate, one pound of trace mineral mix, 2.5 pounds of vitamin mix and 0.75 pounds of coated ascorbic acid.

Though small, Texas cultures a wide variety of species. In terms of value, the top five aquaculture industries are: catfish, aquatic plants, penaeid shrimp, crawfish, and sportfish. Other species are less widely established, but have growing production; include tilapia, baitfish, hybrid striped bass, red drum, alligators, carp, freshwater shrimp, and goldfish. Figure 2 gives the 1989, 1990 and 1991 farm-gate value of major cultured species in Texas. This information was based on 1989 data from TDA and ten percent was added to each for 1990 and 1991. Most of the species listed in Figure 2 are discussed in detail later.

Figure 2. 1989, 1990, 1991 Farm-Gate Value of Major Cultured Species on Texas



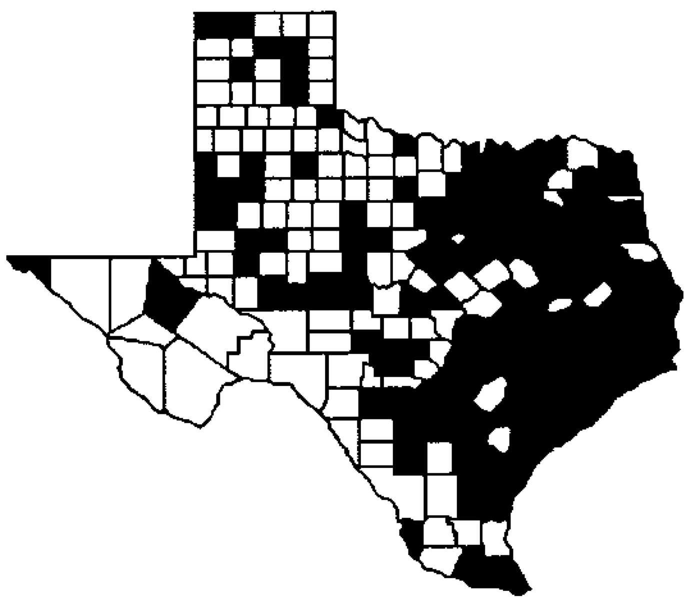
Texas lags behind other states in catfish production for a variety of reasons, some of which are controversial. A brief description of the major determinants of future growth for aquaculture development will serve to illuminate some of the current impediments, as well as opportunities facing the industry. (For more information on aquaculture in Texas, see Johnson (1990).

Natural Resources

Water

Texas has a variety of fresh-and salt-water resources which can support aquaculture systems. This includes 2.9 million acres of freshwater and 1.5 million acres of bays and estuaries. Unlike other southern states, Texas has an abundance of undeveloped coastal land of sufficient elevation suitable for pond construction, as well as plenty of inland locations with the proper combination of cost, topography, water and soil type necessary for freshwater pond development. Counties in Texas with aquaculture production, according to TDA fish farm licenses registry are shaded in Figure 3.

Figure 3. Counties with Aquaculture Production According to the TDA Fish Farm Licenses Registry (Dark Areas).



A major restriction on freshwater aquaculture expansion in Texas is water availability and water-use rights. Because of the large amounts of water required for most aquaculture operations, operators must either purchase irrigation water from a commercial source and pay industrial water rates (until Texas laws are changed to allow lower agricultural or aquacultural water rates) or rely on ground water. Many areas of the state restrict the use of ground water for these types of operations because of subsidence or depletion of underground reserves.

A recent precedent was attempted when the Texas Water Commission (TWC) wanted to limit the amount of groundwater a catfish farm could take. On November 19, 1991 the *Austin Statesman* newspaper reported that the TWC requested the Texas Attorney General to overturn a water 150 year old law which said that surface landowners could pump as much water from under their land as they wished. The catfish farm, owned and operated as a flow-through facility by Ron Pucek, Jr. was pumping 43 million gallons a day from the Edwards Aquifer (six times the amount of water used by the city of San Marcos). Pucek agreed to cease pumping while he gets waste discharge permits for the water, which flows into the Medina River. If not limited by intake, he will be limited by discharge The regulation of groundwater withdrawal is still not resolved. However, the result is the same, there is a resource conflict and a water-use battle.

Climate

All of Texas is subject to temperature extremes which can inhibit the growth of, and sometimes destroy different species. The early winter temperatures of November, 1991 killed an estimated 140,000 pounds of (13-15 count per pound) marine shrimp on one farm in Port Lavaca, and killed an estimated 266,275 pounds valued at $984,416 on four saltwater farms in Cameron County. As a result of the same cold front, snow fell in Brownsville, and water temperatures dropped rapidly from 76° to 45°F, which caused the shrimp to burrow into the mud. Coupled with overall wet conditions, this made it impossible to harvest. Other species, like redfish and tilapia, are also extremely sensitive to temperature drops. To some extent, they are being produced in indoor overwintering facilities in an attempt to make this a year-round industry. Others, such as catfish and hybrid striped bass, adapt well to the typical Texas climate. The entire state can provide the optimum temperature for warmwater species (77°F) for at least part of the year. Most farm-raised fish and shellfish grow faster in warmer climates, which gives Texas the advantage over most states.

The important consideration with respect to natural resources in Texas is that producers must carefully match the appropriate species and culture systems with the resources in a given region.

Regulatory Environment

Compared to other Gulf states, Texas has considerably more regulatory restrictions on aquaculture development, and these appear to be on the increase. Much of the problem stems from the fact that, in the past, licenses and permits were issued by resource management agencies, such as Texas Parks and Wildlife Department (TPWD), whose charter is to conserve natural resources, rather than promote their development. Since the passage of the Fish Farming Act of 1989, the responsibility for promotion and licensing of aquaculture has been transferred to the (TDA). TPWD controls exotic species and gamefish, but in the opinion of many, has a problem with enforcement.

Another problem remains, however, because the TDA budget was not increased with the added responsibility. According to some in the Department, TDA lacks the resources to do a proper job. Equally important is the fact that even after many of these regulatory responsibilities (licensing and promotion), were transferred to the TDA a number of producers were not careful about following the rules and restrictions required by the licenses. One or more of the producers accidentally released exotic shrimp into surrounding waters, prompting TPWD to exercise their authority and limit the exotic marine shrimp cultured to only one species *(P. vannamei)* and add new discharge screen design requirements.

These new requirements were taken by TPWD to minimize the risk of future releases. In addition, TPWD added new disease certification requirements for exotic shellfish and now requires farms to give 72-hours notice before harvesting.

According to the Texas Register, TPWD also raised the licensing fees for permits, which amount to $550,000 during the first year and approximately $275,000 each succeeding year. Unfortunately, the wrong-doing of a few has resulted in more regulations which affect the whole industry, thus making it more difficult to compete in the world market.

Permitting is a complex and time consuming process. As many as nine local, state and federal agencies have the potential to regulate aquacultural activities in Texas. A permitting manual (Hightower *et.al* 1990),for coastal aquaculture (available through Texas A&M University Sea Grant) describes procedures for acquiring permits; but, according to one industry spokesman, the process is still so cumbersome that it intimidates prospective entrants. The authors of the permitting manual have found that it needs constant updating, as the permitting process is under constant revision, with new codes, rules and regulations being added or replacing old ones.

Many industry officials believe that, with time, the regulatory environment will become more accommodating as the industry consolidates its goals and gains political strength. An alternative view is that regulations are being progressively-tightened and have not yet shown any sign of bottoming out. Much of this is concerned with water-and land-use rights or resource conflicts. Who has control of each?

Infrastructure

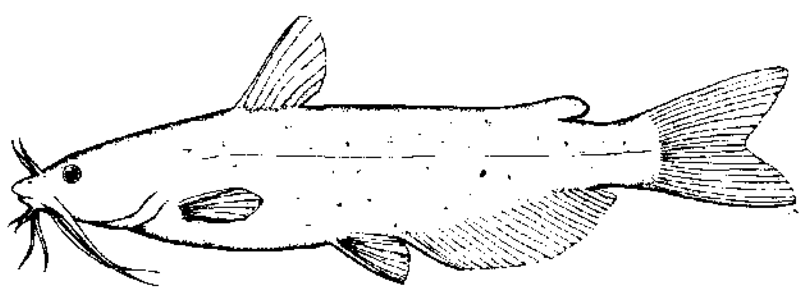
In the past Texas aquaculture has been characterized by small, family-owned farms which sell their product to local markets. Most operations are unable to expand to larger markets because important support facilities are limited. But farms are generally increasing in size and efficiency with time. Marine shrimp farms are moving in this direction. Introduction of a catfish processing plant in Brazoria county, (November 1990), heralds integration of that industry. Though off to a shaky start, it appears to be making a slow comeback, despite operating in a poor economic environment. Apparently quick expansion of planned pond production (to keep the processing plant busy) did not occur. Consequently the plant, designed to process 60,000 pounds of fish per day, became a liability, rather than an asset. When production increases to match the plant's capacity, other benefits will be realized, but this is slow in coming. It has been said that Texans consume between 45 percent to 70% of the catfish produced in Mississippi, and Texas is one day closer than Mississippi to the California market; so it does seem to make sense to establish a fish farm in Texas. Unfortunately, it is not as simple as that.

Still, processing plants are lacking for alligators and crawfish, rendering plants, and marketing networks. Contributing to this situation is the lack of financing mechanisms. The current status of the banking industry and the relative novelty of aquaculture in Texas complicate financing new ventures. Also, since 1991, one individual from the aquaculture field, with backing and support from a harvest association, has been writing many of the banks, discouraging them in funding aquaculture projects. This has made it even more difficult to acquire funding assistance. Most banks require several years of experience with a proven track record and good collateral before making a loan. Infrastructure is improving in Texas for aquaculture. East Texas Feeds has opened a feed mill in Liverpool and Rangen Inc. plans to open a Houston area branch for better feed distribution. Also in 1992, the first Farmers Home Grant was issued for aquaculture in Caldwell, Texas.

Important Aquaculture Species in Texas

This section updates the status of Texas aquaculture. by addressing each species independently, reporting recent and projected production, as well as technological and business developments. Each summary contains a brief history of the species, its potential for growth, and a discussion of specific attributes and limitations peculiar to each. This is not a comprehensive listing of all species which could potentially have some impact on the industry, but rather a status report on those which have proven records or appear particularly promising (see Figure 2).

Freshwater Species



Catfish

According to The Aquaculture News, (March 1992), the U.S. imported 8.64 million pounds of catfish in 1991, and will import 8.67 million pounds in 1992. Catfish continues to lead Texas aquaculture production and imports. Approximately 28 percent of the farm-gate value (the value of the products when sold by the farmer) of Texas aquaculture is attributed to catfish (Texas Aquaculture, 1990).

The total number of U.S. operations declined four percent in 1990; declined two percent in 1991; but increased by four percent in 1992. (Table 1). The amount of water acreage increased seven percent in 1990, and again in 1991; but declined slightly in 1992. In Texas, the number of operations increased from 116 to

145 in 1991, and the total water surface area increased over 50 percent from 2,300 to 3,600 acres in 1991, but declined slightly in 1992 (USDA, 1992).

The most widely produced species is the channel catfish (*Ictalurus punctatus*). It is distributed state-wide and is abundant in the larger lakes and streams. It ranges from Montana to the Ohio Valley, southward through the Mississippi Valley to the Gulf of Mexico, and to Mexico and Florida. The channel cat is bluish or olive above, fading to silver on the sides and white on the belly. As the fish grows larger and reaches maturity, it becomes darker. Although it may reach a weight of 25 pounds, five pounds is considered large. Two or three-pound fish are usually the most desirable for eating.

These fish will eat almost anything that comes their way. The hardiness of the channel cat, coupled with this omnivorous appetite, enables it to thrive in water that is not suited to other game fish. As food, the channel cat stands near the head-of-the-class. Its firm, flaky, white meat has an excellent flavor. It is relatively fast-growing, generally not affected by the low temperatures experienced in Texas.

The problem of off-flavor remains a major marketing problem, but can be controlled by maintaining proper water quality. Recent lifting of the restriction on the use of certain species in polyculture with catfish could possibly help alleviate this problem. Other high-production states allow some species of carp to be grown in the same ponds.

Until recently, the catfish industry in Texas was characterized by small "family farm" operations which sold directly to local customers. Lacking adequate processing facilities and marketing networks within which their products could be distributed, producers were forced to match the size of their operations to the size of the local market. As a result, these growers had no hope of competing with the mature markets in Mississippi, Alabama, and Louisiana. Louisiana, for example, had 14,080 acres of catfish ponds in 1990, bringing the state a $52 million farm-gate revenue.

With the advent of NAIAD's new processing facility in Brazoria County, Texas and the opening of two nearby feed mills (East Texas Feeds and Rangen Inc.) dedicated to production of pet foods and aquaculture feeds at least the potential is there for this industry to continue expansion. According to officials at NAIAD, 90 percent of all commercial catfish in Texas is processed at the Brazoria County plant. The 1991 processing production was approximately 18 million pounds, a 50 percent increase over 1990. This is because existing growers are increasing pond acreage and newcomers to the industry are developing larger operations to take advantage of the economies of scale provided by these new facilities. Although an estimated 1,500 to 2,000 additional acres supplied the plant during 1991, it is still operating at less than full capacity. This is because the company did not expand their own pond acreage during 1991 due to financial restructuring. To be fully efficient, the plant needs to process 60,000 pounds of fish per day. Current total acreage supporting the plant is approximately 2,500 acres. To remain operational, catfish are being transported from as far as Missouri.

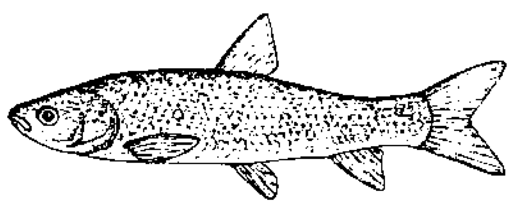
The outlook for catfish farming is still favorable. Texans eat over 100 million pounds of catfish annually; most of it is imported. There are only ten foodfish producers and an additional 11 fingerling producers in the state which advertise on a state-wide basis, even though there are 145 operations with permits.

The nation-wide average yield from a catfish farm in 1988 was 2,984 lbs/ac/yr. The price to the producers for those fish in 1988 ranged from $0.62 to $0.70/lb. In 1990 the price was $0.73 to $0.79/lb. and in 1991 was $0.72/lb, but dropped by years end to $0.53/lb. The average price to the Texas producers in 1991 was $0.77/lb. before the Spring rains. The Texas price dropped, just as the average U.S. price dropped, from $0.75/lb. to $0.50/lb. This likely induced the demise and financial restructuring of several large production and processing operations in Texas and Louisiana. So far in 1992, the average U.S. price is $0.53/lb. A recent study on the U.S. market for farm-raised catfish concluded that consumers perceive catfish as a nutritious, high-quality product that is easy to prepare. Catfish is recognized as a top seller in a majority of groceries and restaurants nation-wide (Arkansas Agricultural Experiment Station, 1990). However, while catfish production increased 16 percent nation-wide in 1989, it increased by only five percent in 1990 and three percent in the first half of 1991, totaling 195.3 million pounds (Fish Farming International, January 1992). In 1991, the U.S. produced between 370-380 million pounds of catfish, a three to five percent increase over 1990. The lower rate of increase is attributed to a decline in farm and processor prices resulting from deterioration of the general economy.

In view of the increasing market and recent infrastructure additions in Texas, the time seems right for expansion; but the poor economic environment presently hinders any such expansion. The Texas economy could benefit by developing this industry, keeping revenues and jobs in state. Texas catfish production growth in the past has been slow. In fact, during 1989, total sales of Texas produced catfish in Texas fell to $831,000-a 36 percent decrease from 1988. Several factors were responsible for this decline. First, over 221,000 pounds were lost primarily to floods in 1989. Secondly, several small operators, selling to the food-fish market, had difficulty marketing their unprocessed fish. The Brazoria County processing plant remedied this problem in 1990 and 1991. In 1989, Rainbow Lakes received a reduced interest rate on their bank loan by utilizing a TDA Linked Deposit. The loan enabled the company to build a 6,000 square foot operation containing a catfish processing plant, freezers and cooler space for storage of 30,000 pounds of fish. The company finalized all of its regulatory requirements and is now supplying local markets.

Danbury Fish Farms, southeast of Houston in Danbury, has been in operation since 1969. The company which specializes in recreational fisheries management and has a total of 500 acres of ponds and produces 30 different species of fish including catfish, has expansion plans. There are, however, other limitations to the industry. Inadequate natural resources pose the greatest restriction on aquaculture development, the most crucial of which is water supply. Areas which do not have access to authorized water suppliers are severely handicapped because water from run-off is inadequate in most areas during average rainfall years. Soil type, elevation, and topography represent the next greatest resource restriction on catfish farming. Most areas are flat enough to avoid any topographical problems that can increase pond construction costs and restrict harvesting, but insufficient elevation to properly drain farm ponds is a problem, especially in flood plain areas. In areas with open, permeable soils, improperly sealed ponds can cause problems.

