Overview of Aquaculture in the United States

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Aquaculture in the United States is a diverse industry which includes production of a variety of fish, crustaceans, molluscs, and plants. Total estimated U.S. aquaculture production in 1992 was 313,518 metric tons with production income totaling $724 million (1). Thus, in terms of economic importance, the aquaculture industry is comparable in value to the sheep industry and equivalent to either 18 percent of the swine industry or 30 percent of the turkey industry. Also, an infrastructure of producers, processors, wholesalers, and retailers exists that is similar to that found in traditional livestock. A system of providers exists, which numbered over 2,000 in 1994, that supplies feeds, vaccines, fish diagnostics, medications, growth hormones, and physical equipment (pumps, feeders, processing machines) (2). The objective of this report is to investigate diversity within the industry by providing an overview of the types of aquatic animals being cultured in the U.S., trends in the size and geographic distribution of specific components of the industry, existing Federal and State regulations, and Veterinary Services' current role in aquaculture.

Principal Aquaculture Species

There are five principal aquaculture fish species in the U.S. (catfish, trout, salmon, tilapia, and hybrid striped bass) and two categories of non-food fish production (baitfish and ornamental fish). Contribution to total aquaculture production of other fish species such as walleye, sunfish, and largemouth bass is rather limited. In addition to fish, several crustacean species, crawfish and varieties of shrimp, and molluscs are commercially important.

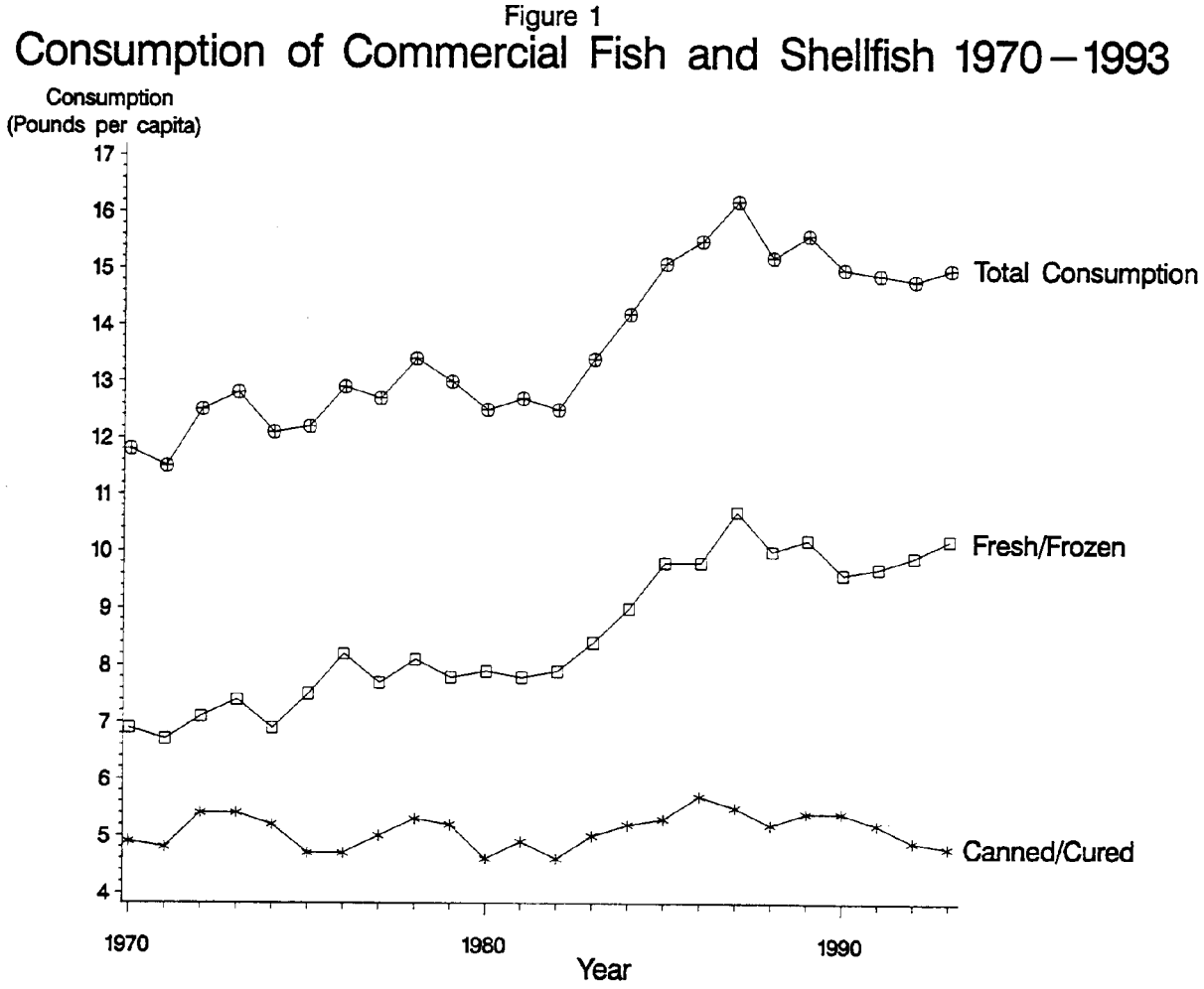
Although each of these aquaculture industries is developing independently, one limit to their combined expansion in the domestic market will be consumer demand for aquaculture products. Demand will be primarily in the form of consumption, except for the baitfish and tropical fish industries. Per capita consumption of fish (canned, fresh and frozen, cured) in the U.S. increased from 12.5 to 16.2 pounds per capita in the early 1980's but subsequently has remained relatively stable (Figure 1) (1). The average per capita consumption of fish is less than consumption of beef (68.5 pounds), poultry (51.8 pounds), or pork (47.3 pounds), but substantially more than veal (1.2 pounds) or lamb (1.0 pounds) (3).

Since consumption of aquaculture products does not appear to be increasing substantially in the U.S., industry development will depend on becoming competitive on the international market and filling the niche left by declining catches from the ocean. In 1992, the National Marine Fisheries Service (NMFS) listed fisheries stocks, many of which are the Nation's most valuable fisheries resources, that are being over utilized and/or are below the population levels need to sustain projected yields (4). The fisheries include New England groundfish, Atlantic sea scallops, gulf shrimp, highly migratory pelagic stocks, Pacific salmon stocks, and many near shore stocks (some oyster populations, bay scallops, abalones, Pacific striped bass).

Catfish

Catfish, primarily the channel catfish (*Ictalurus punctatus*), is by far the largest aquaculture industry in terms of weight of product (Table 1) and value (Table 2)(1). Between 1983 and 1992, the value of the catfish industry represented almost 40 percent of the total estimated value of the aquaculture industry. A majority of the catfish industry is located in the south where longer growing seasons and warmer water is conducive to production (Figure 2).

Figure 1



Source: NMFS, Current Fishery Statistics

Total water surface area in production in 1994 was 153,640 surface acres with 97 percent of the acreage occurring in five States: Mississippi (93,700 acres), Arkansas (21,900 acres), Alabama (18,170 acres), Louisiana (11,070 acres), and Georgia (4,000 acres) (5). All other States each had less than 2,500 surface acres in 1994. The geographic distribution of the industry has been fairly stable since the early 1980's (Figure 2)(6). Since 1982, the industry has increased in number of farms from 1,494 to 2,155 with most of the increase occurring between 1982 and 1987 (Table 3). Much of the increase in the number of farms has occurred in three States (Louisiana, Mississippi, and Alabama), while notable increases have occurred in both of the Carolinas.

Growth of the catfish industry was fairly steady throughout the 1980's, but in the last few years production has been a leveling off. In 1994, catfish production fell 4 percent as farmers cut back due to low prices in 1993 (7). However, production is expected to expand 5-7 percent in 1995 due to increasing sales prices. Total acreage of ponds for catfish culture was up in 1994 by 1 percent which follows 2 years of decline.

Table 1 - Estimated U.S. aquaculture production (metric tons) of selected species. (Source: NMFS:Fish. Stat. Div.)

Species	Year									
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Baitfish	10,000	10,704	11,252	11,706	11,794	11,975	10,899	9,802	9,608	9,352
Catfish	62,256	69,970	86,916	96,959	127,232	133,861	155,085	163,492	177,297	207,460
Salmon	833	1,213	1,779	1,305	1,825	3,074	3,857	4,114	7,599	10,858
Trout	21,954	22,653	22,952	23,133	25,513	25,416	25,187	25,772	26,954	25,521
Clams	762	947	907	1,163	1,093	965	1,075	1,669	1,716	1,942
Crawfish	31,524	30,064	29,489	31,676	31,752	29,868	29,937	32,205	27,481	28,591
Mussels	335	355	549	533	528	483	280	275	95	128
Oysters	8,807	11,505	9,936	11,102	10,853	11,067	10,095	10,066	9,359	10,880
Shrimp (Freshwater)	125	144	121	81	91	130	159	184	184	147
Shrimp (Saltwater)	116	239	200	614	1,205	998	680	900	1,600	2,000
Misc. [1]	3,175	4,491	6,350	7,031	7,734	9,072	11,340	11,218	12,127	16,638
Total Weight	139,887	152,285	170,451	185,304	219,619	226,909	248,584	259,697	274,021	313,518

The long-term trend appears to be similar to what has occurred in other animal industries: concentration into fewer but larger farms. Still there appears to be room for smaller producers, since the average size of fish farms in Mississippi dropped by 20 acres to 323 acres in 1994 (7). More detailed analysis of production and processing linkages would be necessary to determine the future role of small producers. The industry is trying to promote itself as evidenced by a 1994 Catfish Institute investment of $1.6 million on an advertising campaign that was designed to increase public awareness of farm-raised catfish (2).

Trout

Trout, principally rainbow trout (*Oncorhynchus mykiss*), production is about one-sixth the size of the catfish industry on weight basis but about one-fourth the size on a value basis (Tables 1 and 2). Between 1983 and 1992, value of the trout industry represented 13 percent of the total estimated value of the aquaculture industry. The number of trout farms was 513 in 1982 and 577 in 1992 (6). Trout farms are spread throughout the country, except they do not tend to be found in the southeast (Figure 3). Need for cooler water temperatures during the whole year is the principal driving force in determining the industry's geographic distribution. The geographic distribution of trout farms over time indicates an increase in numbers of farms in the eastern U.S., especially North Carolina.

[1]Miscellaneous includes ornamental fish, alligators, algae, aquatic plants, hybrid striped bass, tilapia,and others.

Table 2 - Estimated value of U.S. aquaculture production of selected species (X $1,000). (Source: NMFS: Fish. Stat. Div.)

Species	Year									
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Baitfish	44,000	47,045	51,280	51,522	71,500	71,000	62,489	53,978	55,948	61,183
Catfish	83,860	106,899	138,922	142,789	173,347	225,463	245,142	273,210	246,639	273,506
Salmon	2,548	3,414	5,465	4,399	7,462	20,647	23,742	26,341	44,156	75,193
Trout	50,000	54,435	55,154	55,590	57,556	57,927	60,041	64,640	59,142	53,942
Clams	6,368	6,670	4,698	8,173	10,311	11,320	12,721	13,486	11,133	11,539
Crawfish	32,664	27,936	29,350	35,009	29,400	24,364	20,460	34,000	33,285	24,860
Mussels	340	309	642	1,032	1,024	1,130	1,136	1,173	947	1,162
Oysters	32,034	47,906	38,882	49,666	49,549	58,900	58,082	77,949	63,463	82,432
Shrimp (FW)	1,500	1,698	1,541	893	1,250	1,922	2,537	2,407	2,407	1,728
Shrimp (SW)	510	874	1,566	1,687	3,408	7,609	7,551	7,937	14,110	17,637
Misc.[2]	7,000	9,900	20,000	21,700	32,285	40,000	45,600	99,991	104,998	111,005
Total Value	260,824	307,086	347,500	372460	437,092	520,282	539,501	655,112	636,228	724,187

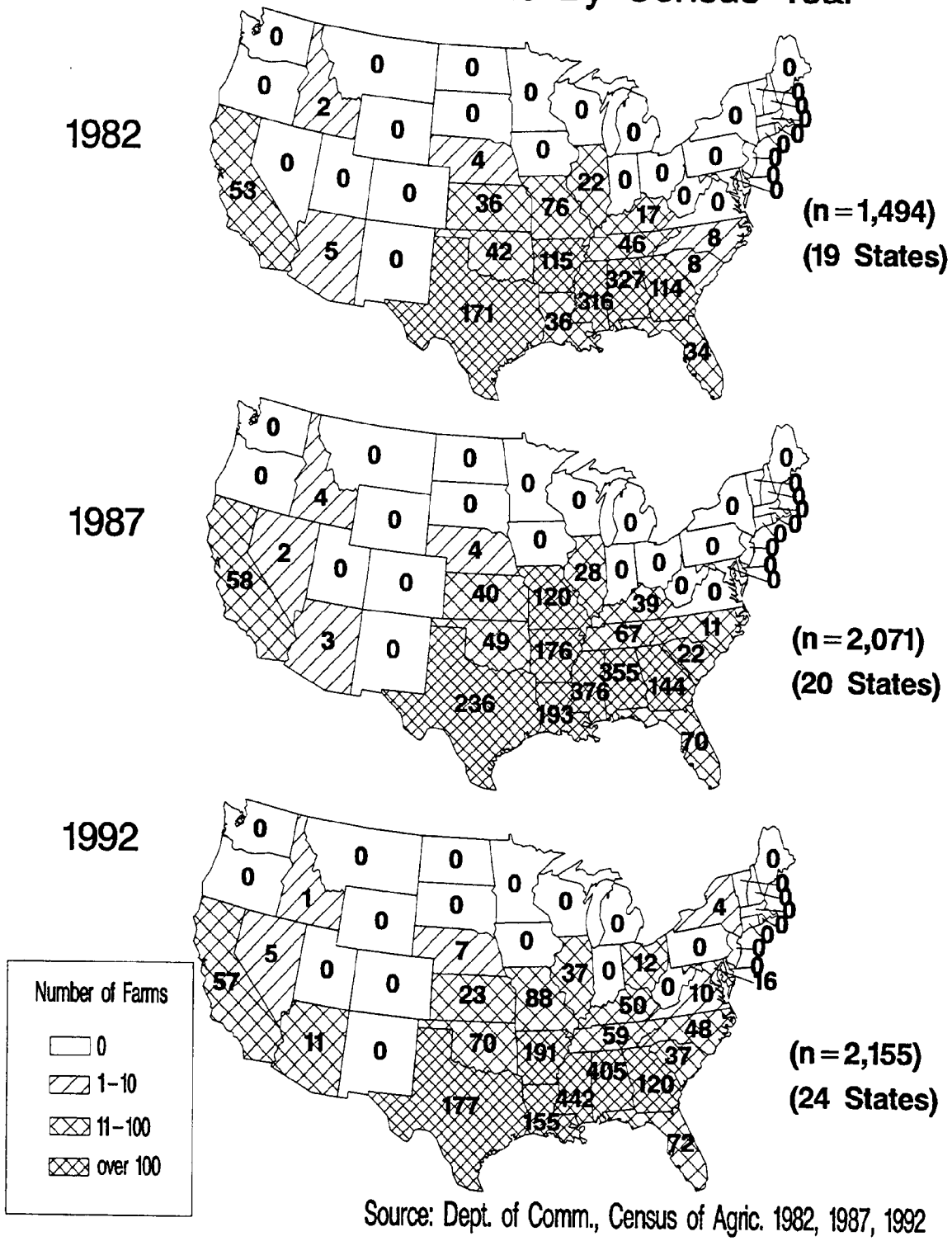
Value of production provides a different perspective on the industry. Idaho produces 50 percent of U.S. farmed trout with the next closest State being North Carolina, which accounts for 8.6 percent of the U.S. trout production (Table 4)(6). Total U.S. production is increasing at a higher rate than is the rate of increase in Idaho which has resulted in declining percentage of total production for Idaho in spite of steadily increasing actual production.

Production of trout was fairly steady during the mid-1980's and into the early 1990's (Table 1). Sales of live trout and trout products peaked in 1990 at $64.6 million (Table 2). Declining production, somewhat offset by recent increases in sales prices, resulted in sales of only $53.9 million in 1994 (7). Sales in all facets of the industry except exports (eggs, fingerlings, stocker, and food-size fish) declined in 1994 (7). Exports of trout products have steadily increased in the recent past, but still only represent about 5 percent of estimated U.S. production, and are roughly equivalent to trout imports. These trends combined seem to indicate that the trout industry is not poised for substantial expansion in the near future. A major constraint may be the availability of sufficient supplies of cool, clean water that can be diverted to aquaculture production. For example, flow-through production

[2]Miscellaneous includes ornamental fish, alligators, algae, aquatic plants, hybrid striped bass, tilapia, and others.

Figure 2

Number of Catfish Farms By Census Year



Source: Dept. of Comm., Census of Agric. 1982, 1987, 1992

Table 3. - Number of farms for selected freshwater species in 1982, 1987, and 1992.
(Source: Dept. of Comm., 1992 Ag. Census)

Year	Species					
	Catfish	Trout	Hybrid Striped Bass	Crawfish	Other Fish	Other Aquaculture Products
1982	1,494	513	NA	NA	NA	128
1987	2,071	547	NA	NA	NA	443
1992	2,155	577	121	340	669	397

can require between 5,000 to 10,000 gallons of water to produce a pound of fish (8). The United States Trout Farmer's Association is trying to implement a quality assurance program that emphasizes decreasing production costs, improved management practices, and avoidance of drug and chemical residues (2). They hope to promote self-regulation with their program (2).