Although catfish farming has adequate production technology and marginal infrastructure, it is not without risk. Substantial business risk results from a relatively narrow profit margin. Profit margins range from eight to ten cents per pound. This requires operators to be efficient managers and is one reason for the increase in farm size. Costs and returns for catfish farms with recirculating ponds along the upper Texas Coast have been covered recently in a manuscript by Lambreghts *et al.*, (1991).



Grass Carp (*Ctenopharyngodon idella*)

The grass carp (White Amur) is one of the largest members of the minnow family *(Cyprinidae)*. The species is native to large Asian rivers in China and the Soviet Union. In their native habitat grass carp typically reach weights of 65-80 pounds, but fish have been reported up to 400 pounds. Grass carp are easily distinguished from common carp in that they are more slender and have no barbels ("whiskers").

Reproduction in normal grass carp is influenced by temperature, age/size, and water conditions. Fish reach maturity when about four years old at weights of 9-11 pounds. Spawning occurs when water temperature rises above 68°F. Because grass carp eggs are slightly heavier than water, current during spawning is required to keep eggs suspended while they wait to hatch. In general, successful spawning takes place under rising water conditions in very long rivers. The number of eggs produced by each female is very high in normal diploid grass carp (fish with two sets of chromosomes in each cell). Females may produce over one million eggs in a season.

Grass carp fry begin feeding on microscopic animals, but by the time they reach about three inches in length they are virtually 100 percent herbivorous. Feeding is strongly affected by temperature. Active feeding begins at 45°-46°F and peaks at 68°-79°F. Whereas triploids feed at nearly the same rate as diploids, hybrids (a cross between a grass carp and a bighead carp), feed at substantially lower rates. Therefore, vegetation control is most efficiently achieved with diploid or triploid grass carp. These fish may consume more than their own weight in plant material each day. However, grass carp exhibit strong preferences for different aquatic plant species. Hydrilla and similar species are almost always most preferred, and control or elimination is usually assured if proper stocking densities are used. Vegetation control has been reported with stocking densities as low as two or three grass carp per vegetated acre.

Grass carp do not seem to impact native (North American) fish species directly, through predation or competition. However, their influence may be strongly felt in that vegetation removal can affect a wide variety of species by destroying feeding and nursery habitat. As a result, grass carp should not be stocked in areas where declines in plant-associated fish species is of concern.

Results of research with triploid grass carp indicate that soon after stocking, fish become associated with aquatic vegetation. Subsequent movement of fish is a function of size and age. Older, larger fish tend to move more than young grass carp. As a result, fish should be stocked in ponds with no outlets, or barriers should be used to prevent escape.

Grass carp were first introduced into the United States in 1963 by the U.S. Fish and Wildlife Service, and were used in experiments at the Fish Farming Experimental Station, Stuttgart, Arkansas. They were first legally introduced into Texas in 1981. At that time 270,000 were released in Lake Conroe as part of a scientific experiment to determine their usefulness, effectiveness, and safety. Total elimination of aquatic vegetation was soon achieved.

Currently, grass carp are allowed for vegetation control in 35 states. Of those only ten allow diploid fish. As a result of diploid stocking in the central U.S., grass carp are reproducing in the Mississippi and Missouri rivers, as well as in a number of major tributaries. There is the possibility that reproduction may occur in some Texas waters if diploid fish are allowed in the state. Therefore, to guard against the possibility of unchecked reproduction (and the environmental problems that could result), the TPWD will allow the use of triploid grass carp only.

The TPWD approved controlled use of triploid grass carp on January 23, 1992. Triploid grass carp have been altered in the egg stage with heat or pressure so that three-rather than two-sets of chromosomes are present. This renders the fish functionally sterile. Triploids are as effective as normal diploids for control of submerged vascular aquatic plants (any kind of "moss" other than algae). Minimum stocking rates for specific situations are still unknown, but TPWD will not approve permits requesting more than seven fish per acre.

Grass Carp in Texas

As of March 1, 1992, use of triploid grass carp became legal in Texas. However:

- To possess triploid grass carp, a valid Triploid Grass Carp Permit is required.
- To sell triploid grass carp, a valid Exotic Species Permit is required.
- It is ILLEGAL to possess DIPLOID grass carp in the state of Texas
- Permits are required for stocking these fish in private ponds or tanks by private landowners.
- Fish must be purchased from a licensed, permitted, resident fish farmer.
- A private landowner can haul 30 fish or less himself. More than that must be delivered by Exotic Species Permit Holder.
- A maximum of seven fish per acre will be allowed at this time.
- Cost will be $15 plus $2 per fish above the purchase cost.
- Private landowners can not sell, give away, or otherwise dispose of the fish, except for personal use as food.
- Fish smaller than 12 inches should not be stocked into ponds with large bass, and fish smaller than eight inches are not recommended for stocking.
- The number to stock will vary depending on type of weeds, depth of water, and amount of weeds in the pond.
- They will eat floating or sinking pellets and compete with catfish.
- If all weeds are removed, more muddy or cloudy water can result with increased bank erosion.

The preceding information on grass carp was provided as support material for the catfish industry, not for grass carp aquaculture as a food source.

Aquatic Plants

According to TDA (Figure 2), production of aquatic plants in Texas constituted a $2.4 million industry in 1989. Six growers in Texas produce ornamental waterlilies and aquarium plants. In the past, much of the aquatic plant harvest came from the wild, but this is not the case now.

Crawfish

Crawfish, (which may be called crayfish, or other local names), are found in freshwaters on all continents except Africa. There are more that 300 species worldwide, over 100 species in the United States and 29 known species in Louisiana. In size and color, variation is extremely wide: the dwarf crawfish of Louisiana reaches full maturity of about one inch in length, while the Marron crawfish of Australia reaches a length of 16 inches and a maximum weight of four pounds. The world's largest freshwater crawfish is a Tasmanian species which attains a weight of eight pounds.

Crawfish culture has taken place historically in the South, especially in Louisiana. Although some production (primarily of the red swamp crawfish, *Procambarus clarkii)* exists elsewhere in the U.S., the majority of the total U.S. supply still comes from Louisiana's wild catch in the Atchafalaya basin. Louisiana's crawfish aquaculture industry actually peaked in 1988 with 135,000 acres under production. In 1990, there were 105,600 acres under production, generating a farm-gate value of $35 million. According to the March, 1992 issue of Aquaculture News, Louisiana's crawfish culture acreage now is estimated at 90,000. Texas has approximately 1,600 acres in crawfish aquaculture production. Still, the majority of the U.S. production is wild-caught. This harvest is totally dependent upon the water levels which occur naturally in the basin, and is extremely variable. The markets in Texas and elsewhere are greatly affected by the availability of crawfish in Louisiana, and this market is very unstable. During a good year, when supplies are high, the price of crawfish has dropped from $0.40/lb. to $0.22/lb., just because the basin production "floods" the market. Louisiana produced 71 million pounds of crawfish in 1991 worth $31 million (Aquaculture Magazine, 1992).

A moderately strong demand for crawfish exists in Texas for food and bait . Production totals and acreage farmed are difficult to determine because the crawfish industry, like most subsectors of Texas aquaculture, has no accurate and dependable reporting mechanism. For example, industry officials reported an estimated 5,000 acres in production in 1988, but a survey conducted by the Texas Agricultural Extension Service from November 1987 to June 1988 reported that the current production base was 1,610 acres, 81 percent of which is located in Chambers, Jefferson, Liberty, and Orange counties. Just over 600,000 pounds of crawfish were produced in Texas during the 1987-88 season. (See TAEX Pub. B-1661 for further details concerning Texas crawfish aquaculture). This 30-page report addresses current industry conditions, marketing activities, and producer thoughts about issues confronting the industry. Some feel that the difficulty in obtaining production data is a result of inadequate marketing strategies. Because there is no established network for crawfish, producers are forced to become marketers, as well. This often results in the product being sold locally, as most farmers lack the time and expertise to promote their products. Marketing strategy used by Texas crawfish producers is to say that "cultured Texas crawfish are superior to the wild-caught Louisiana variety because they are generally purged prior to sale." The truth is that many Louisiana crawfish producers purge too. The purging process, which involves holding the animals in clean water without food for a period of 24 hours, allows them to clear their gut, thereby greatly improving their quality and shelf-life.

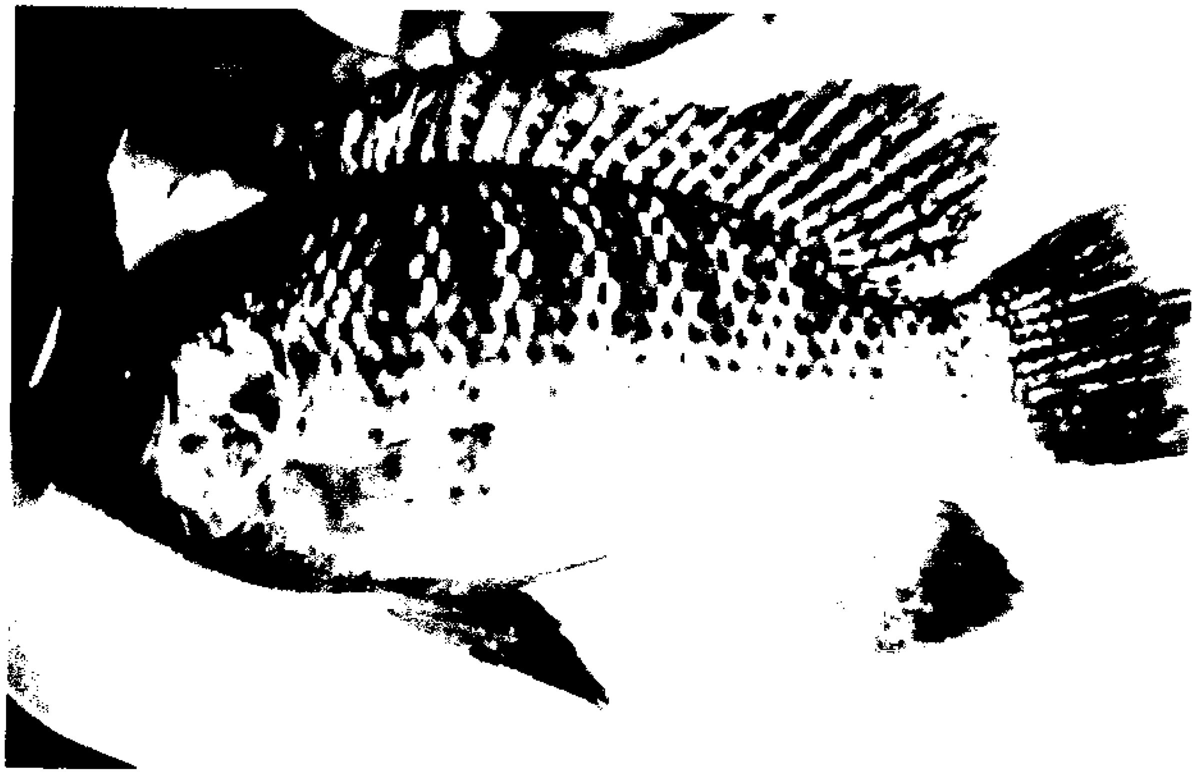
Further expansion of the crawfish industry will hinge on research and development. The soft shell crawfish market provides an example. Crawfish farming relies heavily on natural reproduction, and if a dependable hatchery system was developed, some type of selective breeding could begin. Breeding for larger crawfish and increased yields per acre might help crawfish compete with shrimp in the marketplace (USDA, 1991). According to Jay Huner (of Louisiana), in the future crawfish producers need to put high priority in developing crawfish producing equipment including peeling machines and meat-bone (shell) separators to recover usable meat from peeling wastes. Furthermore, the industry needs to continue to emphasize the production of large, high value crawfish for the live market because it is unlikely that the growing Chinese competition can deliver live crawfish to the U.S. and still make a profit. Recent advances in crawfish feeds have been attributed to one Matagorda County crawfish farmer's success. He states that, "after all of these years, I am finally making some money".

Sportfish

Black bass have been cultured in the U.S. since 1890. Until the late 1970s, TPWD supplied pond owners with free fish in Texas. Since then the private sector assumed the role ot providing fish. Florida black bass, introduced into Texas in the 1970s, generated much interest. The private sector generally utilizes open pond culture, whereas State and Federal facilities generally use tanks, raceways, and ponds.

There are approximately 15 sportfish producers in Texas who advertise regularly. The private sector consists of approximately 250-300 acres, and State and Federal agencies maintain approximately 150 acres. Private facilities produce 1-3" bass and sunfish for stocking, which constituted a $1.5 million industry in 1989, according to TDA (see Figure 2 for 1990 and 1991). Industry production is generally leveling off.

This industry suffered from drought problems until recently. Some of the other problems facing this industry in Texas are: predators, such as cormorants; competition by government sources producing fish; and out-of-state competition.



Tilapia

Tilapia is a tropical freshwater fish originating from Africa and Israel. Records indicate that Tilapia were caught in the Sea of Galilee as early as 2500 B.C, and they were marketed as Saint Peter's fish for some time. Paintings of tilapia have been found in the tombs of Egypt, and there are at least 50 known species world-wide. It is an increasingly important food fish in many regions of the world. Taiwan, for example, has 26,000 acres devoted to tilapia with an annual yield of 100 million pounds, and world production of tilapia is estimated at one billion pounds a year. Two species of tilapia (*Oreochromis mossambicus* and *Oreochromis aureus*) and their hybrids are currently being produced in Texas. These are not necessarily the fastest growing species of tilapia. There are others such as O. *niloticus* and O.*hornorum* which grow more rapidly, but are not allowed. Introduced from Africa and Israel, they are classified by TPWD as exotic species and as such are heavily regulated. Permitting restrictions are meant to ensure that these fish do not escape their impoundments and enter the wild.

Tilapia are utilized for food in much of the world, although some are used for aquatic vegetation control. They resemble sunfish and are the second most widely cultured group of fishes in the world today, surpassed only by the carps. Tilapia were introduced into Texas during the 1960s. Tilapia have been reared and marketed successfully in Texas. Their primary advantage is hardiness. However, the primary concern in Texas is that tilapia begin to die when the water cools to about 50°F. The fish begin to reproduce at a very early age, often before they are six months old. Tilapia eat pelleted feeds, some types of rooted aquatic plants, and may indirectly limit aquatic vegetation through increased turbidity.

The very attributes that make them a favorite with aquaculturists are restricting their development. Tilapia are probably the most prolific and hearty species in production. They grow exceedingly well in intensive environments and varying water qualities. Tilapia grow rapidly on commercial feeds, and do not suffer handling and transportation stress like many other species and require less management than catfish. They can grow as much as 300g within one season in Central Texas and perhaps an even greater production is possible in South Texas, but has not been tested. Because tilapia are so strong, officials at TPWD fear their introduction into the environment would be harmful to native fishes. However, there is evidence that tilapia have already been well established. TPWD has indeed stocked tilapia in many lakes as forage fish for red drum. Tilapia cannot be raised in floodplains without special safeguards which greatly increase the cost of pond construction. This limits development in many coastal areas.

Like redfish, tilapia are sensitive to cold temperatures. They also must be transferred indoors when temperatures fall below 55°F. Some producers in Texas are raising tilapia in indoor systems. One such company in Fort Bend County has an indoor hatchery and outdoor grow-out ponds. Greenhouses have been built for overwintering purposes. In 1990 tilapia production in Texas was valued at $550,000. Production increased in 1991 and is expected to expand even more in 1992. Tilapia is relatively unknown in many parts of Texas, and consumer acceptance is key to further expansion of the industry. Other areas such as New York have marketed the red hybrid as "cherry snapper". The Food and Drug Administration (FDA) stopped this when they began to require truth in labeling of foods. Some competition from imports, mainly from China, pose a problem, and there are no known processing plants for tilapia in Texas. A prominent retail grocery chain recently conducted a customer satisfaction survey on tilapia. They reported that 80 percent of their sales were repeat customers. To reduce processing costs, tilapia are usually sold to grocery chains either gutted and packed in ice, or live. The live fish are displayed in tanks. Once purchased, the butcher dresses the fish for the customer. One producer contracts with an out of state restaurant chain.

Some industry experts feel the regulatory restrictions on tilapia are unwarranted. Should these restrictions be lifted, many people see tilapia as having the necessary characteristics to make it a major factor in aquaculture in Texas. The U.S. Department of Agriculture recently reported steadily increasing production nationwide (USDA, 1991). It is reported that over the last several years tilapia in the U.S. has grown from practically nothing to an estimated six million pounds (live weight) in 1990. The American Tilapia Growers Association estimated an even higher production for 1991. USDA (1992) reports that nine million pounds of tilapia imports entered the U.S. through Southern California alone. Most other states are not as restrictive in their regulation of tilapia production.

Texas produces over 500,000 pounds of tilapia annually. Average price received from grocers and wholesalers is $1 per pound while costs average $0.60 per pound. A 20 percent increase in production was realized in 1991, and one new facility was started in Waller County.