Salmon

Between 1983 and 1992, the value of the salmon industry represented on average about 3.5 percent of the total estimated value of the aquaculture industry (Table 2). The percentage has steadily increased from less than 1 percent in 1983 to more than 10 percent in 1992 (6). Farmed Atlantic salmon (*Salmo salar*) and Pacific salmon (*Oncorhyncus* sp.) production in 1992 was 10,858 metric tons (1) but had risen to 12,000 metric tons in 1994 (Table 2)(7). Maine and Washington are the primary producers of farmed salmon. Maine produces about twice as much farmed salmon as does Washington.

Table 4. -Top 10 States in value of trout production for 1992. (Source: Dept. of Comm., 1992 Ag. Census)

State	Sales (x $1,000) and percent of U.S. sales by year					
	1982		1987		1992	
	Value	Percent	Value	Percent	Value	Percent
Idaho	26,502	55.9	34,013	52.1	37,060	47.4
North Carolina	2,026	4.3	3,481	5.3	6,738	8.6
Pennsylvania	2,480	5.2	3,697	5.7	6,000	7.7
California	3,960	8.4	5,479	8.4	5,962	7.6
Washington	2,375	5.0	2,161	3.3	4,199	5.4
Colorado	1,241	2.6	2,096	3.2	2,578	3.3
Virginia	940	2.0	1,572	2.4	2,125	2.7
Utah	NA	NA	NA	NA	1,914	2.5
Missouri	837	1.8	NA	NA	1,558	2.0
Wisconsin	809	1.7	589	0.9	1,521	1.9

Table 5- Value and quantity of U.S. imports of selected seafood products.
(Source: ERS, Situation and Outlook Report)

Commodity	Value by year ($1,000)				Weight by year (metric tons)			
	1991	1992	1993	1994	1991	1992	1993	1994
Shrimp, frozen	1,713,992	1,882,286	1,998,302	2,459,708	227,209	253,900	252,824	263,641
Shrimp, fresh and prep.	142,676	135,162	171,288	224,128	18,062	16,719	20,348	21,777
Atlantic Salmon, fresh	107,912	125,857	155,196	169,708	18,050	22,201	28,573	31,025
Pacific Salmon, fresh	113,411	76,682	59,951	54,899	25,299	18,216	15,418	14,524
Ornamental fish	36,105	41,122	45,249	46,770	0	0	0	0
Oysters, fresh or prep.	44,045	46,419	47,238	40,110	8,143	7,636	7,860	700
Tilapia	NA	6,029	18,029	25,586	NA	3,397	11,268	14,585
Atlantic Salmon, frozen	10,531	16,133	19,983	21,019	1,676	2,410	3,506	3,569
Salmon, canned & prep.	16,350	14,449	13,138	16,849	1,336	1,214	933	1,450
Pacific Salmon, frozen	13,310	19,908	16,841	14,390	3,978	4,636	5,300	5,095
Mussels, fresh or prep.	7,090	7,619	8,661	13,178	2,998	3,480	4,390	5,015
Clams, fresh or prep.	6,758	6,935	6,822	9,936	3,170	2,815	2,645	3,757
Trout, fresh & frozen	4,417	6,189	5,230	5,467	1,758	2,817	2,155	1,763
Trout, live	76	106	208	116	0	0	0	0

World production of salmon in 1994 is estimated to be 500,000 metric tons which is about equal to the U.S. wild harvest (primarily in Alaska)(7). Norway is the largest producer of farmed salmon with a 1994 harvest of 210,000 metric tons.

The U.S. supply of farm-raised salmon continues to expand. Projected small increases in aquaculture production will not mitigate forecasted decreases in the wild harvest from Alaska. Demand for salmon will be met with increased imports of farmed Atlantic salmon in 1995 (7). In 1994, about 35,000 metric tons of Atlantic salmon were imported, a 75 percent increase over the 1991 levels (7). The imports were almost three times as large as domestic production, so the domestic, farm-raised salmon industry has the potential to grow to fill the niche currently filled by imports. U.S. industry may be at a competitive disadvantage to foreign producers for a number of reasons, including: 1) the expense of complying with State and Federal regulations, 2) overlapping jurisdictions of regulatory agencies, 3) opposition to new marine leases, 4) high costs relating to management of diseases, and 5) limited access to investment capital.

Tilapia

Tilapia (*Tilapia* sp.), a member of the cichlid family, is a relatively new species to the aquaculture

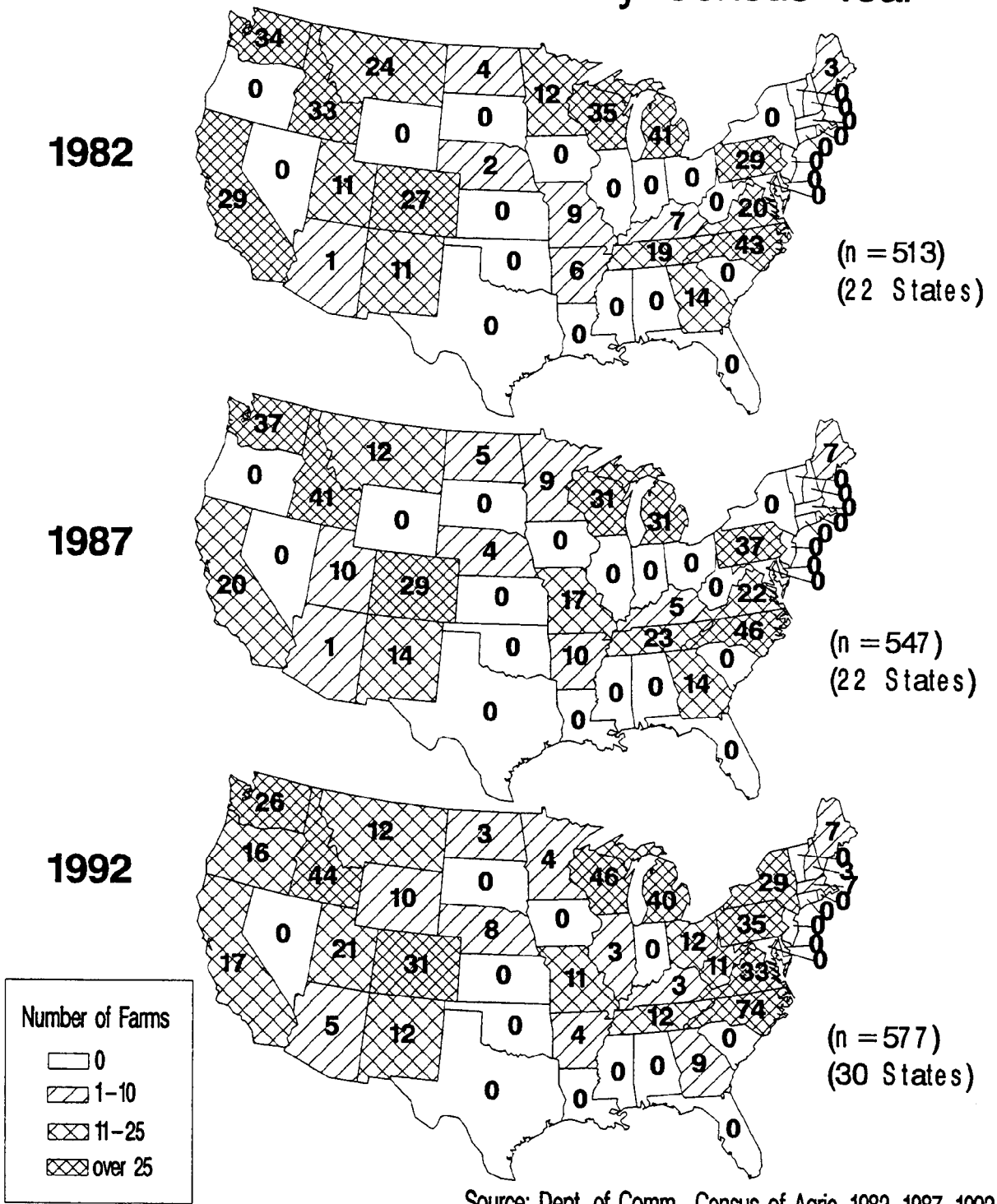
Table 6- Value and quantity of U.S. exports of selected seafood products
(Source: ERS, Situation and Outlook Report)

Commodity	Value by year ($1,000)				Weight by year (metric tons)			
	1991	1992	1993	1994	1991	1992	1993	1994
Pacific Salmon, frozen	359,818	594,794	485,488	476,910	90,304	109,124	117,160	118,395
Canned & pres. salmon	135,146	171,939	162,261	163,687	30,540	38,995	38,739	41,088
Shrimp, frozen	64,134	66,382	61,806	55,258	6,809	8,219	7,511	6,192
Shrimp, fresh & pres.	44,611	49,653	48,500	52,988	5,847	6,678	6,507	7,172
Pacific Salmon fresh	29,502	46,871	36,765	40,305	6,763	9,389	11,034	10,220
Ornamental fish	12,746	16,455	17,366	18,867	0	0	0	0
Clams, fresh or prep.	7,037	6,699	6,284	5,779	2,002	2,272	1,917	1,720
Oysters	2,397	2,781	3,514	6,892	422	502	661	1,197
Atlantic Salmon, fresh	1,647	4,920	11,203	3,649	215	635	1,826	538
Trout, fresh & frozen	2,652	2,873	3,233	3,475	739	803	839	890
Mussels, fresh or prep.	1,864	2,657	2,802	2,115	757	1,053	1,041	880
Trout, live	1,383	992	976	1,636	0	0	0	0

industry in the U.S. but worldwide it is a very important species. The popularity of tilapia culture arises from the species' ability to tolerate crowded conditions and poor water quality but still have excellent taste and rapid growth from sources of feed low in the food chain (zooplankton and phytoplankton) (9). Production in the U.S. was about 6,800 metric tons compared to worldwide production of more than 405,000 metric tons(10). Tilapia are grown in most areas of the U.S. The combination of imports (about 20,000 metric tons in 1994) and domestic production puts tilapia usage in the U.S. near that of the domestic trout market.

Tilapia are prolific breeders which makes them suitable for aquaculture production. In many warm weather areas in the U.S. production in open ponds is banned due to the species' ability to proliferate. The concern is that the species would eventually escape into the wild and become uncontrollable (Pers. Comm. Rodney Horner, Ill. DOC). Even in northern areas, where the species could not survive under natural conditions, there is concern that it could get into an artificially-heated environment like a power plant cooling pond and proliferate. Consequently, most U.S. production of tilapia comes from tank systems using recirculated water. Producers' ability to become more efficient and reduce costs of heating, filtration, and pumping water, will determine the industry's future. The abundant supply of tilapia from countries like Taiwan, Costa Rica, Indonesia, and Thailand may put domestic producers at a long-term disadvantage.

Figure 3
Number of Trout Farms By Census Year



Source: Dept. of Comm., Census of Agric. 1982, 1987, 1992

Hybrid Striped Bass

Hybrid striped bass are crosses between female striped bass (*Morone saxatilis*) and male white bass (*M. chrysops*). Over the last decade, the hybrid, sometimes called Palmetto Bass or wipers, has been used by State fish and wildlife agencies as sports fish, but they have also become popular as cultured species. Recently, the reciprocal cross, male striped bass and female white bass, has been produced, and they are known as Sunshine Bass. The decline in wild stocks of anadromous[3] striped bass (about 6,800 metric tons in 1973 but only 450 metric tons in the late 1980's) is seen as the primary factor for the attention being paid to the hybrid (11). Work in the mid-1980's by the North Carolina Sea Grant program helped develop the potential for the hybrid bass to become a marketable commercial product. The species' recent arrival is also demonstrated by the fact that production figures were first reported for the species in the 1992 Census of Agriculture (6). Most production currently is located along the eastern seaboard (Maryland, Florida, South Carolina, North Carolina, Virginia, and West Virginia), but Texas, Arkansas, and California also produce the hybrid (6). In 1994, approximately 2,700 metric tons were produced in the U.S. The average sales price was about $2.73 per pound which is substantially higher than the $0.70 to $1.01 per pound price for catfish and trout (2).

Hybrid striped bass production is gaining in popularity, but it is not known whether the industry will grow to the size of either the trout or the catfish industries in the near future. Since many States allow stocking of the species into State waters there may not be much resistance to expansion on the part of State Conservation Departments. One current limitation to the production of the hybrid is the need to obtain brood stock from the wild (11). This method of obtaining brood stock restricts production of fry to the spring when the species naturally spawns.

Baitfish

Several fish species are cultured for use as bait for sport fishing. The three main species are the golden shiner (*Notemigonus crysoleucas*), the fathead minnow (*Pimephales promelas*), and goldfish (*Carassius auratus*). The combined value of the wild and cultured baitfish industries places it at a comparable level to catfish culture (12). The value of the total U.S. cultured baitfish industry is about $61 million. Most baitfish production occurs in the southeastern part of the U.S., but by far, the industry is concentrated in Arkansas. In 1994, Arkansas had 29,500 acres in baitfish culture and produced almost 7,000 metric tons of baitfish valued at close to $44 million (13). Louisiana and Alabama each had about 2,000 acres in production, and Mississippi had about 1,500 acres of baitfish ponds (13).

Arkansas has a history of baitfish production dating back to 1948. The predominance of Arkansas is most likely related to this history, progressive technological development of baitfish culture, and to available warmwater resources. Large-scale expansion of the baitfish industry outside of Arkansas is not likely due to these factors being present in Arkansas. Overall expansion of the industry will likely track increasing sport fishing activity. Currently, wild caught baitfish probably

[3]Migrate from saltwater to freshwater for breeding.

represents a substantial part of the baitfish industry. Recent concerns about harvesting impacts on the environment, however, may lead to restrictions on the number and types of fish that are allowed to be taken and sold as baitfish. Decreases in wild catch may lead to increased production of farmed baitfish. The ease of handling domesticated strains of some of the most popular cultured baitfish species may also lead to decreased pressure on wild fish (14).

Ornamental Fish

Common ornamental species cultured for commercial sales, typically for aquariums, include guppies, mollies, swordtails, tetras, gouramies and goldfish. Net sales of ornamental fish (sometimes referred to as tropical fish) from Florida alone in 1993 was estimated to be $46.7 million up from $21.7 million in 1987 (15). In Florida there are approximately 187 growers and most of the production occurs in Hillsborough and Polk counties, with some also occurring in Dade and Palm Beach counties. The limited geographic distribution of ornamental fish production in Florida is reflective of the intensive culture techniques on smaller physical operations. The total water surface area in production in Florida in 1994 was 3,735 acres.

Exports of ornamental fish species, worth $17 million in 1993 and $18.9 million in 1994, probably make these species the highest valued domestic aquaculture export. The U.S. is still a net importer of ornamental fish. The top five ornamental fish producing countries are Thailand, Indonesia, Singapore, Hong Kong, and the Philippines (16). The EU market has been one of the largest importers of U.S. ornamental fish but in early 1994 only the United Kingdom was increasing its imports. Most of the growth of U.S. exports of ornamental fish has occurred with Japan, Taiwan, Hong Kong, and Singapore. The forecast for growth in exports from the U.S. is good as the southeastern Asia economies grow and strengthen.

Crustaceans

Freshwater crawfish, primarily red swamp crawfish and a small proportion of white river crawfish, is currently the only crustacean species cultured on a large-scale basis in the U.S. Over a ten year period ending in 1992, the value of crawfish production, on average, represented 12 percent of the total value of aquaculture in the U.S. In 1993, over 27,000 metric tons (value $26.7 million) were produced in Louisiana on more than 143,000 acres of ponds operated by 1,618 producers (2). The production represents over 90 percent of total U.S. farmed production (28,591 metric tons in 1992). There are approximately 21,000 acres of ponds used for culturing crawfish in neighboring Texas. Mississippi, Maryland, South Carolina, North Carolina, Florida, Georgia, and California are all farming crayfish to some degree (17). Louisiana is the primary production area for several reasons including: 1) regional demand for crawfish is high, 2) warmwater for growing, and 3) source of food which is primarily decaying plant material (rice field stubble) (17).

Other crustaceans produced in the U.S. but which currently play a minor role in the aquaculture industry are marine shrimp (*Penaeus* sp.) and freshwater prawns (*Macrobrachium rosenbergii*). U.S. marine shrimp production is about 2,000 metric tons a year of which about 1,700 metric tons are produced in Texas (2). South Carolina and Hawaii are also areas of concentration for the

industry. International production of marine shrimp was 730,000 metric tons in 1994 (2). China, Indonesia, Ecuador, India, the Philippines, Taiwan, Thailand, and Japan are all large shrimp-producing nations. Production of the freshwater prawn is about 150 metric tons in the U.S. (1). Internationally, there are about 26,000 metric tons produced annually, largely in Thailand and other Asian countries (10).

The future for crustacean species culture in the U.S. is mixed. Biologically, the crayfish is well suited to aquaculture in the southeastern U.S., and the potential for expansion is considered excellent especially in areas of rice production. A major advantage of the crawfish industry is the simple culture method. There are no hatcheries to produce young; nor are there formulated rations for feeding. Young are produced by brood stock contained within the pond, and vegetation is utilized as forage. Disadvantages include the high volume of water required to maintain water quality (70-100 gallons per minute per surface acre) and the high expense of harvesting through trapping (18). Another limiting factor of industry growth will likely be the regional nature of consumption of crawfish. Marketing activities may be able to broaden the appeal for crawfish. Marketing of soft-shell crawfish is seen as an area for development since consumers are acquainted with soft-shell crabs. Also, in 1987 a national restaurant chain purchased over 317 metric tons of crawfish from Louisiana producers (2). Competition from imports will be a challenge to the crawfish industry as demonstrated by the doubling of imports in 1994 from China of crawfish meat that is priced below the reported Louisiana production costs (7).