Baitfish

Baitfish (goldfish, golden shiners, fathead minnows, etc.) production generates a $250,000 industry in Texas each year (from approximately 100 acres). This only makes up a small portion of the demand. More than $10 million of baitfish are transported each year from Arkansas to Texas. The industry in Arkansas became well-established in the 1950s and 1960s. In 1972, that state had 30,000 acres of golden shiners.

The production from bait facilities ranges from 250-1,000 lbs/ac and the U.S. industry average is 600 lbs/ac/year. Consult the "Manual for Baitfish Culture in the South" (U.S. Fish and Wildlife Service and the Arkansas Coop. Extension Service) at the University of Arkansas at Pine Bluff for more information on this subject. Larry Dorman and Dr. Carole Engle, from the University of Arkansas at Pine Bluff, have published economic analysis information on bait-fish feeding strategies. Dorman and Engle prepared a budget so breakeven price could determined. The computerized economic analysis compared net economic returns with yield, increasing feed prices, and a combination of increased feed price and different yields. They found that less money is lost if production is maintained. When production yield is decreased 14.3%, the net economic return declined 22.%. As feed prices increased 38%, net returns declined only 10%. They concluded that baitfish production has a relatively low production for high fixed costs. Therefore, profits are more sensitive to changes in yield and less sensitive to changes in feed cost. This analysis shows that substituting a lower quality feed reduces yield (lowering net return) more quickly than increasing feed prices. For more information, contact: Larry Dorman, Lonoke, Agriculture Center, P.O. Drawer D, Lonoke, AR. 72086.

Some of the problems in the industry are: aerial spraying; minimal baitfish research facilities; and many predators (birds, frogs, snakes, turtles, dragonfly nymphs).

Ornamental/Tropical Aquarium Fish Production

The following information was provided by Brian L. Brawner (Aquaculture Division of Red Ewald, Inc.):

Production 8-10 farms.

- one large koi producer in Brazoria County.
- one large (18 ponds) tropical fish producer in West, TX (Colorado City) mostly livebearers.
- Four to six farms, two to four ponds and/or indoor tanks-mixture of livebearers, egglayers, angels, cichlids, etc.
- Also., numerous "garage shop" operations scattered across the state mostly angels and other cichlids.

In Texas there are approximately 530 retail shops and 20 wholesalers (per Gabriel Ojeda, Fritz Chemical). This does not include places such as Winn's, Walmart, etc. that also carry fish.

Livebearers - platies, guppies, swordtails, mollies, etc.
Egglayers - gouramis, danids, barbs, tetras, cichlids, etc.

Standard production ponds for tropicals - 80' x 20' x 5'deep. Koi and goldfish ponds are often larger.
Florida tropical fish business valued at $32.8 million during 1991 (Aquaculture News, July 1992).
U.S. imported approximately $36 million of tropical aquaruim fish, mostly from Southeast Asia in 1991, (USDA Outlook Report, 1992, Spring).

Drawbacks:
- Cold winters can kill fish without adequate protection (greenhouses, buildings, etc).
- Lack of product diversity (most retail shops and some wholesalers prefer to "One-Stop" shop).
- Industry is spread out across the state (in Florida at least 75% of industry is in a 3-county area).
- Little or no research in Texas on ornamental/tropical fish culture.
- Slim to moderate profit margins.

Advantages:
- Available markets.
- Reasonable resources (land & water).
- Moderate startup costs for small farms.
- Little regulatory pressure (may not last).
- Current movement by the Ornamental/Tropical Section of the Texas Aquaculture
- Association to organize and promote Texas products.

Most producers in Texas have made progress and have gained knowledge through trial and error. Very little published information or research is available for this industry.

Alligators

The following background on alligators is from the TDA and Fish Farming International (1992):

The legal and illegal hunting of alligators reached such proportions that wild populations declined sharply throughout the 20th century. Alligators were placed on the endangered species list in the early 1970s. In the 1970s, Louisiana, Texas and Florida made concerted efforts to increase the number of alligators by operating state-run hatcheries. Eggs collected in the wild by state employees or licensed gatherers were gathered seasonally and taken to state facilities. Hatching rates in controlled facilities reached the 90 to 95 percent rate throughout the 1970s, spurring a dramatic comeback in the alligator population when young alligators were returned to the wild. In 1987, alligators were officially removed from the endangered species list but are still closely monitored.

The most important role of state governments in the development of the alligator industry was in bringing the species back from the brink of extinction. Several Gulf Coast states provided additional assistance to the industry beyond simple conservation efforts. As early as the late 1970s, surplus alligators from state facilities were provided to research farms and later to commercial growers in Louisiana and Florida. Both states aided the development of the industry by conducting market research and production research aimed at improving the commercial farming industry.

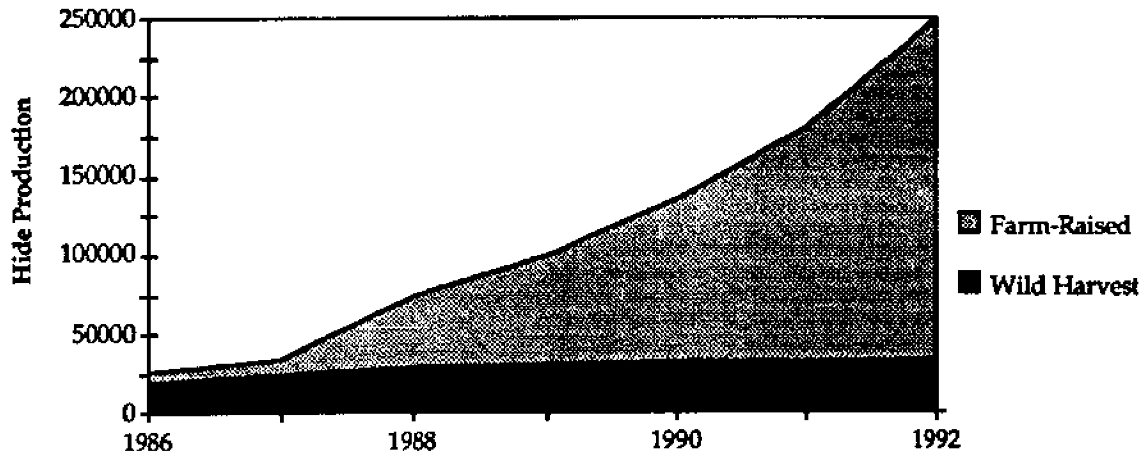
World demand for hides varied between an average of 150,000 and 300,000 hides per year during the 1980s. Today world production has passed 400,000 hides per year. According to a University of Florida study, an estimated two million hides will be needed to meet demand by 2000.

Current world demand could be sufficient to support an American industry of up to 80 farms assuming each farm had no more than 500 alligators, according to an estimate from the University of Florida, but Asia and Africa are expected to become strong competition in the market.

U.S. alligator farming has grown rapidly over the past decade primarily because of the recovery of wild populations, new production techniques and growing demand for alligator skins and meat. Alligators can bring $35 per linear foot and up for hides. The by-product meat brings about $4.50 per pound. This means a four-foot farm-raised alligator has a value of between $155 and $225 per animal including meat and hide. In 1989 the average carcass value for wild caught alligators was $358. Prices may drop if markets are filled. Prices did drop in 1991, but are rising again.

The U.S. produced 100,507 alligator hides in 1989, a 248 percent increase over 1986 farm produced alligators. Production is projected to increase another 100,000 hides by 1992, when almost 250,000 four-foot alligator hides will hit the market (see Figure 4).

Figure 4. U.S. Alligator Harvest



Source: Fish Farming International (Feb. 1992)

The American alligator farming industry is expected to continue growing with most producers planning on increasing the size of their operations. These increases will depend, however, on the strength of the market. As these hides enter the market, plus the Asia and Africa hides, hide prices are projected to drop to $16 to $20 per foot. To compensate for a portion of these low prices, alligator producers have two immediate opportunities to improve their cash flow.

First, market development for alligator meat will be essential because an estimated 1.6 million pounds of meat will be available soon. On a farm level, alligator meat from a four-foot animal brings an average of $16-20 per animal, or between $2.50 and $6 per pound. On a retail level, alligator meat is often marketed as a novelty item and is popular with many American restaurants. In Rhode Island, grilled alligator medallions sell for $19.95 per plate and fried gator tail in Florida sells for $6 per plate. Continued market development for alligator meat will allow producers to minimize waste and maximize product use and profit.

Second, tourism is another potential addition to an alligator farm. Monies generated from tourism can add considerably to the total revenues of an operation with a good tourist location.

Early alligator farmers raised alligators in open ponds, but the current trend is toward production in enclosed facilities. Concrete ponds covered by sheet-metal sheds now house thousands of alligators in Florida, Louisiana and Texas. Raising alligators indoors reduces stress on the animals and losses due to predation. These insulated buildings are kept at temperatures in the high 80s to low 90s to speed alligator growth. Under controlled conditions, alligators can reach a market size of four to five feet in less than two years. Conversely, alligators grown in the wild take five to six years to reach four feet and nine to ten years to achieve over six feet in size. Indoor production could conceivably operate in many areas of Texas which have adequate water supply.

According to The Aquaculture News, Mar. 1992 there are 120 farms in Louisiana, forty in Florida and Texas, two in Alabama, four in Georgia and Mississippi has five.

Louisiana currently produces 70 percent of the nation's alligator hide supply. In 1986 the Louisiana hide market was primarily dependent on the wild harvest. This situation has been reversed as alligator ranching programs have been initiated. In 1989, a total of 74,000 hides were harvested in Louisiana, and farm-raised alligators accounted for almost 70 percent of the supply. By 1995, it is projected that Louisiana will harvest 80 percent of its alligator supply from farms and will produce about 75 percent of the total U.S. supply. In 1990, 300,000 eggs were harvested in Louisiana and sold to farms. Then farms produced 90,000 alligators, creating a $24.5 million farm-gate (LA. Co-op. Ext. Ser., 1991). Louisiana's operating costs per animal for a farm with a herd above 3,000 is about $30. One half of the expense is feed. Alligators are usually fed dry pellets, fish, chicken, beef, nutria and horse meat.

According to the latest estimates from Fish Farming International, (Feb. 1992) the U.S. in 1992 will produce some 250,000 alligator hides, most of them coming from farms. (Figure 4.). Louisiana's farm output has reached 150,000 for the standard four-foot farmed alligator hide. Hides from wild alligators may bring above $50 a foot, but these are often seven feet in length. Customers are mostly companies outside the U.S., which process the hides and manufacture the finished products.

Florida shows a growth pattern similar to Louisiana with the farmed alligator harvest exceeding the wild harvest as new farms come on line. In 1986, Florida's wild and farm harvests were almost equal at about 4,000 hides each. The gap between the wild and farm harvests has grown to 8,000 alligators harvested from the wild and 16,386 from farms in 1989. The farm production is projected to increase to 58,000 hides by 1995 with 25 percent from wild and almost 80 percent from farms.

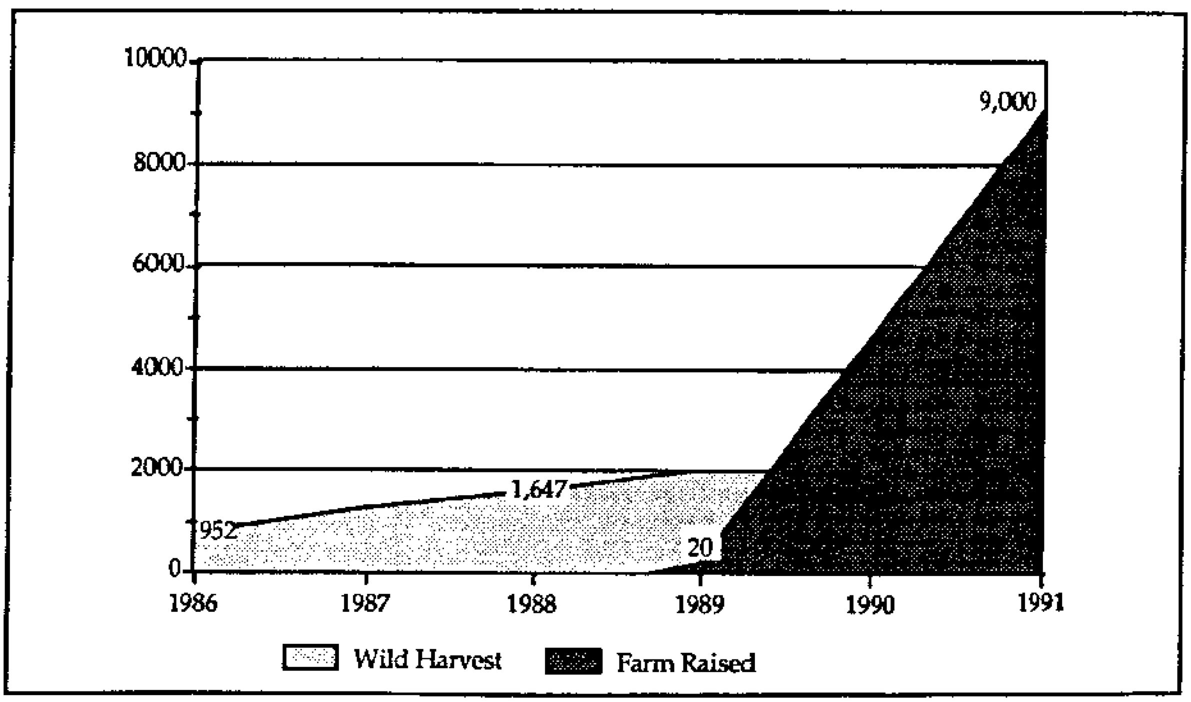
The Rockfeller Refuge (Research), and the Louisiana State Wildlife Dept. have produced a very informative video on alligator farming, as a result of years of research.

Alligator industry development trends in Texas

The industry is developing in Texas. Many farms are in their pre-production phase. That can last anywhere from a year to four years, depending on whether the operation is a grow-out facility for young alligators or a fully integrated farm with an established breeding program.

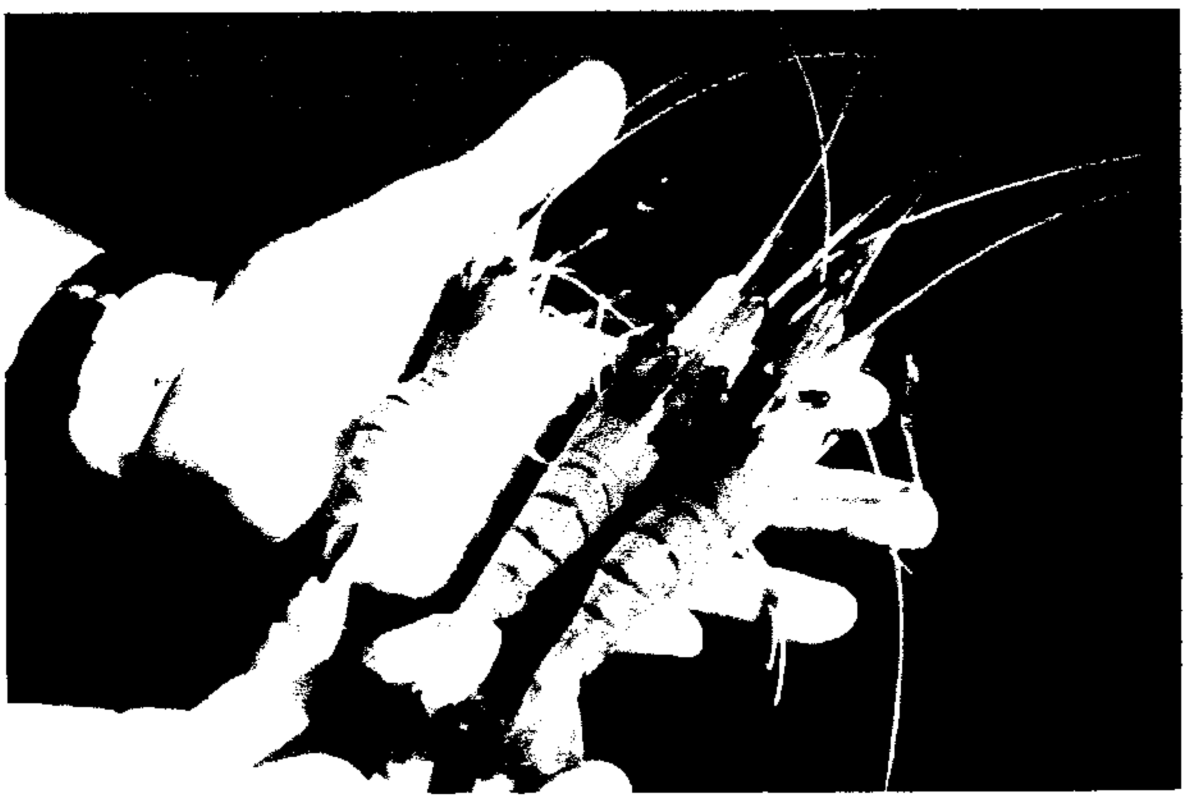
According to TDA, Texas had 24 licensed producers in 1990, up from 1989. Only half of these licensed producers are pursuing commercial operations, and the others keep alligators as "pets". Virtually all of the state's production is located in East and Southeast Texas. Texas production has primarily been from alligators harvested in the wild. In 1986, only 952 wild caught alligators were sold, and by 1988 the wild harvest increased to 1647 hides. The first sales of Texas farm-raised hides occurred in 1989, when 20 hides were sold. Texas growers produced 9,000 hides in 1991 according to Fish Farming International, 1992 (see Figure 5). Dr. Bill Harvey, director of special programs, fisheries and wildlife division of TPWD, estimates that there are 20,000 alligators on Texas farms. According to Dr. Jim Davis, (personal communication), one alligator farmer has 8,000 gators approximately 4 feet long, but only has a market for 1,000 to 1,200. The TDA projections for alligator growers are much more conservative. They projected that Texas growers would not reach the 5,000 hide level until 1995.

Figure 5. Texas Alligator Harvest



Alligators are a valuable segment of Texas aquaculture primarily because of hide sales. Although a market for the meat exists, there are currently no certified meat processing plants in Texas. Prices obtained in Texas are essentially the same and have ranged from $30 a foot for a farm-raised hide to $52 a foot for hides harvested from the wild. Both Texas and Louisiana allow a certain number of wild animals to be harvested in order to control populations (25,000 annually in Louisiana and approximately 1,600 in Texas). Because of the length differential between wild and farm-raised alligators, this practice has a significant impact on total revenues. Alligator farmers in Texas are having the most success by raising the animals in indoor facilities. By carefully controlling the water and air temperatures and lighting (alligators prefer dark environments) an alligator can be raised from a hatchling. Beyond the four-foot length alligators grow much less rapidly, resulting in higher production costs. In the wild, an alligator usually averages a growth rate of one foot per year. Recent experiments with a high protein (57 percent) feed have produced faster growth rates than the usual feed mixture. This technique may reduce production costs and eliminate the necessity of maintaining a cold storage facility on site. The cost to raise an alligator to the four-foot length varied depending on the size of the operation, but can be as low as $26. One alligator farm in Crescent, Texas was hurt badly in 1991 when the price of hides dropped.

Alligator regulations were recently modified by TPWD. The eight member Alligator Resources Advisory Board, made up of a broad range of alligator users and constituents, suggested to the TPWD Commission that the fees be increased to $10 for wild caught alligators and lowered from $5 to $4 for each farm-raised alligator. The farmers had been paying the same hide tag fee for alligators worth less money. Another change will allow alligator farmers to get tags from some field offices instead of from TPWD headquarters in Austin. (Source: Texas Parks and Wildlife News, 5/29/92).



Freshwater Shrimp *(Macrobrachium rosenbergii)*

In 1974, Sun Oil Company established a pilot freshwater shrimp farming company (Aquaprawns, Inc.) near Brownsville, Texas. The firm developed several new techniques for cultivation of freshwater and saltwater shrimp, including use of a harvest pump. In 1978 Sun closed its non-petroleum related subsidiaries and a new company (CSCI, managed by Durwood Dugger) was formed. In 1980, CSCI built a 68 acre freshwater shrimp farm. The operation was located several miles inland, but used saline ground water to operate the hatchery. Even though they are called freshwater shrimp, a certain part of their life cycle is spent in salt water. The natural life cycle involves the adult shrimp migrating down rivers to estuaries to have their young; juveniles return to the rivers to complete the cycle. CSCI produced large amounts of shrimp, but closed in 1985, unable to find a large enough high-value market for the product.

Freshwater shrimp require brackish water (12-15 ppt) for larval development and can tolerate up to five ppt in their growout. They are tropical in temperature requirements and might represent a summer growout opportunity in west Texas with low-salinity ground water, assuming the farmer has developed an adequate market for his product in advance of production. At least three companies in Texas produce and sell of freshwater shrimp. In Cameron County (Sweet Water Aqua-Farms Inc.), re-opened the CSCI farm in 1989, raises freshwater shrimp to market size, and distributes them nationwide. In 1990, this company produced 1,200 pounds of red claw, as well as 21,000 pounds of freshwater shrimp (*M. rosenbergii*. Although the numbers are not large when compared to marine shrimp production, these animals are considered specialty items and bring premium prices. The freshwater shrimp are shipped fresh (killed and shipped heads-on at 35 to 38°F). Unfortunately, this farm suffered the loss of 22,000 pounds of shrimp (valued at $254,540) due to an early cold front in November, 1991. The owner said that he was able to save the broodstock and that he still made a little money, despite the freeze loss. He plans to increase the crawfish output to 10,000 pounds per year and double the freshwater shrimp crop.

Freshwater shrimp postlarvae are quite expensive relative to saltwater shrimp (generally selling for $27/1000 from Hawaii or Puerto Rico). Saltwater shrimp postlarvae generally sell for $8-10/1000 if purchased in the U.S., less if purchased from South America. The larval cycle is longer for the freshwater shrimp (25-45 days), whereas the saltwater shrimp cycle generally takes 18 days. Cannibalism has been a major problem in the freshwater shrimp industry. The larger shrimp prey upon the smaller ones. Producers of freshwater shrimp provide habitat or hiding places, vegetation in the pond and harvest the larger animals routinely to minimize the problem. Another problem faced by the freshwater shrimp industry in the U.S. is that two thirds of the animal is head and one third tail muscle. Most producers are forced to sell the product fresh, head-on.

Australian Redclaw Crawfish *(Cherax quadricarinatus)*

The Australian Redclaw Crawfish *(Cherax quadricarinatus)* has been mistakenly called a freshwater lobster by some and is currently produced in a hatchery near Friendswood, Texas. The owner of Texas Freshwater Lobster (Paul Boyd) reports that he sells only juveniles and broodstock at this time but expects to open five acres of growout ponds in Brazoria County, Texas. Ray Tharp (also in the Houston, Texas area, telephone (713) 442-8262, has plans to enter production. Marshall Schnider, of Sweetwater Aqua-Farms, Inc. in Cameron County, Texas produced 1,200 lbs. of the redclaw in 1990 and distributed them nationwide, live via Federal Express. He plans to increase production to 10,000 pounds per year. The redclaw appears poised on the threshold of a bright future in aquaculture as interest in the farming of this freshwater crawfish spreads. The following information is taken from INFO-FISH INTERNATIONAL (1992).

The redclaw is a freshwater crawfish of the family *Parastacidae*, which comprises over 100 species in Australia. Other members of the genus include the yabby, *C. destructor*, and the marron, *C. tenuimanus*, both of which are commercially farmed.

The redclaw has a tropical distribution, being found in river systems between Cape York and Darwin in Australia, and in the southern part of Papua New Guinea and Irian Jaya. Within this range the redclaw usually inhabits turbid, slow moving waters and is often found in clay-based billabongs with over-hanging vegetation. It has also successfully colonized several man-made impoundments. Despite the many positive attributes of the redclaw in terms of aquaculture, interest in farming only developed in the mid to late 1980s, after the failure of marron farming in Queensland. Prior to that the species was relatively unknown, a consequence of its remote distribution. There is no commercial fishery based on natural populations, and recreational fishing is limited to isolated areas adjacent to townships.

Physiological Tolerances

The redclaw exhibits fast growth rates over a comparatively broad range of temperatures. Growth rates in excess of 70 percent of maximum growth rate occur between 23°C and 31°C and lethal temperatures have been estimated to be below about 10°C and above 35°C. In comparison, the temperature-growth relationship of the giant freshwater prawn, *Macrobrachium rosenbergii* (which cohabits the same river system with the redclaw), indicates a much narrower temperature tolerance.

Salinity tolerance experiments have indicated that the redclaw will tolerate reasonably high salinities for extended periods. Redclaw maintained for 21 days in salinities up to 12 ppt (1/3 seawater) are unaffected. This has two advantages. Firstly, farming in low salinity water is feasible, and secondly the physiological impact of saline results in a significant improvement in flavor.

The redclaw also displays an extraordinary tolerance to low dissolved oxygen levels. When dissolved oxygen is very low, the redclaw can continue to respire anaerobically through a process called glycolysis which produces lactic acid as a byproduct. This mechanism will sustain the animal for several hours. When oxygen levels rise, the normal aerobic respiration takes over and the lactic acid is metabolized.

Although specific assessment of the redclaw's tolerance to other parameters has not been made, it is clear from general experience that it is physiologically robust and will tolerate extremes that many other species would find lethal.

Feeding and Growth

The redclaw is a detritivore and is thus capable of obtaining much of its dietary requirement from natural productivity within earthen ponds. Microbial organisms (primarily fungi and bacteria) associated with decaying organic material are high in protein. Thus, food for the crayfish can be generated by low-cost measures such as fertilizing the pond to promote natural productivity, adding simple organic material (*e.g.* hay) and feeding low protein, cereal-based formulated diets.

Growth of the redclaw is dependent on the prevailing physical conditions (primarily temperature) and the type of nutrition. In addition, there is considerable variability in growth rate between individuals. Generally, however the redclaw will achieve a size of between 60-120 grams in one year. Although a maximum size in excess of 400 grams is possible, growth rate slows appreciably after the first 12-18 months and commercial production of crawfish larger than 150 grams is not likely to be viable.

Reproduction

The reproductive characteristics of redclaw are well suited to aquaculture. Both males and females mature at 6-9 months of age (approximately 40-60 grams for both sexes) and will mate and spawn continuously while suitable temperature conditions prevail.

After mating, the fertilized eggs are carried beneath the tail of the female who nurtures them during the incubation period. The number of eggs carried is dependent on the size of the female and will vary from around 300-1000 per brood. The eggs change color as they develop, from an olive green at spawning through darkening shades of orange to red at hatching. The incubation period is also temperature dependent, and may range from 6-10 weeks. All larval stages are completed within the egg. The hatchlings have the adult form, and are about 8 mm long when newly hatched. They remain associated with the mother for about 2 weeks, and are fully independent at a size of about 12 mm.

The breeding, hatching and nursery phases can be managed within an earthern pond system. This permits large scale juvenile production with a minimum of capital expenditure and technical expertise.

Diseases and parasites

Aquaculture of the redclaw is significantly advantaged by a lack of potential disease problems. The only pathological disease identified to date in wild stock is *microsporidiosis* or "white tail".

Response to water currents

A highly advantageous characteristic of redclaw specifically in regard to harvesting is its response to water current. Like many freshwater species, the redclaw responds to flowing water by moving upstream. This response is particularly strong and has been incorporated into harvesting procedures through the development of flow traps. These traps are of various designs, and many farmers are now incorporating screens in the flow traps to facilitate size-selective retention or escapement, and thus automatic grading.

Marketing characteristics

In appearance, the redclaw resembles a true lobster. This association is of value as lobsters, including the clawed marine lobsters (*Homarus sp* and *Nephrops sp* and spiny rock lobsters (*Panulirus sp* and *Jasus sp*) represent the top end of the crustacean market.

Presentation-wise, the redclaw has an attractive appearance both live and cooked and is easily recognized as a crawfish. From a size perspective, the redclaw is larger than typical marine shrimp and smaller than marine lobsters. Meat yield (tails and claws) from boiled redclaw averages about 27 percent of the total weight of the animal.

A further marketing advantage is conferred by the ability of the redclaw to be held out of water with a minimum of stress. Providing the crawfish are kept cool and moist, they can be maintained for at least several days. Transport costs can be kept to a minimum, and it is a simple matter to supply live animals to distant markets.

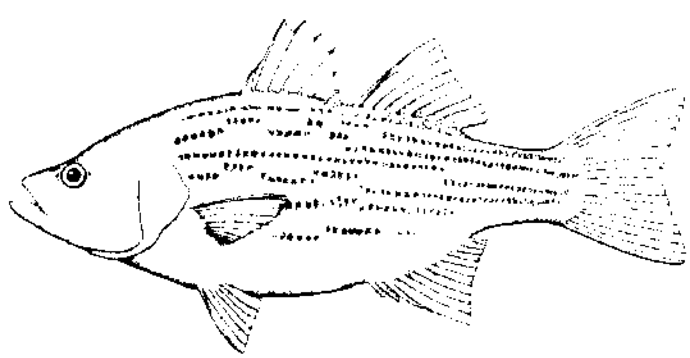
The redclaw rates well against other crustaceans in taste panel evaluations. The flavor can also be enhanced by holding animals in salt water, although this is presently not done commercially.

Industry development

Production of redclaw in Australia is presently about 50 tons per annum and in Texas is expected to increase to 5 tons per annum. This low level reflects the very new state of the industry, with farmers having to learn by experience rather than from established technology. Production should expand in the near future both in Australia and Texas.

Virtually all farms are semi-intensive, and use earthern ponds varying between 0.1-1.0 ha. Some farmers have reported yields in excess of 4 tons/ha/annum, but the average yield is considerately lower.

In 1990/91, prices for redclaw ranged between A$10 -20/kg with the average price received by Australian growers being A$14.45/kg and the average price to Texas growers is comparable.



Hybrid Striped Bass

Hybrid striped bass are a cross between striped bass (*Morone saxatilis*) and white bass (*Morone chrysops*). The original range of these species in the wild was from Nova Scotia to the Gulf of Mexico. They were introduced to the Pacific Coast of the U.S. in the 1800's and now have spread from British Columbia to Mexico. They survive in a wide range of environmental conditions, but optimum growth occurs in the 25-30°C temperature range and salinity 0-25 ppt. Hybridization occurs occasionally in the wild, but most of the current stock is commercially produced. Hybrids of the two have done better than wild stocks in aquaculture environments. The first cross was accomplished in South Carolina in the 1960's. There is a national market for hybrid bass as a food fish. Twenty-four states currently culture this species. They are generally cultured in fresh water, but may adapt to salt water. Commercial culture of the hybrid striped bass in the U.S. grew from zero in 1982 to 890,000 pounds in 1989. According to Aquaculture Magazine (1992), 1.5 million pounds in live-weight fish were produced in 1990 at U.S. aquaculture facilities, and 20 growers produced two million pounds in 1991. The price of the wild-caught fish (then at $1.40 per pound) was lower and was influencing the price of aquaculture fish. Restrictions have been placed on commercial fishing in areas of the northeastern U.S. due to decreasing fish populations. Total U.S. commercial landings of striped bass were less than 300,000 pounds in 1989 and 1990. Production of hybrid striped bass is increasing rapidly in other states, especially North and

South Carolina. Recently, legislation in Texas (HB 1105) has made it legal to produce hybrid striped bass for human consumption and allows sale of all farm-raised freshwater native fish for food other than largemouth bass. Other states have lifted similar restrictions to accommodate aquaculture interests.

Hybrid striped bass have great potential for aquaculture in Texas for several reasons. This species is popular as both food and as a game fish. A majority of the current production is for stocking ponds and recreational lakes. Hybrids are fast growers in early stages and adapt well to intensive aquaculture environments. Normal growth of 225-350 g (a little less than one pound) can be seen in one year, and two to three-pound fish may be obtained the second year. Generally, fish less than 50 mm long feed on insects, crustaceans and zooplankton from natural pond productivity, and fish over 100 mm are given prepared foods. Hybrids grow faster in the warmer Texas climates, but their main attribute is their ability to withstand cold temperature. When the extreme temperatures in December 1989 destroyed most of the redfish, tilapia, and other type stocks, hybrids were unaffected. This fact allows them to be raised in outdoor grow-out ponds, which are much less expensive to construct and maintain than indoor facilities. Another desirable attribute is their wide salinity tolerance, all the way from freshwater to 25 ppt. They also tolerate higher salinities out of their optimum growth range.

Data on the cost of producing hybrids in Texas is not conclusive, but states with a more mature industry report average costs to be approximately $1.50 per pound. A recent report by the USDA (1991) indicated the average farm-gate price in the U.S. was $3 per pound. This is far above the $1.40 per pound that wild fish sold for in 1990. The major consumer complaint with hybrids from certain parts of the U.S. is off-flavor.

One redfish hatchery in Collegeport, Texas had hybrid striped bass in 1992, but had trouble finding a buyer. Producers are still unsure of the fish.