Marine shrimp grow best in less than full strength ocean water (19). Culture facilities must be located near the coast to accommodate this requirement, but in the U.S., there are many laws and regulations that restrict the use of brackish water areas that are often important wetlands(19). Culture of freshwater shrimp is currently restricted to tropical areas. Special techniques would need to be developed for the species to be cultured in subtropical and temperate regions. Growth in the U.S. shrimp industry will most likely be in production of disease-free brood stock and post larvae for international distribution.

Molluscs

Clams, oysters, and mussels are the primary molluscs (shellfish) cultured in the U.S. The total production value of these three molluscs was estimated to be $95 million in 1992 (Table 2). Regionally, shellfish production can represent a substantial part of the value of the aquaculture industry. A survey of Virginia aquaculture found that almost 70 percent of the sales generated from saltwater species was from shellfish (2). In 1992, 31 percent of the total value of aquaculture production in Hawaii was from shellfish.

Most farm-raised clams are Manilla clams (*Tapes philippinarum)* from the West Coast or hard shell clams (*Mercenaria mercenaria*) from the East Coast. Close to 2,000 metric tons of clams were produced in 1992 (Table 1) which represented a small proportion of the total domestic landings (farmed and wild catch), 67,000 metric tons in 1993. Clams are the only mollusc species that appear to have increased production from 1983 to 1992. Pacific oysters (*Crassostrea*

gigas) in the U.S., are primarily from the West Coast and are almost exclusively the product of aquaculture production. American oysters (*Crassostrea virginica*) are produced on the East Coast and the Gulf of Mexico. Louisiana had 1,964 oyster producers in 1993 with a gross farm value of almost $21 million. Total U.S. farmed oyster production in 1992 was estimated to be almost 11,000 metric tons (Table 1) worth $82.4 million (Table 2)(1). Oyster landings in the U.S. during 1993 were over 15,000 metric tons valued at $87 million (16). Mussel (*Mytilus* sp.) production is concentrated on the West Coast. Estimated production of mussels in 1992 was 128 metric tons worth slightly over $1 million (1). Domestic mussel landings in 1993 were 2,900 metric tons (Table 1) valued at $2.6 million (Table 2)(7). These landings represented a 31 percent decline over the 1992 landings because of low production from storm damaged beds on the East Coast (16).

Overharvesting of wild populations will likely open the way for more aquaculture production of mollusc species. Restrictions on marine leasing may limit production. Clams have a production advantage over other molluscs because they are typically consumed at small size which shortens the production time for the premium product. Oysters take much longer to produce so, that even in the face of increased export demand, growers are cautious about expanding before they see if demand will continue in the long term. Other problems for the oyster industry include the impact of pathogens and the public's attitude toward safety of consuming molluscs, oysters in particular.

Imports and Exports of Fisheries Products

Statistics for imports and exports of fishery products generally do not distinguish between farmed and wild-caught animals, so discussion of trade necessarily combines both types. The U.S. is a net importer of both edible and nonedible fisheries products even though it is still the largest exporter of fisheries products in the world. In 1993, $10.62 billion of fisheries products were imported, while $6.92 billion were exported (3). Value of imports of both edible ($5.85 billion) and nonedible ($4.77 billion) products were at record levels in 1993 (1). Shrimp make up more than one-third of the value of imports of edible fisheries products (Table 5). Primary exporters of shrimp to the U.S. are Thailand, Ecuador, Mexico, China, and Indonesia. Salmon account for less than 5 percent of the edible imports. Farm-raised salmon, primarily Atlantic but also Chinook and Coho (Pacific salmon), make up at least 78 percent of the fresh or frozen salmon imports. Most of the salmon imported into the U.S. comes from either Canada or Chile. Norway does not export much to the U.S. despite its world lead in farmed production of salmon.

Value of U.S. exports of nonedible products peaked in 1993 ($3.85 billion), but exports of edible products ($3.08 billion) dipped from a 1992 peak (Table 6). In 1993, export of wild-caught and cultured salmon (fresh and frozen, canned, and roe) represented about 28 percent ($871.4 million) of the value of U.S. export of edible fisheries products (1). Japan received 82.5 percent of the fresh/frozen export while the United Kingdom and Canada imported 79 percent of the U.S.

Table 7: List of important aquaculture diseases of fish

Diseases	OIE Status	Occurrence in the U.S	Regulations				Principal Species Affected	Distribution Outside U.S.
			Can	CA	WV	WY		
Epizootic hematopoietic necrosis (EHN)	Notifiable	No	N	N	N	N	Redfin perch	Restricted to Australia
Infectious hematopoietic necrosis (IHN)	Notifiable	Northwest	Y	Y	N	Y	salmonids	Canada, Japan, Italy, France, Germany
Oncorhyncus masou virus disease (OMV)	Notifiable	No	N		N	Y	salmonids	Japan
Spring viremia of carp (SVC)	Notifiable	No	N	Y	N	Y	carp species	U.K., Europe, Middle East
Viral hemorrhagic septicemia (VHS)	Notifiable	W. Coast	Y	Y	Y	Y	salmonids	Continental Europe
Infectious pancreatic necrosis (IPN)	Concern	widespread	Y	Y	Y	Y	many species	Worldwide
Bacterial kidney disease (BKD)	Concern	widespread	N	Y	N	Y	salmonids	Europe, Iceland, Canada
Enteric septicemia of catfish (ESC)	Concern	widespread	N	Y	N	N	catfish	Thailand (not widespread)
Channel catfish virus disease (CCVD)	Concern	widespread	N	Y	N	N	catfish	None
Infectious salmon anemia (ISA)	Concern	Northwest	N	N	N	N	Chinook, Coho, Atlantic	Norway, Japan
Salmonid rickettsial septicemia	Concern	No	N	N	N	N	Chinook, Atlantic salmon	British Columbia, Chile
Encephalitis virus disease	Concern	No	N	N	N	N	Sea-bass, barramundi, parrotfish	Japan
Epizootic ulcerative syndrome (EUS)	Concern	No	N	N	N	N	many species	Southeast Asia
Whirling disease (*Myxobolus cerebralis*)	Unlisted	Spreading	Y	Y	Y	Y	salmonids	Russia, U.K., N.Z., Lebanon
Ceratomyosis (*Ceratomyxa shasta*)	Unlisted	OR,CA, WA,ID	Y	Y	N	Y	salmonids, other species	British Columbia
Furunculosis (*Aeromonas salmonicida*)	Unlisted	widespread	Y	Y	N	Y	freshwater fish	S. America, Europe, Asia, Australia, Africa
Enteric redmouth (*Yersinia ruckeri*)	Unlisted	widespread	Y	Y	N	Y	salmonids, goldfish, bass	Europe, Canada, S. America
Proliferative kidney disease (PKD)	Unlisted	ID,CA,WA	N	Y	N	Y	salmonids	Europe, British Columbia, Newfoundland

Table 7: List of important aquaculture diseases of fish (Continued)

Diseases	OIE Status	Occurrence in the U.S	Regulations				Principal Species Affected	Distribution outside U.S.
			Can	CA	WV	WY		
Proliferative gill disease (hamburger gill)	Unlisted	Southeast, CA	N	N	N	N	Catfish only	None
Columnaris disease	Unlisted	widespread	N	N	N	N	Catfish, other freshwater spp.	Widespread
Salmon leukemia virus	Unlisted	West Coast	N	N	N	N	Chinook salmon	None
Herpesvirus salmonis (HVS)	Unlisted	West Coast	N	N	N	N	Rainbow trout, Chinook	None
Vibrio salmonicida septicemia (Hitra disease)	Unlisted	East Coast	N	N	N	N	Atlantic salmon	Europe, Canada (east coast)
Salmon lice(*Lepeophtheirus salmonis, Caligus sp.*)	Unlisted	East & West	N	N	N	N	salmonids	Worldwide

canned salmon export. Fresh and canned shrimp exports represent only about 5 percent of the value of U.S. export of edible fisheries products. The relatively low value of shrimp exports ($108 million) compared to imports ($2.75 billion) results in a large trade imbalance. Most of the shrimp is exported to either Canada or Mexico (1).

Diseases and Disease Monitoring in Aquaculture Production

Knowledge of diseases affecting aquaculture species is rapidly expanding along with other technological aspects of the industry. In 1981, there were 27 reported viral agents in fish; 16 isolated in cell culture and 11 seen by electron microscopy (20). By 1988, there were 59 viral agents reportedly causing disease in fish; 34 viruses were isolated, and another 25 that had been visualized but not yet isolated (20). From 1988 to 1993, another 35 new viral agents were described in the literature. New isolates were being described so quickly that researchers who summarized the virus isolations suggested that some of the new isolates may be similar, if not identical, to isolates previously described in the literature. The rapid increase in the isolation of viruses was attributed to increased surveillance of fish populations (20).