Other Freshwater Species

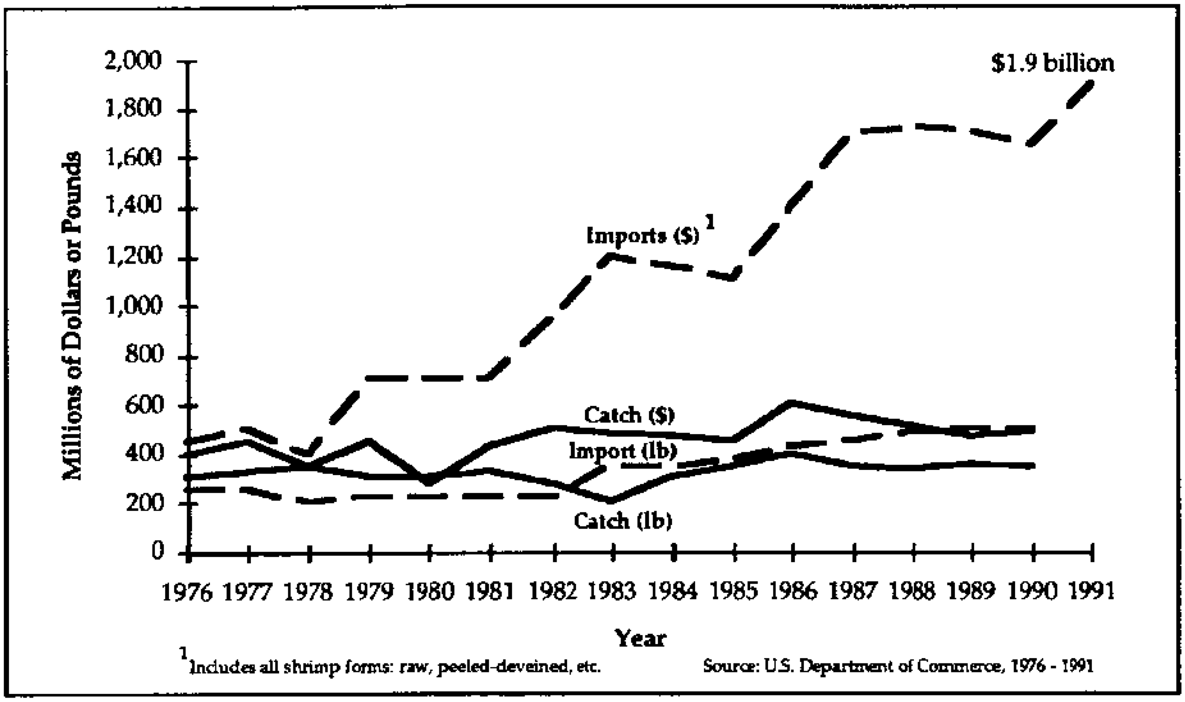
Buffalo (*Ictiobus sp.*), Chinese carp, Indian carp, common carp, frogs, and ornamental fishes are also cultured in Texas. Farm-gate value may be seen for most of these in Figure 2. Consult the Inland Aquaculture Handbook (available from the Texas Aquaculture Assoc., Austin, Texas) for more information on freshwater aquaculture.

Marine Shrimp *(Penaeus vannamei)*

Farm-raised marine shrimp production in the U.S. was approximately 2 million pounds in 1990 and 3.5 million pounds in 1991. Texas produced approximately 1.4 million pounds in 1990 and 1.5 million in 1991. In 1991, the approximate 1,000 acres of production ponds produced an average of 3,500 pounds of shrimp per acre per year in the U.S, higher than any other Western Hemisphere country and larger than most Eastern Hemisphere averages (Rosenberry, 1991). Only Taiwan and Japan top this average pond production with 3,750 and 7,000 pounds per acre, per crop, respectively. The U.S. produces only a small portion of the two million metric ton world shrimp crop (harvested and aquacultured), and a very small percentage of the 700,000 metric ton world aquacultured shrimp crop. This is only a fraction of the shrimp consumed domestically every year. Domestic landings of shrimp account for 25-35 percent of total domestic consumption and net shrimp imports to the U.S. in 1990 were 502 million pounds (USDA 1991) valued at 1.7 billion dollars (NMFS, 1990). In 1991, U. S. shrimp imports reached 1.9 billion dollars according to USDA (1992) or $1,856,677,000 according to NMFS (1992). 539,591,000 pounds of shrimp were imported into the U.S. in 1991 (NMFS, 1992).

According to USDA (1991), China, Thailand, and Indonesia shipped a total of over 200 million pounds of shrimp to the U.S. in 1990. Mexico and Ecuador also contribute largely to shrimp imports to the U.S. market, most farm raised. In fact, nearly one shrimp in three supplied in the world today now comes from farms. World shrimp aquaculture production in 1991 was around 700,000 metric tons, up nine percent from 1990, (Rosenberry, Jan 1992: in Fish Farming International, Jan. 1992). The U.S. and Japan are the biggest importers of shrimp. Figure 6 shows U.S. shrimp catch and imports since 1976.

Figure 6. U.S. Shrimp Catch (—) and Imports (— —)



History of shrimp farming in Texas

Hatchery

Although other forms of aquaculture have been practiced for centuries in the Eastern Hemisphere, a Japanese researcher (Dr. Motosaku Fujinaga) produced the first written record of shrimp culture techniques in 1934 and the Japanese work in the 1930s and 1940s laid the foundation for other work to follow. This work influenced many groups, including those in the U.S. Those groups working in Texas will be discussed here.

From a listing of the National Marine Fisheries Laboratory, Galveston, Texas, publications and reports related to marine shrimp it can be seen that J.C. Pearson described the eggs of penaeid shrimp in 1935 and the early life histories of some American penaeids in 1939. In 1953, Paul E. Heegaard attempted to spawn the white shrimp, *Penaeus setiferus*, in Port Aransas, Texas. In 1954, Gunter and Hildebrand worked with wild postlarval shrimp in Texas and National Marine Fisheries Services researchers began to work with the biology of commercial shrimps (Lindner and Anderson, 1954). The Texas research to this point did not have aquaculture of shrimp as a goal.

"Research on the culture of larval shrimp started at the NMFS Galveston Laboratory in 1959 as part of an investigation into the life history of commercial shrimp in the Gulf of Mexico. Samples of plankton were taken in the Gulf to study the seasonal abundance of shrimp larvae of the commercial species. There was little information available about larvae of the different species and it was not possible to differentiate the commercial species from the non-commercial species. A project was started to collect gravid females of the various species, spawn them and culture the larvae so that specimens could be obtained for use in identificatiôn of larvae collected in the plankton samples. The research program on larval culture was successful and the Director of the Laboratory, Milton J. Lindner, was then instrumental in obtaining the funding necessary to develop the methodology into a prototype hatchery system"(Personal communication, Harry Cook, 1992).

This was the actual beginning of the development of the clearwater hatchery (intensive culture technique), called the Galveston technique by some. From this point it passed through years of refinement and modifications by countless researchers and groups and is still being modified to meet the needs of individual hatcheries. Each group which followed this original group "carried the ball" or "carried the torch" magnificently and helped the cause and helped to spread the knowledge.

Historians like to have a clean and concise date with only one person to cite, so that they can pin point "when and where" an exact science started. It is not that easy with shrimp hatchery developments. Since the 1960s, clearwater hatchery technology (Galveston Method) has had three major contributors or groups of contributors to the development, refinement and transfer of that technology to the international community: 1. Harry Cook and the NMFS staff in the 1960s, 2. Corny Mock and the NMFS staff in the 1970s (when the World Mariculture Society became of age and began to recognize and publish this work, making it more visible to the aquaculture community), and 3. NMFS staff and University Groups (mostly Texas A&M University) in the 1980s (which has continued into the 1990s).

The following is an abbreviated chronological literature search of NMFS Galveston Laboratory publications and reports related to the culture of marine shrimp larvae:

Cook, H.L. 1965. Rearing and identifying shrimp larvae. U.S. Fish and Wildlife Service (U.S.F.W.S.) Circular No. 230.
Cook, H.L. and M.A. Murphy. 1966. Rearing penaeid shrimp from eggs to postlarvae. Proc. S.E. Assoc. of Game and Fish Comm.
Cook, H.L. 1966. Identification and culture of shrimp larvae. U.S.F.W.S. Circ.246.
Cook, H.L. 1966. A generic key to the protozoan, mysis, and postlarval stages of the Penaeidae. U.S.F.W.S. Bull. 65 (2):437-447.
Cook, H.L. 1967. Identification and culture of shrimp larvae. U.S.F.W.S. Circ.268.
Cook, H.L. 1968. Taxonomy and culture of shrimp larvae. U.S.F.W.S. Circ. 295.
Cook, H.L. 1969. Larval Culture. U.S.F.W.S. Circ. 325.
Cook, H.L. 1969. A method of rearing penaeid shrimp larvae. FAO Fish. Report No. 57, 3: 709-715. (Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome, Italy).
Cook, H.L., A. Brown, C.R. Mock and M.A. Murphy. 1970. Larval culture. U.S.F.W.S. Circ. 343.
Cook, H.L. and M.A. Murphy. 1969. The culture of larval penaeid shrimp. Trans. Am. Fish. Soc. 98 (4).
Cook, H.L. and M.A. Murphy. 1971. Early developmental stages of the brown shrimp reared in the NMFS Galveston Laboratory. Fish. Bull. 69 (1): 223-239.
Mock, C.R. and M.A. Murphy. 1971. Techniques for raising penaeid shrimp from the egg to postlarvae. Proc. World Maricul. Soc. 1: 143-156.

The source of these publications was: "List of NMFS Galveston Laboratory Publications and Reports Related to Marine Shrimp (*Penaeus* sp.) Aquaculture". Compiled by: Maurice L. Renaud, Ph.D., Charles W. Caillouet, Ph.D., NMFS-SEFC Galveston Laboratory, 4700 Ave U. Galveston, Tx. 77550.

There were also other groups working on larval rearing of penaeids besides NMFS in the state of Texas. Texas Parks and Wildlife and some of the Universities published works on this subject very early on. One example is:
Ewald, J.J. 1965. The laboratory rearing of pink shrimp, *P. duorarum*. Bull. Mar. Sc. Gulf and Caribb. 15(2):436-449.

Others whom should be recognized (as working on penaeid shrimp in connection with the NMFS Lab, either directly or indirectly), in a historical account are: Dave Aldrich, C. E. Wood, Neal Baxter, D. M. Allen, T.J. Costello, W.W. Anderson, J.E. King, W.C. Renfro, R.H. Rigdon, C. Hanna, G.L. Beardsley, R.J. Berry, M.G. Kleve, D. Patlan, W.H. Clark, P. Talbot, B.R. Salser, F.S. Conte, M.S. Duronslet, J.C. Parker, J.D. Corliss, Z.P. Zein-Eldin, J.M. Lyon, F. Marullo, A.I. Yudin, R.S. Wheeler, J.L. Fenucci, C.T. Fontaine, R.G. Bruss, I.A. Sanderson, S.E.P. Gislason, W.L. Trent, R.A. Neal, D.B. Revera, R.A. Gould, D. Grajcer, G.W. Griffith, L.A. Ross, E.F. Klima, J.H. Kutkuhn, L.M. Lansford, C.W. Caillouet, K.T. Marvin, A.L. Lawrence, D. Ward, S. Missler, J. McVey, B.S. Middleditch, J.K. Leong, D.H. Lewis, K. Hanks, R.R. Procter, A.K. Sparks, J.R. Adams, A.M. Heimpel, F. Marullo, R.C. Benton, M. Hines, E.S. Chang, J.L. Munro, D. Dimitriou, A.C. Jones, M.L. Parrack, J.C. Pearson, R.R. Proctor, R.C. Benton, R.H. Ridgon, R.D. Ringo, G. Zamora, M.A. Solangi, A.K. Sparks, D. Tave, R.F. Temple, F.W. Weymouth, J.M. Fox, J. Wilkenfeld, Linda Smith, and numerous others.

Although the Japanese research in the 1930s and 1940s did have some influence on work in the U.S., the Japanese (Dr. Motosaku Fujinaga and Dr. Mitsutake Miyamura) visit to the National Marine Fisheries Service Laboratory in Galveston in 1963 was not for the purpose of information transfer and was not a turning point or beginning point for shrimp culture in Texas as we have been led to believe for many years by various historical accounts. The purpose for the Japanese visit (which only lasted a few hours at the Galveston Lab) was to find a place for shrimp growout in the U.S. The Japanese wanted to lease East Matagorda Bay for this purpose, but ended up in Florida and in 1967 established Marifarms, Inc. The project was destroyed by a storm shortly after harvesting had started and later other problems including the environmental problems caused them to move out of the U.S.

Growout

Success in larval rearing stimulated grow-out trials in ponds during the late 1960s and 1970s. In 1968, the Texas Agricultural Extension Service began its shrimp program in Brazoria County. This program, funded through Texas A&M University's Sea Grant College Program, the Brazoria County Mosquito Control District, Texaco, Ralston Purina, and Dow Chemical Company, developed and expanded into a 22-pond operation. This project was managed and operated by Texas A&M University's Dr. Wallace Klussmann, Dr. Jack Parker, and Mr. Hoyt Holcomb. 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 1972, Ralston Purina's Crystal River Mariculture Research Center (Florida) determined that white shrimp (*P. setiferus* and *P. vannamei)* provided better yields than brown shrimp (*P. aztecus*). This was also confirmed in Texas. In 1972, a second Texas A&M Agricultural Extension Service mariculture facility managed by Dr. Fred Conte and later by Dr. Addison Lawrence- was established near Corpus Christi, Texas, in cooperation with Central Power and Light Company and Ralston Purina. Utilizing technology developed at the Brazoria County facility, a production module was designed and constructed at the Barney M. Davis Generating Station to demonstrate the feasibility of intensive shrimp culture. Consisting of three adjacent ponds of one-eighth, one-fourth, and one-half acre, through which shrimp were rotated as they grow, the tri-pond concept provided better utilization of space and capital investment than previously experienced with single pond units.

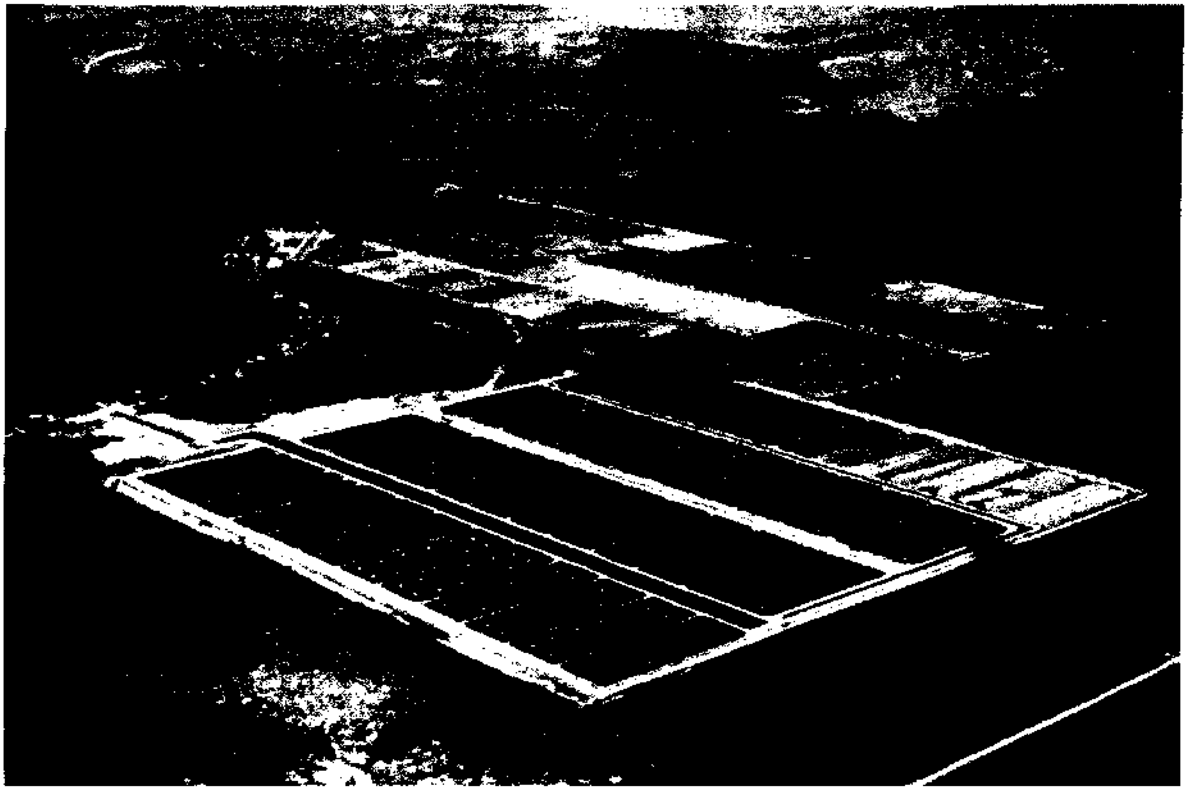
At the World Mariculture Society Conference in 1974, Dr. Jack Parker, then with Texas A&M University, reported results of a 1973 small scale experiment conducted by Dr. Fred Conte, Parker *et al.*,(1974). Conte found that *P. stylirostris* performed very well in pond culture, as did *P. vannamei* the first year; but the second year found that *P. stylirostris* performed poorly, and *P. vannamei* continued to produce. Based on these results, Parker, *et al.* (1974), concluded that such a system was capable of producing 2,000 to 3,000 kg/ha (1,800 lbs to 2,700 lbs/ac) during the six-to-seven month growing season available in Texas, but could produce up to 6,000 kg/ha (5,344 lbs/ac) in regions where year around operation is feasible. They also concluded that *P. stylirostris* was not a desirable species for culture under the intensive conditions of that experiment.

Also in 1972, two Ward County gravel pit operators, Mr. Hal Brown and Mr. Dean Phipps asked the local county agent to help them explore the possibility of using the saline ground water in some of their gravel pits for aquaculture. In 1973 County Extension Agent Mr. Johnny Harris, with the help of Dr. Jim Davis and Dr. Jack Parker, stocked the first shrimp using the saline waters of several gravel pits. Early experiments were crude and little data were obtained, other than in a number of cases in west Texas significant numbers of shrimp survived, indicating the biological feasibility of shrimp cultivation in west Texas. Stocking continued, and gradually a body of information has been accumulated supporting the possibility of commercial shrimp farming in west Texas.

July 15, 1992 marked the opening of a new research and development center in West Texas (Imperial, Texas), sponsored by Texas A&M University, General Land Office, and Pecos Water District No. 3. Redfish and salt water shrimp research will be conducted in ponds using ground water

In 1974, construction was begun on an additional complex of eighteen one-fourth acre ponds adjacent to the 1100-acre cooling lake at the Barney M. Davis Generating Station. These ponds complemented the facilities in Brazoria County and allowed capabilities for testing production techniques under the high salinity characteristic of the Laguna Madre, whereas the Brazoria County facilities evaluate production in the lower salinity water of Galveston Bay. Both locations were designed to conduct replicate studies using variations in diet, species, stocking densities, water fertilization, and disease control. Each compared production capabilities of the native white shrimp (*P. setiferus*) against two white shrimp species imported from the Pacific Coast of Central America (*P. vannamei* and *P. stylirostris*) and evaluated stocking densities.

To utilize non-indigenous species, it became necessary to control reproduction in captivity. During the 1970s and early 1980s, methods for inducing reproduction of penaeids were implemented by researchers in other parts of the world and, simultaneously, at the NMFS Laboratory and later carried on at Texas A&M University (Brown and Patlen, 1974; Brown *et al.*, 1980; and Lawrence *et al.*, 1980). Soon afterwards, commercial development efforts in Texas began. Laguna Madre Shrimp Farms in Bayview, Texas constructed hatchery and pond facilities in 1981 after Jack Parker left Texas A&M in 1980. Harry Cook started the second commercial operation in Olivia, Texas (Ocean Ventures, Inc., Wolf Point Shrimp Farm) in 1985. A brackish-water impoundment near Anahuac was stocked with *P. setiferus* post larvae from Chris Howell's Continental Fisheries hatchery in Panama City, Florida, both in 1984 and 1985. The last commercial source of *P. setiferus* ended when Howell's operation shifted exclusively to the production of *P. vannamei* and produced 70 million post larvae in 1986. Randy Guffey built a 40-acre farm on Port Bay near Rockport, Texas in 1986 and had crops the following two years. A Taiwanese group (MAITAI) has control of the eight five-acre ponds now, and is building a hatchery (foundation has recently been laid). The King Ranch then built six 20-acre ponds for semi-intensive culture and the U.S. Army Corps of Engineers funded the construction and semi-intensive culture trials on a 230-acre facility in Cameron County. MariQuest, Inc. managed these trials and attempted a winter crop with *P. penicillatus*. Other farms have been built since then. In 1989-1990, several Taiwanese companies invested in shrimp farms in south Texas. Chung Mei split into three major groups, stocking a total of 36, five acre ponds (180 acres). The three main groups are: [1] Chung Mei managed by Gordon Lipscomb), [2] managed by Wang, [3] managed by Ching. In 1990, shrimp was cultured in 38 ponds (190 acres) and in 46 of the ponds (230 acres) in 1991. The farm averaged 2,600 pounds of *P. vannamei* per acre in one crop. It is unlikely that its first year's production was profitable. Bing Hung (a major investor into the Chung Mei Farm group) split off from their operation and started his own farm, located nearby, he also obtained ownership of Lone Star Hatchery, Inc. (operated up to that point by the Chung Mei group. The Hung farm completed 78 five acre ponds (390 acres) and cultured shrimp in 46 of the ponds (230 acres) in 1992 They produced 395,400 lbs. in 1991. The Hung farm completed 94 ponds (470 acres) in 1992, and stocked them all. Part of the production from Lone Star Hatchery is *P. setiferus* and according to Dr. Ya Sheng Juan (personal communication) the *P. setiferus* PLs (when produced) will be grown in a nursery pond this year since the time left in the season is too short for full grow-out and these trial results will be used to further expand the culture of *P. setiferus* at the Hung farm in the 1993 season. The farm has additional construction planned up to 600 acres in the future and has additional land, which can be developed.



Hung Shrimp Farm and Taiwan Shrimp Farm Village (formerly Chung Mei Shrimp Farm).

Most Texas shrimp farms are located on the coast, but several small-scale, intensive farms have developed in west Texas using saline ground water. All culture the same species, *P. vannamei*.

On June 16, 1989, Harold Bowers received *P. vannamei* postlarvae from Panama (Agromarina de Panama) which was infected with baculovirus (BP). The 120,000 animals were tested upon entering the country; results were reported to TPWD. Mr. Myron J. Hess, TPWD Attorney and Legal aide, instructed Mr. Bowers to quarantine the pond (no water flow in or out) and/destroy the animals. This was done, and the pond was not used the following season. A similar incident occurred in June, 1991, with the Hung farm. Six million postlarval shrimp from Ecuador were found to have BP and the nursery pond was quarantined. Water was pumped out on to dry ground and the animals were captured and disposed of.

In recent history, three pilot ventures in west Texas should be noted. In Martin County, Charlie McKaskle has produced commercial crops of shrimp, one in 1989 (810 pounds per acre) and another in 1990 (over 2,000 pounds per acre). Mr. McKaskle has demonstrated the ability and carrying capacity (27,000 pounds per acre) of greenhouse nurseries to early-start shrimp crops in west Texas. His pilot, one-acre outside growout pond produced marketable sized shrimp at 2,000 pounds per acre considered to be potentially profitable (Dugger, 1991). According to Dr. Jim Davis (personal communication) Mr. McKaskle produced 9,100 lb. of shrimp in 4.2 acres in 1990 and has not had a crop since.

In Crockett County, Mr. Jack Parker (no relation to Dr. Parker formerly of TAMU) also has built a pilot scale shrimp production facility. He also has used a greenhouse nursery system. In 1989, Mr. Parker produced an average of 1,068 pounds per acre from his pilot facility. In 1990, despite several efforts to restock his ponds, Mr. Parker was not able to receive any viable seedstock during the growing season. Mr. Parker and Mr. McKaskle have both experienced problems in obtaining shrimp seedstock in good condition from distant commercial hatcheries. In the past, Mr. Parker and Mr. McKaskle were able to sell their entire production of shrimp for $6.50 per pound to the local markets (Dugger, 1991).

The third pilot facility was built at Imperial, Texas by the Pecos County Water Improvement District #3. This six-one acre pond facility was stocked with *P. vannamei* and red fish in 1992, but results were poor during this "learning curve".

In 1991, there were 13 shrimp farms in Texas (not including Redfish Unlimited, located near Palacios, Texas which only stocked shrimp in 1990). There was a total acreage of 1,703 acres (774 ha).

In 1990, nine farms-with a total of 461 acres (209 ha)-were stocked and produced a combined crop of 1,405,100 lbs (638 mt) of heads-on *P. vannamei*. In 1991, six farms totaling 768 acres (349 ha)-were stocked and produced 1,513,400 lbs (687 mt) of heads-on *P. vannamei* (see Table 2). The other farms did not stock shrimp in 1991.

Also in 1991, 266,275 lbs. of aquacultured saltwater shrimp valued at $984,416.00 were killed in four saltwater shrimp farms in Cameron County, Texas during an early November cold snap. A freshwater shrimp farm lost an estimated 22,000 lbs. of aquacultured freshwater shrimp valued at $254,540.00 during this same period (the same period which 140,000 lbs. of saltwater shrimp were lost at the Port Lavaca Plantation Farm). Water temperatures dropped below 50°F at all the shrimp farms causing these extensive mortalities. The total loss for aquacultured shrimp in Texas during 1991 is estimated at $1,658,956.00.

Potential for shrimp farming in Texas

Labor costs in the U.S. are generally too high for domestic growers to compete with culturing methods employed by our major suppliers. The Chinese government, for example, supplements their shrimp farming industry by providing seed-stock and sometimes, the army to assist with harvests and pond construction. Another limiting factor is the one crop-per-year limitation in Texas outdoor ponds. Shrimp farmers in the U.S. and Texas must use intensive culture techniques (higher density), to justify the high costs. Even then, there is no assurance that the farm will produce every crop or be profitable even if it does produce once a year. One farm owner who has produced 300,000 pounds of whole shrimp from 60 acres of ponds for the last two years has still not been able to make the farm profitable. He states that "there are many soft or hidden costs that keep you down". What it boils down to is just another way of farming. If you do everything right and nothing goes wrong, you have a good year. This seldom happens, but when everything comes together, the returns can indeed turn out the way they did on paper before starting.

In the past, a major impediment to the growth of shrimp farming in Texas was the quality and availability of postlarvae. Postlarvae (PLs) are young shrimp (approximately three weeks old) which are seeded in grow-out ponds. Bacteria, viruses, and other problems have troubled the industry, but progress is being made to assist the industry in coping with all these problems. Unfortunately, there have been far more failures than successes in this business. But things are not all grim. A new shrimp hatchery was built in Port Isabel and another under construction in Port Mansfield should be productive during 1993. These should double PL production for Texas.

Hopefully, with the increased number of hatcheries there will not be a shortage of high-quality PLs in the 1993 coming season. With" Specific Pathogen Free animals" (SPF) as broodstock in Hawaii and off-spring from these SPF animals being called "High Health Animals" in many other U.S. hatcheries, the PL quality should be much improved and the domestication of this shrimp species should proceed. "High Health" animals have originated through the assistance of USDA regional aquaculture funding. USDA, (through their U.S. shrimp farming program and the Gulf Coast Research Laboratory Consortium) has developed a "Specific Pathogen Free" (SPF) shrimp. Those shrimp have been quarantined in Hawaii and certified to be free of IHHNV, HPV, BP-Type virus, Microsporidians, Gregarina, Nematodes and cestodes. Test results using SPF animals indicate superior growth and survival compared to controls, (Castille, 1992 and Perez, Ecuador, personal communication). A number of different teams have drawn the same conclusions as a result of tests with SPF animals, and it appears that the entire industry will soon move to obtain these "High Health" Animals.

Also, progress has been made in dealing with a gut disease problem referred to as granuloma. Intra cellular gran negative bacteria (Johnson, 1989, page 5) have been found to cause problems, and treatment with medicated feeds is possible with early identification of the problem. Researchers in the College of Veterinary Medicine at Texas A&M University and a private farm were able to obtain permission from FDA to administer medicated feeds to shrimp the last two years with very positive results. The intensive culture farm produced approximately 300,000 pounds of heads-on shrimp from 60 acres of ponds in 1990 and 1991.

Marine shrimp aquaculture has expanded in Texas the last three years despite its problems. Figure 7 shows the historical production of farm-raised shrimp in Texas.

Texas Saltwater Shrimp Aquaculture Production for 1991-1996)

Shrimp Farms	Acreage Stocked						Heads on Production Pounds					
	1991	1992	1993	1994	1995	1996	1991	1992	1993	1994	av. 500 lbs./ac 1995	1996
Arroyo Aquaculture Assoc.	230	180	365	395	395	425	300,000	1,104,000	* see below	1,680,000		2,000/ac.av.=790,000 ••
Bowers' Shrimp Farm	37.8	37.8	111	200+	325	345	113,400	238,140	721,500	1,200,000		2,000/ac.av.=700,000
Harlingen Shrimp Farm Inc.	180	450	450	370	450	200	550,000	1,300,000	* see below	560,000		200 ac. *P.setiferus* x *** 1,500=300,000
M&M (Olivia, TX)	57.5	0	0	0	57.5	57.5	300,000	0	0	0		est. 100,000
Port Lavaca (R&G)	28	0	0	28	28	70	0	0	0	152,000	150,000	est 50,000
Southern Star	230	470	470	5	0	0	395,400	1,200,000	•1,389,632	15,000	No stock	0
St. Martin's Seafood				0	60	130	0	0	0	0		est. 100,000
Triton (West Texas)		6	10	40	30	30	0	1140	25,000	80,000		4,000/ac.=120,00****
Austwell Aqua Farms	0	0	0	0	0	20	0	0	0	0		est. 20,000
MANTAI Shrimp Farm	0	0	0	0	0	40	0	0	0	0		est. 40,000
Totals	763 ac	1144 ac	1406 ac	1038 ac	1346 ac	1318 ac	1.66M lbs.	3.8M lbs.	4.2M lbs.	3.69M lbs.	**1.4M lbs	2M lbs.
	309 ha	463 ha	569 ha	420 ha	545 ha	533 ha	753 mt	1723 mt	1905 mt	1672 mt	634 mt	907 mt
Estimated feed use in Texas (assuming 2:1 average)							1506 mt	3446 mt	3810 mt	3344 mt	1268 mt	1814 mt
Estimated farm-gate value of crop								$11 M	$11.2 M	$12.8 M	$3.5 M	$9 M

M = Million; lbs. = pounds; mt = metric tons (1mt = 2,205 lbs.); ac = acres; ha = hectares (1 ha = 2.47 ac).

Estimated worth of 1992 crop; Farmgate average value $2.84/lb. (heads-on); $10,911,677.60 = $11 Million crop; Estimated worth of 1993 crop; (1.) Farmgate average U.S. $2.94 per pound for Bowers crop (heads-on) = $2,121,210 (2.) 3,469,500 lbs. Valley Production @ $2.60/lb = $9,020,700
(3.) 25,000 lbs - 40% for head removal = 15,000 lbs @ $4.50/lb = $67,500. Add 1-3 = $11,209,410. Assuming 1,285 ac in Harlingen area produced 2,700 lbs/ac @ $2.60/lb (heads-on) farmgate price.

* Together both farms produced an average of 2,552 lbs/ac on 815 ac or approximately 2,079,868 total, but did not want individual farm production printed.

** Taura Syndrome Virus severely affected the 1995 crop. Most farms averaged 10% survival in 1995 and 20% in 1996 because of TSV.

*** Harlingen stocked only 200 acres of P. seterifus at low stocking densities when they heard that TSV was back in 1996.

**** Bart Reid reported that at least 2 ponds produced 6,000 lbs./ac with others producing from 4,000 — 5,000 lbs./ac.

• Source: Dr. Ya Sheng Juan

•• Some of the early harvests reported by Hamper and Lipscomb were 3,400 lbs./ac or 17,000 lbs. per five ac. pond.

Revised 11/25/96

Bowers has purchased 550-600 ac total (developed & stocked approx. 300 acres in 1995 with 1.8 M lbs. expected, but production fell short because of TSV. in 1995. 10% survivals in 1995. 20% survivals in 1996. 345 surface acres now. Bowers reported that most of the early harvested ponds with P. vannamei in 1996 averaged 2,000 lbs./ac. with TSV, but later harvested ponds only averaged 1,700 lbs./ac.)

South Carolina also reported TSV in 1996 which came in with larvae form Mexico (Maritec). Benner was the first Texas farm to report TSV in 1996 (larvae also from Mexico).

Thahn Van Nguyen owner, St. Martin's, Palacios built 12 five acre ponds in 1995 and added more in 1996 (Total 130 ac.). In 1995 larval mortality occurred in transit of during acclimation and severely limited crop results. Estimated total heads-on production from Texas in 1996 is 2 million pounds worth $9 million of shrimp.

Austwell and MANTAI do not have permits to discharge which has contributed to poor production (along with TSV).

Source of Table: Granvil Treece, Aquaculture Specialist, Texas A&M University, Sea Grant College Program, 1716 Briarcrest Dr., Suite 702
Bryan, Texas 77802, Phone: (409) 845-7527, Fax: (409)845-7525

Sources: Tony Reisinger, Louis Hamper & Gordon Lipscomb, Cheryl Bowers, Fritz Jaenike, Dr. Ya Sheng Juan, R.A. Benner, Bart Reid and Dyer Moore.