Diseases associated with all types of aquaculture have spread, sometimes very rapidly, over wide geographic areas. An example of disease being introduced into the U.S. is the Taura virus in Pacific white shrimp (*Penaeus vannamei*). In 1992, the virus was first isolated near the mouth of the Taura River in Ecuador. Within 3 years the virus has spread throughout Ecuador, into Central America and Hawaii, and recently reached the continental U.S. causing severe disease problems in cultured shrimp in Texas. Enteric septicemia, an economically devastating disease of catfish, was first described less than two decades ago from a locality in the U.S. Extensive movement of fish and the highly infectious nature of the bacteria, *Edwardsiella ictaluri*, have led to epizootics in all of the southeast States and Idaho, Indiana, Colorado, Maryland, Arizona, and California (21). Despite the widespread nature of the bacteria in the U.S., there have only been two reports of the

disease outside the U.S. Infectious hematopoietic necrosis in salmonids was first described in 1960 in California and was later isolated in Oregon (22). The virus has spread to other parts of the U.S. and the world through movement of contaminated fish and fish eggs from the Pacific Northwest. The disease is considered endemic to the Pacific Coast of North America and Japan.

The physical spread of disease in aquaculture differs from spread of disease in traditional livestock due to the nature of the aquatic environment and physiology of the aquatic organisms. Many potential disease pathogens are continually present in the aquatic environment which, under natural conditions, are not pathogenic due to natural defense mechanisms of aquatic species. Fish, for example, have a mucus layer, scales, skin, and antibody defenses against disease (23). Systemic bacteria are typically present in healthy fish and are not typically considered to be problematic unless a large number of similar types of bacteria are found in more than one fish from the same pond (Personal communication, Andrew Mitchell, Nat. Biol. Serv.). Decreased resistance to disease may be a result of factors that induce physical stress and physical injury. Conditions in commercial operations that may lead to stress include high fish densities, poor water quality (low dissolved oxygen, undesirable temperature or pH levels, high levels of waste products including carbon dioxide and ammonia), inadequate nutrition, and poor sanitation (23).

In 1960, the Office International des Epizooties (OIE) formed a special commission for fish diseases (24). The Fish Disease Commission maintains a list of communicable fish diseases considered to be of economic or public health importance. These diseases are reportable to the OIE. The Commission also annually updates a list of diseases of aquatic animals that are of concern. In 1988, the focus of the commission was extended to include molluscs and crustaceans. Currently, there are five and six diseases for fish and molluscs, respectively, that are reportable to the OIE (Tables 7 and 8). No diseases of crustaceans are currently listed as reportable. OIE lists eight and six diseases of fish and crustaceans, respectively, as diseases of concern. No diseases of molluscs are present on the list of diseases of concern.

There are several fish diseases not listed by the OIE that are of either National or regional concern. These additional diseases were obtained from regulations from Canada, California, West Virginia, and Wyoming, and from a list of diseases from the Fish Experiment Station at Stuttgart, Arkansas. Whirling disease has received a great deal of attention because of its introduction into wild fish populations. Recently, the disease has spread in the Rocky Mountain States and there is concern in the Northeast where it may have harmful effects on wild and cultured salmonids.

Monitoring and surveillance for fish diseases do not currently exist at a National level in the U.S. During the 1980's, a diagnostic disease laboratory reporting system was initiated by the Fish Experiment Station at Stuttgart, Arkansas. Southeastern States reported data for 11 years until the project ended in the early 1990's. The U.S. Fish and Wildlife Service operates nine regional fish health centers that have provided diagnostic services to Federal and State hatcheries and private aquaculture operations. Each center submits an annual report, but reports are not standardized or compiled. The Association of American Veterinary Laboratory Diagnosticians has formed a

committee to investigate available information concerning diagnostic laboratories and commercial reagent suppliers. They hope to look into processes for laboratories to obtain accreditation. At this point, existing data on national aquatic animal health appear limited.

Regulations Affecting the Aquaculture Industry

State Regulations

The aquaculture industry is regulated by many different Federal and State agencies. The diversity of agencies with jurisdiction over the industry is due to the nature of the industry and its history. Both aquaculture and native/game species often share the same water source; the same species may be grown for aquaculture but still be regulated by State fish and game agencies. Use of water (both fresh and salt), treatments of water for therapeutic, water quality, or pesticidal reasons, and discharges of effluent wastewater or treated water are all regulated, as often is land use and modifications to the land. Issues regarding nonindigenous species, escapes of cultured animals, disposal of bait species, and habitat also are under the purview of several regulatory agencies. When aquaculture animals are intended for food use another set of agencies is involved, and if the product is destined for export, regulations of other countries can impact the industry.

State regulations are highly variable. In some States, the lead regulatory authority rests with the Agriculture agency, but in others it falls under the Natural Resource agency. Typically, a number of other State agencies will also have some authority over the aquaculture industry. The only summary of State regulations currently available was included in a 1993 survey of State aquatic health policies that was conducted jointly by the Maryland Department of Agriculture's Aquaculture/Seafood Programs and the National Association of State Aquaculture Coordinators (27). The survey results are discussed below. Regulations obtained directly from a few States are also presented since the survey did not thoroughly address State regulations. The brief review of regulations from four States demonstrates the diversity of authorities, permiting and reporting requirements, and importation restrictions.

Thirty-five States, Puerto Rico, and Guam responded to the survey. Almost 65 percent of the States required health certificates for fish entering the State, while only 2.7 percent reported requiring a health certificate when leaving the State. Health certification for intrastate movement and for release into public waters was required by 21.6 percent and 35.1 percent of the respondents, respectively. About one-third of the respondents charged fees. Lists of animal pathogens or species prohibited from introduction into State waters were kept by 49 percent of the respondents.

Aquaculture regulations in Missouri are structured such that the Missouri Department of Conservation (MDC) plays a minimal role in regulation of the aquaculture industry (Pers. Comm. Gary Novinger, MDC). No reporting or permits are required by MDC. MDC has a list of 47 fish species and 3 crustaceans (all three are crayfish) that it allows to be cultured in the State. MDC

Table 8: List of important aquaculture diseases of molluscs and crustaceans

Diseases	OIE Status	Occurrence in the U.S.	California Regulations	Species Affected	Distribution outside U.S.
Bonamiosis	Notifiable	W. Coast	Yes	oysters, clams	Europe
Haplosporidiosis	Notifiable	E. Coast	Yes	Atlantic and Pacific oysters	France, Korea, Japan
Marteiliosis	Notifiable	Florida	No	oysters, clams, mussels	South U.K. to Portugal
Perkinosis	Notifiable	E. Coast, HI	No	oysters	Caribbean
Iridovirus	Notifiable	Yes, unknown distribution	No	molluscs (?)	None reported
Monodon baculovirus infection (MBV)	Concern	Texas	No	penaeid shrimp	Widely distributed in cultured shrimp
Yellowhead monodon baculovirus infection (YMBV)	Concern	No	No	penaeid shrimp	S.E. Asia, Indo-Pacific region
Baculovirus penaei infection (BP)	Concern	HI, South	No	penaeid shrimp	Peru to Mexico in the Pacific, Central Brazil to U.S. in Gulf of Mexico
Baculoviral midgut gland necrosis virus infection (BMNV)	Concern	None	No	penaeid shrimp	Japan, Korea, Philipines, possibly Australia and Indonesia
Infectious hepatopancreatic and hemato-poietic necrosis (IHHN)	Concern	HI, Southeast	Yes	penaeid shrimp	Asia, S. America, Australia, Israel, Philipines, C. America
Crayfish plague	Concern	Widespread	No	crayfish	Europe, U.K.
Vibriosis	Unlisted	Ubiquitous in marine culture	Yes	molluscs, crustaceans	Ubiquitous
Denmand Island disease	Unlisted	None	Yes	Pacific oyster	Canadian west coast
Taura virus disease	Unlisted	TX, HI	No	*Penaeus vannamei*	Ecuador, S. and C. America

does restrict importation of live fish and eggs from the Salmonidae family (trout, salmon, chars) by requiring a health permit that certifies the source of fish or eggs to be free of viral hemorrhagic septicemia, whirling disease, or other diseases that may threaten the fish stocks within the State. The Missouri Department of Agriculture does not have any regulations that supplement those enforced by MDC. No information was available on discharge permits nor dam permits, but since the basis for these are Federal regulations, it can be assumed that they are needed.

In Oklahoma, the Oklahoma Department of Wildlife Conservation is the lead agency and will provide aquaculture permits to raise aquatic animals for sale, fee fishing permits for any operation allowing people to fish, and export/import permits for anyone transporting aquatic species into or out of Oklahoma (Personal Comm., Dr. Marley Beem, Oklahoma Cooperative Extension). In addition, a grower may need permits for water rights from the Oklahoma Water Resources Board, for water discharge from the Oklahoma Department of Environmental Quality, and for fish processing from the Oklahoma Department of Health. If a dam is constructed, the grower would

need a dam inspection from the Oklahoma Water Resource Board.