TABLE 2

TEXAS SHRIMP AQUACULTURE PRODUCTION FOR 1990, 1991 AND 1992

Shrimp Farms	Pond Acreage Completed			Acreage Stocked			Heads on Production Lbs.		
	1990	1991	1992	1990	1991	1992	1990	1991	1992 (
Hung's Shrimp Farm	0	230	470	0	230	470	0	395,400	1,200,000
Chung Mei (3 Groups)	190	425	425	190	230	180	500,000	300,000	*1,104,000
Ocean Ventures Wolf Point	57.5	57.5	57.5	57.5	57.5	0	332,000	300,000	0
Harlingen Shrimp Farm	450	450	450	120	180	450	320,000	550,000	950,000
Port Lavaca Plantation	28	28	28	28	28	0	94,000	0	0
Bowers Shrimp Farm	37.8	37.8	37.8	37.8	37.8	37.8	128,520	113,400	**238,140
Lone Star Aquaculture	12	12	12	12		0	48,000	0	0
Redfish Unlimited	7	not used	not used	7	0	0	29,000	0	0
McKaskle's Shrimp Farm	10	10	10	4.2	0	0	9,100	0	0
Totals	792 ac	1250 ac	1490 ac	456.5 ac	763 ac	1,138 ac	1,460,620 lbs	1,658,800 lbs	3,492,140 lbs.
	360 ha	568 ha	677 ha	208 ha	346 ha	517 ha	664 mt	754 mt	1,587 mt

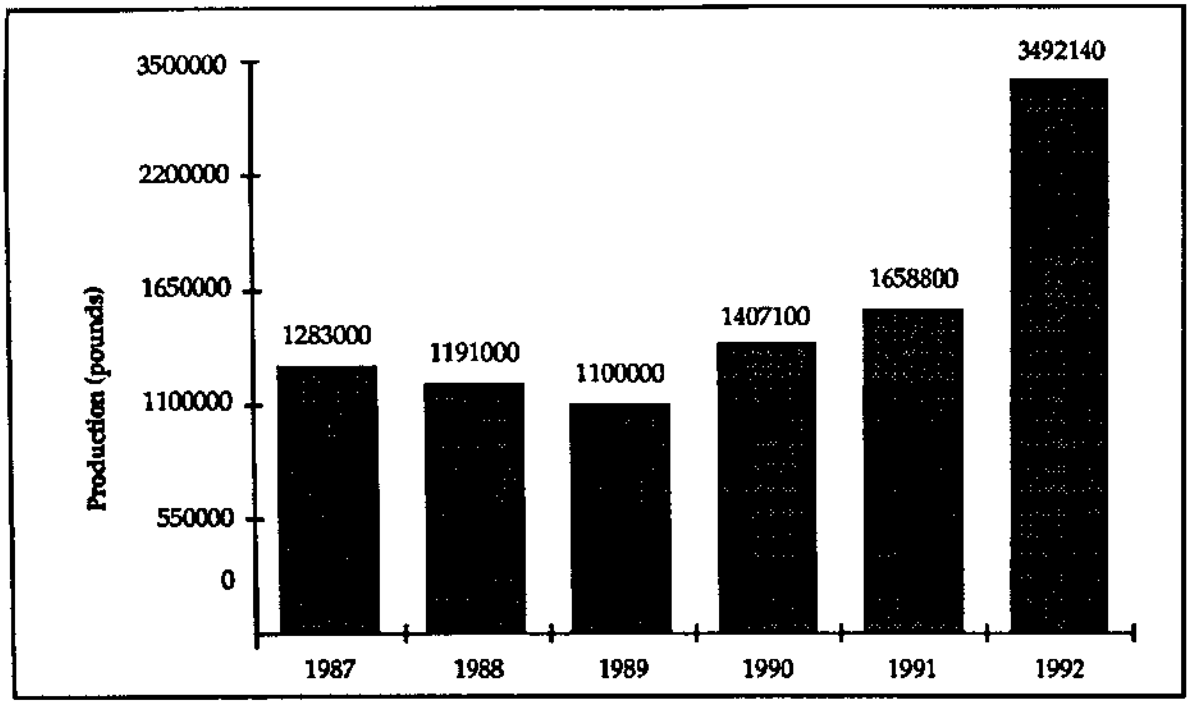
SOURCE: Granvil Treece, Aquaculture Specialist
Texas A&M University
Sea Grant College Program
1716 Briarcrest Dr, Suite 702
Bryan, Texas 77802
Tel: (409)845-7527
Fax: (409)845-7525

* Average 6,133 lbs./ac.
Best 40,000 lbs in 5 ac = 8,000 lbs/ac.
A number of 6,000 lb/ac and 7,000 lb/ac harvests reported.

** 238,140 is estimate. Owner did not have final total production. Worst pond was 6,300 lbs./ac. Best pond was 8,447 lbs/ac. Took worst 6,300 x 37.8 ac. = 238,140 lbs.

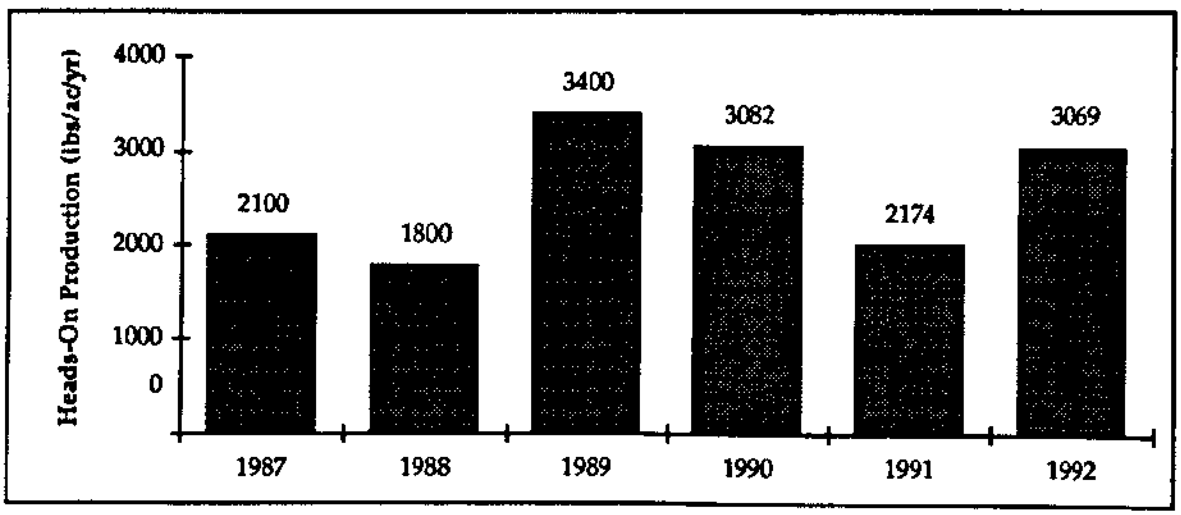
rev. 11/19/92

Figure 7. Historical Production of Farm-Raised Marine Shrimp in Texas



Even though the average yield from commercial marine shrimp farms dropped in 1991, it climbed back to 3,000 lbs./per acre per year in 1992 (Figure 8).

Figure 8. Historical Average Yield from Commercial Marine Shrimp Farms in Texas



Marine shrimp farmers in Texas do not culture the native species *(P. setiferus, P. aztecus and P. duorarum)*. Research and commercial experiences have proven that *P. vannamei*, a Pacific white shrimp, yields higher production; consequently all farming operations have selected this variety to raise. This has created an impediment to the industry in the form of regulatory controls. *P. vannamei* is an exotic species. As a result, TPWD places restrictions on production facilities that many feel are too cumbersome. The Texas Department of Health (TDH) allows polyculture or the combination of shrimp or fish and other shellfish, such as oysters and clams. However, they are only mandated to check and regulate public waters (not private waters), therefore they do not have the personnel and budget to allow the farmer to depurate-or-purge the shellfish in approved waters under strict supervision. This may be changing. TDH may allow private approved laboratories to test the shellfish grown for human consumption.

The Texas coast is well suited to marine shrimp farming. It has an abundance of natural resources which give it a distinctive advantage over most states. Most notable is land that has favorable clay content and sufficient elevation, factors which greatly reduce pond construction costs. Also, water quality and moderate temperatures enhance Texas shrimp-growing capabilities.

Marketing methods vary with the size of the farm. Smaller operations usually sell to local customers, or pool their products with others for distribution. Larger operations sell directly to processors, or have their shrimp processed and market their own product. Some of the farm-raised shrimp in Texas is marketed head-on. Farm-gate price averages between $2.50 and $3 per pound. In 1990 and 1991, one farm marketed its entire crop (300,000 lbs.) in California for $5 a pound. One of the larger farms has its own marketing branch which generally tries to sell the crop to a large supermarket chain. One processor in Brownsville has added a deheading line to accommodate increasing farm-raised shrimp production in the area.

For more information concerning the economics of salt water shrimp farming refer to Lambregts *et al.* 1991 (A comparison of semi-intensive and intensive shrimp farming in Texas).

Figure 9 Commercial Shrimp and Redfish Aquaculture Facilities in Texas
(Locations, Production & Plans)

Shrimp Farms *(P. vannamei)*

Harlingen Shrimp Farms•Bayview, TX (formerly Laguna Madre Shrimp Farm)
Mailing address: Attn: Mr. Fritz Jaenike
Rt. #3, Box 300 K
Centerline Rd.
Los Fresnos, Texas 78566
Total pond acreage: 450 acres
Acreage in production 1990: 120 acres
Hatchery: 40 million PLs/mo.
1991 production (heads-on): 550,000 lbs. of *P. vannamei*
1992 - 950,000 lbs,

Taiwan Shrimp Farm Village • Arroyo City, TX (formerly Chung Mei Shrimp Farm)
Mailing address: Attn:
Route 2, Box 469
San Benito, Texas 78586
Total pond acreage: 425 acres
Acreage in production 1990: 190 acres
1990 production-(heads-on):500,000 lbs. of *vannamei*
1991 production (heads-on): 300,000 lbs. of *P. vannamei*
1992 Chung Mei Group splintered into 3 groups. total of 36 ponds (180 ac.) stocked. (production was 1,104,000 lbs).

Port Lavaca Plantation•Port Lavaca, TX
Mailing address: Attn: Mr. Ron Parmentier
2203 Vail Drive
Port Lavaca, Texas 77979
Total pond acreage: 28 acres
Acreage in production 1990: 28 acres
1990 production (heads-on): 94,000 lbs. of *P. vannamei*
1991 production (heads-on): 0
Freeze killed crop November 1991
1992 no crop.
Farm is for sale.

Lone Star Hatchery, Inc.•Port Isabel, TX
Mailing address: Attn: Ko-Lun An
P. O. Box 578
Port Isabel, Texas 78578
20,000 sq. ft. shrimp hatchery with primary goal of producing post-larvae for the Hung Farm.

Lone Star Aquaculture•Palacios, TX
Mailing address: Attn: Mr. Kai Juan
Star Route, Box 388
Palacios, Texas 77465
Total pond acreage: 28 acres
Acreage in production 1990: 12 acres
1990 production (heads-on): 48,000 lbs. of *P. vannamei*
1991 production (heads-on): Did not stock
1992 - Did not stock

Hung Shrimp Farm•Arroyo City, TX
Mailing address: Attn: Dr. Ya Sheng Juan
One Arroyo Place
Arroyo City, Texas 78586
Total pond acreage: 470 acres (94, 5 ac ponds)
Acreage in production: 1990, 0: 1991, 230: 1992, 470
1991 production (heads-on): 395,400 lb. of *P. vannamei*
1992 - 1,200,000 lbs.

Bowers Shrimp Farm•Collegeport, TX
Mailing address: Attn: Mr. Harold Bowers
Route 1, Box 534
Palacios, Texas 77465
Total pond acreage: 47.8 acres
Acreage in production 1991: 37.8 acres of *P. vannamei*; 10 acres of red drum
1991 production (heads-on): 113,400 lbs. of *P. vannamei*
1992 - 238,140 lbs.

Ocean Ventures•Olivia, TX
Mailing address: Attn: John Kinnamer
Bay City, Texas
Total pond acreage: 60 acres
Acreage in production 1990: 60 acres
1990 production (heads-on): 332,000 lbs. of *P. vannamei* (4 ponds produced over 10,000 lbs/acre crop (the best of which produced 12,500 lbs/ac.)
1991 production (heads-on): 300,000 lbs. of. *P. vannamei*
1992 no crop
Farm is for sale.

Shrimp Farms (con't)

MAITAI • Rockport, Texas (formerly) Guffey's Seafood Farm
Total Pond acreage: 40 acres
Acreage in production 1991 0 acres
1992 - Did not stock. Farm for sale.

Sweetwater® Aquafarms, Inc. • Los Fresnos, TX
Mailing address: Attn: Mr. Marshall Schnider
P. O. Box 1807
San Benito, Texas 78586
Total pond acreage: 70 acres
1990 production (heads-on): 21,000 lbs. plus 1,200 lbs. Australian Red Claw crawfish
1991 Freeze damage resulted in loss of everything but broodstock.

Brownsville Navigation Dist. • Brownsville, TX
Mailing address: Attn: Mr. Dick Berry or
Gene Cockril
Brownsville Navigation Dist.
Port of Brownsville
P.O. Box 3070
Brownsville, Texas 78523-3070
Total pond acreage: 230 acres
Acreage in production in 1991 and 1992: 0 acres

Parker Ranch Seafood • Iraan, TX
Mailing address: Attn: Mr. Doug Parker
10 Meandering Way
Round Rock, Texas 78664
Total pond acreage: 3 acres
Acreage in production in 1991 and 1992: 0 acres

Genesis Seafood, Inc. • Stanton, TX
Mailing address: Attn: Mr. Vernon Holcomb
HCR 72, Box 43
Stanton, Texas 79782
Total pond acreage: 15 acres
Acreage in production in 1991 and 1992: 0 acres. No ground water

McKaskle's Shrimp Farm • Stanton, TX
Mailing Address: Attn: Mr. Charles McKaskle
HCR 71
Stanton, Texas 79782
Total pond acreage: 10 acres
Acreage in production in 1991: 0 acres

Pecos County Water Dist. #3. Imperial, TX
Total Pond acreage: (6) one acre ponds several 1/4 acre ponds.
1992 895 lbs. *P. vannamei*

Red Drum Farms

Stellman Redfish Farm • Rockport, Texas
Mailing address: Attn: Mr. John Stellman
P. O. Box 1111
Aransas Pass, Texas 78336
Intensive indoor raceway system, (8) 45'x10'x4' fiberglass raceways
Acreage in production in 1990: All raceways (indoors)
Hatchery: Yes
1990 and 1991 production: 30,000,000 fingerlings
Plans: Construct 600 acres of growout ponds on property adjacent to the raceway facility.

Bauers Fish Farm • Austwell, Texas
Mailing address: Attn: Mr. Mike McGuill
P. O. Box 161
Refugio, Texas 78377
Total Pond acreage: 20 acres
Acreage in production in 1990: 20 acres
1990 and 1991 production: Primarily a fee fishing operation–production data not available.
Plans: Construct an additional 20 acres of ponds for red drum production (vs. fee fishing). Future plans include a hatchery and indoor intensive culture system for red drum. Employ thermal refugia in grow-out ponds to overwinter fish.

Red Drum Farms (con't)

Redfish Unlimited•Palacios, Texas
Mailing address: Attn: Mr. David Maus
Star Route, Box 386
Palacios, Texas 77465

Total pond acreage: 18 acres plus (2) 24'x8'x4' indoor raceways
Acreage in production in 1990: 4+ acres (plus raceways)
Acreage in production in 1991: 18 acres
Hatchery: Yes
1990 production: 22,000 lbs. (2 to 3.5 lb. fish)
1991 production: 55,000 lbs.(2.25 to 3.5 lb. fish)

Plans: Install additional indoor intensive raceway systems. Stock all 18 acres of ponds with red drum. Achieve production goal of 8,000 lbs/acre market size (3 lbs.) fish in outdoor ponds. Continue hatchery operation. Employ thermal refugia in grow-out ponds to overwinter fish.

Southwest Mariculture•Flour Bluff, Texas
Mailing address: Attn: Mr. Clyde Scott
P. O. Box 6722
Corpus Christi, Texas78466

Total pond acreage: 120 acres. (Old King Ranch Shrimp Farm).
Acreage in production in 1991: 120 acres
Hatchery: Yes
1990 production: Fingerlings were stocked in August. In December had 130,000 1" fingerlings and 50,000 fish in reservoir.

Matagorda Bay Aquaculture•Collegeport, Texas
Mailing address: Attn: Mr. Thomas Holsworth
c/o Matagorda County
Navigation District #1
414 Elizabeth
Palacios, Texas 77465

Total pond acreage: 16 acres
Acreage in production in 1990: 16 acres
Hatchery: Yes
1990 and 1991 production: 500,000 fingerlings, most were sold at 3-4" size. Largest fish raised were 40,000 8" fingerlings.