Massachusetts passed new aquaculture regulations in August 1994. The Division of Fisheries and Wildlife is the lead agency. Their regulations "... are designed to create a clear, concise process for issuing permits for the culture and sale of fish while protecting the Commonwealth's existing fisheries resources from over-exploitation, uncontrolled and unintentional introductions, and disease infestations." (28). The regulations provide for four distinct permits ranging from culture for personal use only to a dealers permit. No harvesting of wild fish is allowed under any aquaculture permit type. The Division has a list of 15 species that are allowed for culture. The class 3 aquaculture permit allows for propagation, culture, maintenance, purchase, and sale of fish. Permits are issued for facilities that meet specified requirements for preventing fish escape. Permit holders must keep records of sales of live fish including the permit number of the buyer. No additional permit is required for selling fish as food, but there are additional packing, marking, and tagging requirements.

Regulations in the State of Illinois are considered to be a model that some other States have used to develop their own regulations. Their regulations are based on an Aquaculture Development Act passed in 1987 and put into place in 1988. The implementation plan was developed in concert with industry, agriculture, and fish and wildlife (Pers. Comm. Rodney Horner, IL Dept. of Conservation). Aquaculture producers purchase a permit to culture aquatic organisms (29). The permit grants them legal title to the fish which is often retained by the natural resource agencies in other States. It is easier for producers to get development money when they have legal title to their crop. Also, they are allowed to use any gear needed to harvest their fish and do not fall under State fishing regulations. The permit is issued for any species on the aquatic life approved species list which includes 37 amphibians, 47 reptiles, 38 crustaceans, 36 molluscs, 62 gastropods, 148 fish, and 105 plants. Any species not on the list cannot be imported without a letter of authorization. A review of a request for importation of a species not on the list is performed by the Aquaculture Advisory Committee which is composed of representatives from the four divisions of the Department of Conservation (Fisheries, Wildlife, Natural Heritage, Law Enforcement), the president of the Illinois Aquaculture Industry Association, the Natural History Survey, the aquaculture coordinator for the Illinois Department of Agriculture, the director of the Southern Illinois University Fisheries Research Laboratory, and the Department of Public Health (Division of Food, Drugs, and Dairies). The head of the division of Fisheries must consider recommendations of the Committee before making a final decision.

Producers in Illinois are not required to report sales or production, but they are required to keep records for 2 years. If the producer holds a State pesticide application permit, they are permitted to apply rotenone. The producer must also get a permit to slaughter fish for sale through the Illinois Department of Health. The Illinois model appears to work well by satisfying the needs of the conservation agency to control introductions and escapes but also allow the flexibility for the industry to culture a wide range of species (Personal Comm., Rodney Horner, IL Dept. of Conservation).

Federal Regulations

Many Federal agencies have jurisdiction over aspects of the aquaculture industry; sometimes several agencies with the same department have different responsibilities. For example, the Department of Agriculture has involvement in animal health, export certification, animal damage control (APHIS), in conducting research in aquaculture production and diseases (Agricultural Research Service), in providing research funds and technical information (Cooperative State Research, Education, and Extension Service), in assistance with pond construction (Soil Conservation Service), and in assistance with financing through farm loans (Farmers Home Administration). The Economic Research Service and National Agriculture Statistical Service both compile information on the size and value of the industry.

Other Federal agencies (not an exhaustive list) with involvement in or jurisdiction over aspects of aquaculture include the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), the Department of Interior's Fish and Wildlife Service (FWS), the Department of Commerce's National Marine Fisheries Service (NMFS), and the Department of Defense's Army Corps of Engineers (COE).

Authority for the FDA to regulate the aquaculture industry arises from the Federal Food, Drug, and Cosmetic Act (25). Under this law the FDA regulates manufacturing, testing, registration, distribution, and use of animal drugs and feeds. The FDA centers with authorities involving aquaculture are the Center for Veterinary Medicine (CVM) and the Center for Food Safety and Applied Nutrition (CFSAN). These centers ensure that drugs used in food-producing animals are safe and effective, free from harmful residues, and develop and enforce standards for good safety, quality, residues, and nutritional labeling. The FDA also administers, in conjunction with the States, the Interstate Shellfish Sanitation Commission, which addresses standards for water quality in growing areas, and processing, transportation, and marketing of molluscs.

The EPA is involved in regulating aquaculture under at least four separate authorities: 1) the Federal Insecticide, Fungicide, and Rodenticide Act; 2) the Federal Food, Drug, and Cosmetic Act; 3) the Clean Water Act (National Pollutant Discharge Elimination System- NPDES); and 4) the National Environmental Policy Act (NEPA). The EPA and FDA have mutual responsibilities under the first two acts and have a memorandum of understanding that provides guidance for jurisdiction. The EPA has jurisdiction over disinfectants, sanitizers, and aquatic treatments for control of algae, bacterial slime, or other pest control but which do not include claims for control of parasites or diseases of fish. The EPA sets tolerances for pesticide residues. The FDA authority covers new animal drugs or products intended to treat or prevent parasites or diseases. The FDA enforces the pesticide tolerances in food products. Under the Clean Water Act, EPA has the responsibility to prohibit discharge of any pollutant to navigable waters unless the discharge is covered by a NPDES permit. Types of discharge of concern include waste water, drugs, and pesticides. NEPA provides for preparation of environmental impact statements when Federal agencies are involved in activities related to wetlands, floodplain management, environmentally-significant agricultural land, and wild and scenic rivers.

The FWS has authority over aquaculture through the Lacey Act, the Endangered Species Act, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and the Fish and Wildlife Coordination Act. The first three authorities give the FWS a role in controlling imports of live fish, fish eggs and fish products. A recent final rule exempted exports of live farm-raised fish and farm-raised fish eggs from the FWS export requirements because exportation was not significantly increasing the risk that illegally taken wild fish were being exported as farm-raised fish. The last authority, the Fish and Wildlife Coordination Act, "requires that Federal agencies involved in actions that will result in the control or structural modification of any natural stream or body of water for any purpose, to take action to protect the fish and wildlife resources which may be affected by the action." (16 U.S.C. et seq). This authority gives the FWS responsibility that sometimes affects the construction or operation of aquaculture facilities.

The NMFS in the Department of Commerce has several legislative authorities that allow the service to oversee aspects of aquaculture in the marine environment: 1) the Magnuson Fisheries Conservation and Management Act for conservation of fisheries resources in the U. S. Exclusive Economic Zone (EEZ); 2) the Marine Mammal Protection Act for monitoring, protection and management of marine mammal stocks in U.S. waters; 3) The Endangered Species Act for monitoring and protection of marine life considered at risk of extinction; and 4) the Fish and Wildlife Coordination Act which provides concurrent responsibilities with FWS for protecting aquatic habitat (4). Essentially, NMFS is the agency responsible for most of the living marine resources within the 200-mile EEZ. The States also have jurisdiction in areas closer to shore, and the various regional fisheries commissions advise or share responsibilities with NMFS in certain areas or with certain species.

The Department of Agriculture, in accordance with a variety of authorities including the Animal Industry Act, the Agricultural Marketing Act, the Animal Damage Control Act, the Federal Noxious Weed Act, the Virus-Serum-Toxin Act, and the Food Security Act, supports aquaculture development through education, extension, research, and financial assistance (26). Several agencies within the USDA support aquaculture. The Cooperative State Research, Education, and Extension Service (CSREES) provides leadership for aquaculture activities in the Department and operates the Aquaculture office. The CSREES also has both National- and State-level extension personnel actively working in aquaculture to provide the public with technical support. The National Agriculture Library has developed the Aquaculture Information Center dedicated to developing reference material on aquaculture. The Farmers Home Administration is authorized to make loans for both ownership and operation of controlled environment aquaculture. Economic trends in the aquaculture industry are monitored and routinely reported by the Economic Research Service. Annual estimates of catfish and trout production are provided through surveys conducted by the National Agricultural Statistics Service. The Agriculture Research Service conducts and sponsors research on freshwater fish production and associated processing/byproduct utilization.

The Animal and Plant Health Inspection Service (APHIS) of USDA has authority to conduct

research on and operations to control depredation by birds and other wildlife, to regulate all veterinary biologics produced in, shipped into, or exported from the U.S., and to certify and inspect animals and animal products. APHIS' role in aquaculture has increased substantially in the past 15 years and its present role is changing quickly. Much of the involvement has been in predation, noxious weed control, and endorsements for export of ornamental species. The biologics program has been active in aquaculture related products for a number of years. In 1993, APHIS began providing assistance to exporters of live fish and eggs, primarily in the form of health certification. Also, in 1993, APHIS was able to facilitate a shipment of seafood into the European Union.

Current Roles of Veterinary Services, USDA

USDA:APHIS:Veterinary Services (VS), until relatively recently, has had a limited role in aquaculture. Certification of ornamental species for export is a service that VS has been providing for some time. VS' role has expanded in several areas as USDA has become more involved in aquaculture.

Headquarters Staff Staff has begun efforts in developing, planning, and assisting in implementation of all of VS' efforts in aquaculture including Federal laws and regulations. A major role for staff is to develop liaisons with State and other Federal agencies, industry, and aquaculture specialists in academia. This coordination includes involvement in cooperative State-Federal-Industry aquatic animal health improvement programs and continued participation in the Joint Subcommittee on Aquaculture. Initial efforts to coordinate activities with industry began with a meeting held in March 1995. Agreements at the APHIS/Industry meeting included 1) work toward designation and inclusion of aquaculture production as "livestock," 2) develop certification process for interstate and international shipment of fish and their products, 3) education and training for public and private veterinarians in aquatic health issues and, 4) improve cooperation with industry by describing services that VS can provide and keeping industry informed of VS activities and plans. Also, the staff is actively involved in determining export health requirements for aquatic species.

National Veterinary Services Laboratories (NVSL) NVSL has taken initial steps toward fulfilling a variety of functions including diagnostics, reagent production, standardization of reagents and references, laboratory certification, and external laboratory quality assurance. Preliminary efforts have included training individuals in diagnostic methods, investigating laboratory certification, establishing cell cultures, and virus isolation of fish pathogens.

VS field force Certification of animal health for exportation is the principal role that VS field force has undertaken. Most of the export certification has been with trout eggs and ornamental species but other species have been involved including hybrid striped bass and shrimp. In Maine, field personnel have been interacting closely with the aquaculture industry, State government, academia, and other Federal agencies. Other field personnel are beginning to assess the size and

diversity of the industries within their respective areas.

Centers for Epidemiology and Animal Health (CEAH) CEAH is in the initial stages of developing a program for monitoring the health of aquatic species which will develop information concerning management practices, welfare concerns, and production. This monitoring will likely have ongoing components driven by data provided by industry, private veterinarians, or even diagnostic laboratories. Periodic on-premises data collection may also be undertaken for the purpose of generating national and regional estimates of aquatic animal health parameters. Information developed during the monitoring process may allow CEAH to assist the industry with quality assurance activities.

Federal, State, and Industry Contacts

Several sources exist to identify organizations and individuals that are involved in aquaculture. The most current and complete source is the document published by the National Agriculture Library titled "Resource Guide to Aquaculture Information" (30). The document lists trade and professional organizations, State Aquaculture Coordinators and contacts, Federal Agencies (regional and national level), libraries (academic, Federal, and State), and Regional Aquaculture Centers. Individual States and State Extension offices often have lists of individuals/business involved in aquaculture. Another valuable source of information for contacts is the Aquaculture Magazine's annual buyer's guide.

Summary

Aquaculture is distributed throughout the U.S., but the majority of production, in terms of both quantity and value, occurs in the southern part of the country. Freshwater production, dominated by catfish, represents a larger segment of the industry than does saltwater production, predominantly salmon and oysters. From 1983 to 1992, the value of catfish production fairly consistently represented about 40 percent of the total value of U.S. aquaculture production. Crawfish, trout, and baitfish each represented about 12-13 percent of the value of U.S. production over the same period. In recent years, the percentage contribution of trout and baitfish to the total value of U.S. production has been declining. Salmon represented a small percentage of the total U.S. value until the early 1990's, when the percentage doubled to almost 10 percent of total value. In 1992, these five cultured species accounted for 75 percent of the value of U.S. production.

Although the value of the industry is comparable to other livestock industries, the number of operations is still relatively few. In 1992, there were only 4,259 farms raising freshwater species. Half of these operations were catfish farms and 13.5 percent were trout farms.

Constraints to growth in the industry are: 1) demand for product, 2) natural resource availability, and 3) a myriad of Federal and State regulations. Domestic demand for fish/seafood probably will not increase dramatically since per capita consumption does not appear to be increasing in the

U.S. Availability of clean water may be a limiting resource for future development of freshwater aquaculture facilities and environmental restrictions may limit marine aquaculture growth. Overlapping jurisdictions and a multitude of concerned Federal and State Agencies tend to inhibit the development of the aquaculture industry. Agencies with the primary role of protecting natural resources are often the lead regulatory agency while agriculture-related agencies have more limited roles.

Aquaculture-related diseases are receiving more attention by researchers and the international community. Still, many diseases have become widespread on a national or an international basis, sometimes over a relatively short time period. Data on national aquatic animal health appear to be limited at this time.

Bibliography

1) United States Department of Commerce, National Marine Fisheries Service. 1994. Fisheries of the United States, 1993, Current Fishery Statistics No. 9300. Washington, D.C.

2) Anonymous. 1995. Status of world aquaculture 1994. Aquaculture Magazine Buyer's Guide '95. v. 24, pp. 8-23.

3) United States Department of Agriculture, National Agricultural Statistics Service. 1993. Agriculture Statistics 1993. Washington, D.C.

4) United States Department of Commerce, National Marine Fisheries Service. 1993. Our living oceans: The annual report on the status of U.S. living marine resources-1993. Silver Spring, MD.

5) Anonymous. 1994. Warmwater Fish Farming Map. Fish Farming Experimental Laboratory, Stuttgart, Arkansas.

6) United States Department of Commerce, Bureau of Census. 1995. 1992 Census of Agriculture: Geographic Area Series, Vol. 1. Washington, D.C.

7) United States Department of Agriculture, Economic Research Service. 1995. Aquaculture Situation and Outlook, March 15, 1995. Washington, D.C.

8) Hopkins, T. A. and W. E. Manci. 1992. Aquaculture: Opportunity Now Part 1. Aqua. Mag. Nov/Dec 1992, pp. 43-47.

9) Stickney, R. R. 1986. Culture of Nonsalmonid Freshwater Fishes. CRC Press, Inc. Boca Raton, FL.

10) Food and Agriculture Organization of the United Nations, Fishery Information, Data and Statistics Service. 1993. Aquaculture Production 1985-1991. FAO Fisheries Circular No. 815 Revision 5. Rome, Italy.

11) Hodson, R. G. 1989. Hybrid Striped Bass, Biology and Life History. Southern Reg. Aqua. Center pub. no. 300.

12) Litvak, M. K. and N. E. Mandrak. 1993. Ecology of Freshwater Baitfish Use in Canada and the United States. Fisheries, Vol. 18, No. 12.

13) Fish Farming Experiment Laboratory. 1995. Facts about Arkansas Aquaculture. Brochure. Stuttgart, Arkansas.

14) Gray, D. L. 1988. Baitfish. Southern Reg. Aqua. Center pub. no. 120.

15) Florida Agricultural Statistics Service. 1994. Florida aquaculture sales total $73 million in 1993. Aqua. Mag. Sept/Oct. 1994 pp. 46-54.

16) United States Department of Agriculture, Economic Research Service. 1994. Aquaculture Situation and Outlook, October, 1994. Washington, D.C.

17) Avault, J. W. 1992. A review of world crustacean aquaculture part two. Aqua. Mag. July/Aug. 1992. p.83-89.

18) de la Bretonne Jr., L. W. 1990. Crawfish culture: Site selection, pond construction and water quality. Southern Reg. Aqua. Center pub. no. 200.

19) Avault, J. W. 1992. A review of world crustacean aquaculture part one. Aqua. Mag. May/June 1992 pp. 84-93.

20) Hetrick, F. M. and R.P. Hedrick. 1993. New viruses described in finfish from 1988-1992. Ann. Rev. of Fish Diseases, Vol. 3, pp. 187-208

21) Thune, R. L. 1993. Bacterial diseases of catfishes. In: Stoskopf, M. K. (ed.). Fish medicine. W. B. Saunders Co., Philadelphia, PA, pp. 511-520.

22) McAllister, P. E. 1993. Salmonid fish viruses. In: Stoskopf, M. K. (ed.). Fish medicine. W. B. Saunders Co., Philadelphia, PA, pp. 380-408.

23) Rottman, R.W., R. Francis-Floyd, R. Durborow. 1992. The role of stress in fish disease. Southern Reg. Aqua. Center pub. no. 474.

24) Office Internationale des Epizooties. 1993. Fish diseases brouchure. Paris, France.

25) Federal Joint Subcommittee on Aquaculture, Working Group on Quality Assurance in Aquaculture Production. 1994. Guide to Drug, Vaccine, and Pesticide Use in Aquaculture. Texas Ag. Ext. Serv. College Station, TX

26) McDowell, R. and C. Tuszynski. 1989. Aquaculture Policy Study: Part 1. Unpublished Report USDA:APHIS:VS, Washington, D.C.

27) Powers, B. and B. Arnella Jr. 1993. U.S. Aquatic Animal Health Services: Current Status Study Report to the Joint Subcommittee on Aquaculture. Washington, D.C.

28) Anonymous. 1995. Division fo Fisheries and Wildlife, Summary of Aquaculture Regulations. Unpub. report, Commonwealth fo Massachusetts, Division of Fisheries and Wildlife, Westboro, MA.

29) Waite, S. W. 1987. The Illinois Aquaculture Development Plan: The Illinois Aquaculture Development Act. Unpub. report to the State of Illinois, Dept. of Agric. Springfield, IL.

30) United States Department of Agriculture, National Agriculture Library. 1994. Resource Guide to Aquaculture Information. Prepared for the Joint Subcommittee on Aquaculture, Aquaculture Information and Technology Transfer Task Force. Beltsville, MD.