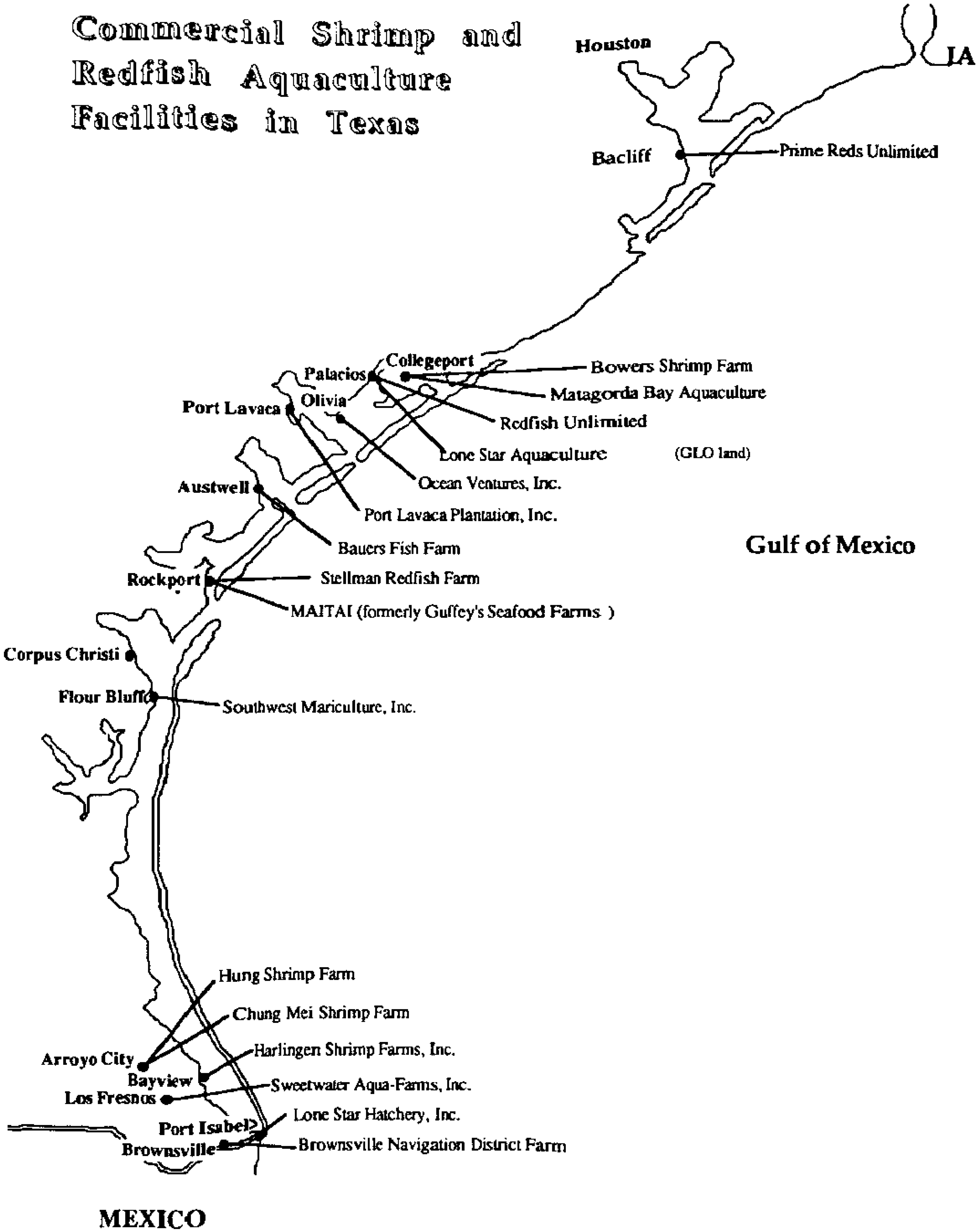
Plans: Continue hatchery and fingerling production. Grow fish to market size if excess fingerlings are available.

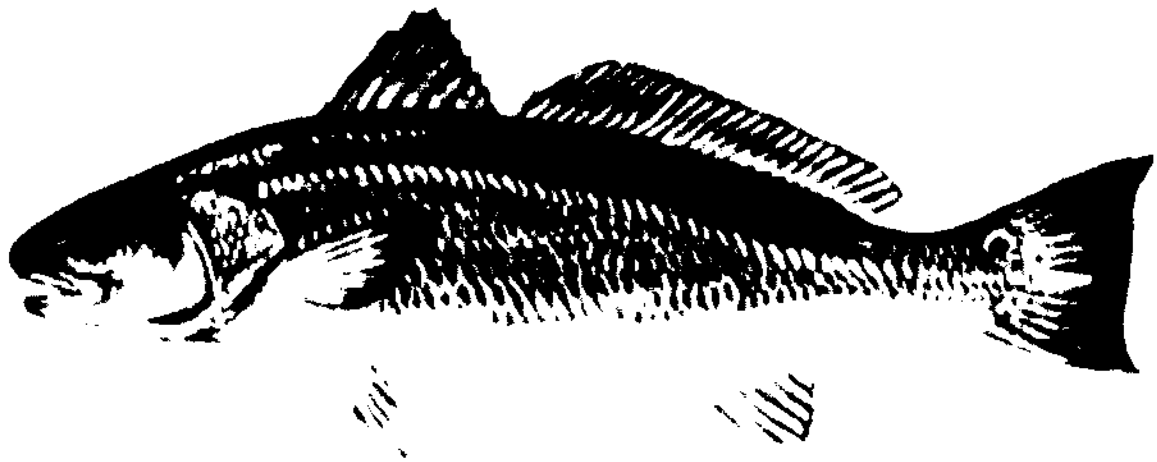
Prime Reds•Bacliff, Texas
Mailing address: Attn: Mr. John Turner
P. O. Box 272345
Houston, Texas 77277-2345

Intensive indoor raceway system
Acreage in production in 1990: All raceways indoors
Hatchery: Yes
1990 production: Not available–all market size fish sold to a retail supermarket chain.

Plans: Continue hatchery and raceway operations. Construct 8 acres of outdoor fingerling ponds. Double indoor raceway volume. Produce 20,000 lbs. of 2 lb. fish each month.

Commercial Shrimp and Redfish Aquaculture Facilities in Texas





Redfish (Red Drum) ***(Sciaenops ocellatus)***

Partly as a result of Paul Prudhomme's recipe for blackened redfish, a national awareness was created that increased the demand for this species, (*Sciaenops ocellatus*). At about the same time, the TPWD successfully lobbied for closure of the redfish fishery to commercial interests due to significantly declining populations and landings.

According to fisheries statistics there were 14 million pounds of redfish harvested from Gulf of Mexico waters in 1986,, much of which came from Louisiana and Texas. Harvesting of this species was no longer allowed in Texas after 1986 and this left a void in the market place which had grown steadily up until that time. These and other factors increased the price of redfish from about $1 per pound to $4 per pound. Prices now have settled to $1.75-$3 per pound (whole fish) in most areas of Texas. Industry experts agree that if demand continues, farm-raised redfish could become a much larger part of the aquaculture industry in the future. Cooperative prices are needed for the producers (stocker fish, feed, etc.), and other "economies of scale" benefits.

Much scientific research on spawning, hatching, and larval rearing of redfish has been completed by The University of Texas, TPWD, and Texas A&M University, as well as other researchers around the country. In 1969, the first marine hatchery (Perry R. Bass Marine Fisheries Research Station) was built near Palacios, Texas and has been operated by TPWD. TPWD started a red drum program in 1975, and a second marine hatchery (John Wilson) was built in 1983 near Corpus Christi. TPWD began stocking selected bays with redfish in 1983. A ban on purse seining in Federal waters occurred in 1986, and in 1989 the Texas Legislature prohibited the sale of redfish unless it was farm raised. Since then commercial grow-out has been attempted along the coast from Beaumont to Port Isabel (see Figure 9 for farm locations). The Sea Grant College Program at Texas A&M University began funding red drum research in the late 1970s. The winters of 1983-1984, 1989-1990 and 1990-1991 all killed redfish, both wild and cultured. In 1986, 55,000 fingerlings were released into several gravel pit ponds in west Texas. Major losses were reported due to predation by aquatic insects. However, some fish survived in water 6-64 ppt salinity and lived long enough to spawn.

Some growout trials have produced two pound fish in one year and four pound fish in two years, but the average is 1.5 lbs. in 18 months. This species (*Sciaenops ocellatus*) has several desirable characteristics which make it especially adaptable to aquaculture. Redfish can be raised in a variety of water qualities with salinities ranging from 0 to 40 ppt and show superior weight gain. Redfish also adapt well to intensive aquaculture environments. Parasites have been a problem in the past, but researchers at Texas A&M University's College of Veterinary Medicine have apparently made progress toward solving this problem.

The optimum temperature for red drum culture is 28°C, but they can endure temperatures between 8-33°C and can survive 4°C for 1-2 days and 0°C for a few hours. TPWD research has shown the Texas strain of red drum to be more cold tolerant than the East Coast strain (in Texas ponds). The primary problem facing redfish producers is low temperature mortality. Redfish cannot survive rapid temperature change. Virtually all the stock not housed indoors was killed in the December 1989 recordbreaking freeze. Currently, several approaches to overwintering redfish are being attempted. These include providing a thermal refuge for fish in a pond (swimming pool cover), providing fish with a diet which will help them become adapted to cold climates, raising the fish in indoor tanks equipped with recirculating systems, use of greenhouse covered ponds, and fish transferring from indoor to outdoor facilities to match the fishes' development cycle with seasonal temperature changes. These facilities are capital-intensive but effective solutions to the temperature problem.

Texas A&M University Sea Grant has funded redfish overwintering research for several years, and progress has been slow. Providing a thermal refuge to fish in ponds, similar to a swimming pool cover, has given encouraging research results and may offer an inexpensive solution to the over-wintering problem. Texas producers are expecting fierce competition from Central America in the near future. One redfish hatchery in Texas, consisting of 16 acres of fingerling production ponds has been selling fish to Belize, Mexico, and other countries to the south. There has not been a big enough demand for fingerlings in the U.S. to keep the company busy.

Spawning of the drums (sciaenids) is relatively simple. Red drum can be conditioned to spawn during two or three cycles a year (natural spawning occurs in Sept. - Oct.). Conditioning cycles can be set up so that eggs are produced every month. Red drum are susceptible to diseases induced by the stress of crowding or handling, and "fatty liver" with reduced viability has been caused by inappropriate feeds. The species can be raised in fresh-water if the hardness is maintained at 250 mg/L or higher.

Two-to four-inch fingerlings cost $0.25 each. There are six or seven farms in Texas, with four commercial hatcheries. There are 154 acres available for culture, but generally a smaller number of acres are stocked. Some culture activity in west Texas utilizes saline ground water. Management techniques for growout range from extensive (low stock, low maintenance, low production) culture to intensive (high stocking densities, high overhead, high production costs and higher production results) culture. One extensive operation is also used for a "fee fishing" or "fish-out" facility. Semi-intensive (between extensive and intensive) crops (one crop per year) produce 4,000-9,000 pounds per acre per year. Yields from small, intensive culture ponds in South Carolina (Waddell Mariculture Research Facility) have been reported to be as high as 20,000 pounds per acre, but economics were not considered (cost of pumping, feed, aeration, etc.). Intensive operations generally have a portion of their facility indoors, are very capital-intensive, and their operating costs are very high. With respect to natural resources, Texas has a greater potential for redfish production than other Gulf Coast states. There is an abundance of land close to Gulf waters, much of which is ideal for pond construction. Most of Texas coastal property southwest of the Brazos River has clay soils and sufficient elevation to facilitate proper drainage.

Currently, commercially produced redfish are hand-processed and marketed to local restaurants and wholesalers. Should production volumes increase, processing facilities and marketing strategies will become necessary. The processing plant in Brazoria County could process redfish.

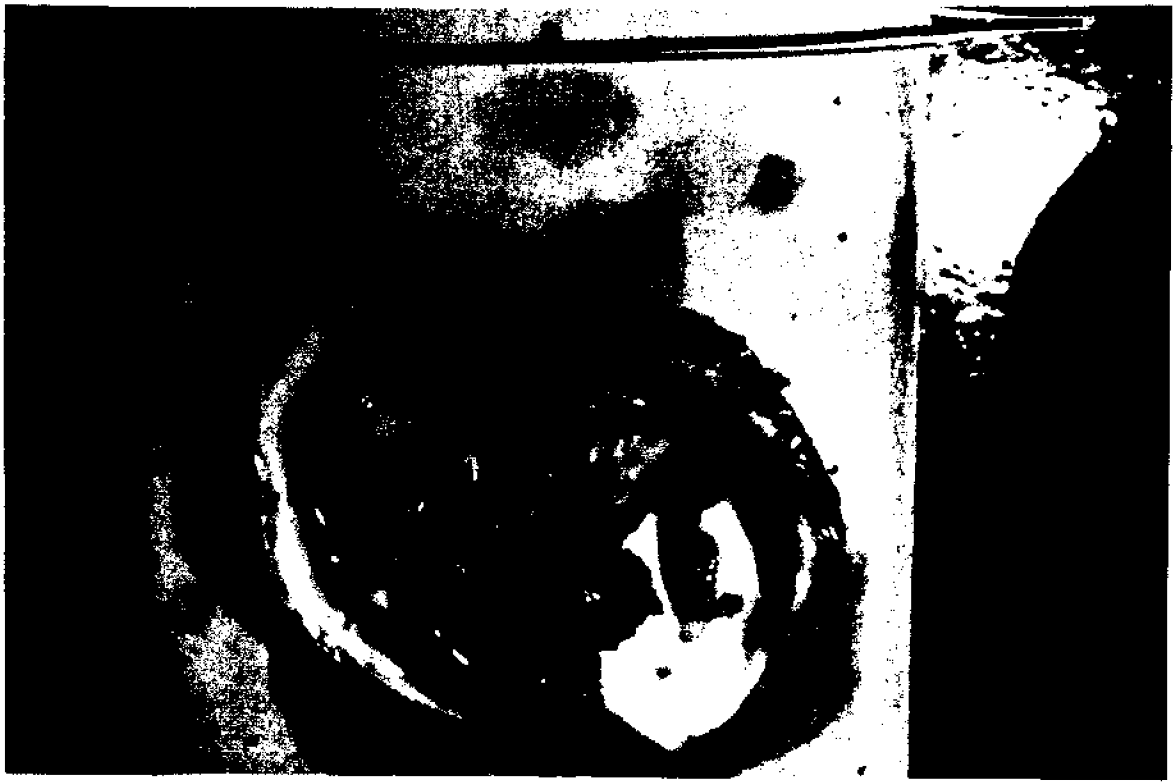
For a list of commercial redfish aquaculture facilities in Texas see Figure 9, and for more information on redfish aquaculture consult "Red Drum Aquaculture" (published by Texas A&M Univ., Sea Grant Program).

Baitfish (Brackish water)

Production of baitfish along the Texas coast is limited. Only one commercial producer, who raises killifish *(Fundulus grandis)*, or mudminnow, as it is known in Texas, is currently in operation. This species is a highly desired live baitfish for salt-water fishing. Particularly effective for flounder, it is used for all major sportfish, especially in areas where live bait shrimp are not available. Fishermen like using mudminnows because they are hearty and, unlike shrimp, they can withstand the wide range of temperatures and water qualities normally encountered in livewells of boats.

Mudminnow production techniques are well developed and technological assistance is available from several state and university programs. Proper site selection and investment in adequate facilities are crucial. One recent attempt to produce mudminnows failed two years in a row. First from flooding during a storm and then from the winter freeze of 1989.

Demand for mudminnows fluctuates seasonally to coincide with availability of other live baits. Also, demand increases in the fall during the flounder run. According to one industry official, the key to profitability is to be able to provide a consistent and adequate supply of mudminnows to bait dealers so they would not need to depend on supply of wild-caught animals. With currently decreasing and erratic supplies of wild-caught mudminnows, the future outlook for this species is favorable.



Oysters, Clams and other Mollusks

The culture of the American oyster *(Crassostrea virginica)* in Texas takes place mainly on private leases. This involves transfer of oysters from closed areas to suitable but presently non-productive publicly-owned areas in the bay. Closed areas, where the animals are more easily cultured, are typically in bays, estuaries and canals and canals where pollutants (primarily sewage) tend to collect. Determinations of the suitability of certain areas for production are made by the Texas Department of Health (TDH).

One of the major problems facing this sector of the aquaculture industry is the fact that the TDH, in addition to being short-handed, has no mandate to assist private industry. Consequently, inspections of private property for the purpose of oyster culturing have been limited. Another limiting factor is the present moratorium on issuance of new private oyster leases. The Texas General Land Office, (GLO) which manages the public lands in the bays along the gulf, has asked TPWD to stop issuing private oyster leases. The reason for this action stems from the fact that these are long term leases. In view of the potential revenues that could be realized from mineral resource extraction (oil), GLO believes that it may not be in the best interest of the citizens of the state to enter into contracts of such long duration. Apparently it is now possible for a shellfish farmer in Texas to pay personnel of TDH to test private or public waters on private lands for the purpose of classifying them as safe or unsafe to culture shellfish for human consumption.

According to TPWD, there are currently 43 leaseholders in Galveston Bay, with a total leased area of 2,322 acres. Total oyster landings from leases and from non-leased open bay areas in Texas in 1990 were 730,000 pounds (of meat) valued at $1.9 million. This represents a five percent increase over 1989 production levels. Forty percent of total oyster production comes from private leases. Oyster harvest in Texas was severely affected by low salinities in 1991 and 1992. In fact, most of the oysters are now dead in San Antonio Bay as a result of above average rainfall in 1992. Polyculture (or growing oysters, clams and/or other mollusks with other species in aquaculture) has been attempted in Texas. In the 1980s, CSCI grew clams *(Mercinaria)* in shrimp ponds successfully and had marketable size clams in 9 months. they were not allowed to sell the crop for human consumption because the intake of the farm was considered to be in "closed waters" (marker 31 of the intercoastal waterway near Brownsville).

Ocean Ventures also attempted polyculture but lost the oyster crop as a result of high salinities in the ponds, lowering the resistance of the oysters to a bacteria ("Dermo"). Attempts by another group to establish an oyster hatchery near Palacios has failed.

CONCLUSION

There is an increasing role for aquaculture as a food source in the United States 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 United States and other areas of the world. The opportunity exists for considerable growth if the appropriate infrastructure, regulatory base, and technological expertise can be assembled.

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