# AQUACULTURE AND CAPTURE FISHERIES: IMPACTS IN U.S. SEAFOOD MARKETS



Report Prepared Pursuant To
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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Washington, D.C.
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# PREFACE

The objective of the National Aquaculture Improvement Act of 1985 was to stimulate development of a domestic aquaculture industry. Expectations were that the Act would help create new jobs, replenish depleted fisheries, and reduce the trade deficit in fishery products.

However, there were concerns marine aquaculture could affect certain traditional capture fisheries in the United States. Thus, an amendment to the National Aquaculture Act of 1980 (renamed the National Aquaculture Improvement Act of 1985) requires the Secretary of Commerce to conduct a study on competition between aquaculture products and capture or "wild" fisheries and to recommend measures to ameliorate any such adverse effects.

This study was undertaken to comply with the Congressional request. Accordingly, the study examines U.S. seafood markets that are supplied with products from commercial capture fisheries and aquaculture enterprises (domestic and foreign). The report focuses on salmon and shrimp which are the most important fisheries in the United States supplied by capture fisheries and aquaculture.

The world aquaculture industry is in a period of dynamic growth. Aquaculture production estimates reported by the National Marine Fisheries Service in 1985 in its study "The Outlook for Salmon and Shrimp Aquaculture Products in World Markets" and revised in this study, have been increased by as much as 100 percent. The business opportunities for capture and aquaculture products are expected to change in the next few years as economic and environmental conditions, and government trade and financial assistance policies affect international seafood markets. Therefore, the estimates and findings in this report will become outdated because of the influence of subsequent events.

Chapter I describes the economics of aquaculture. This chapter shows in theoretical terms, but in layman's language, how capture fishery products and aquaculture may interact in a market.

Chapters II and III, respectively, examine the size of U.S. salmon and shrimp markets and look at the sources of supply. These chapters contain the summary production estimates of aquaculture operations here and abroad.

Chapters IV - VII describe aquaculture operations in the United States focusing on marine species. Appendices I and II provide detailed summaries of salmon and shrimp aquaculture operations outside the United States. These sections rely heavily on reports from U.S. embassies and consulates. Appendix III reviews some of the Federal statutes controlling the siting and permitting of marine aquaculture operations in the United States.

The report was prepared by staff of the National Marine Fisheries Service in Washington, D.C. and field offices, under the direction of Robert A. Siegel. The Summary section and Chapters I - III were prepared by Douglas W. Lipton and Robert A. Siegel of the National Economics Staff, with assistance from Sennen S. Salapare from the Office of Trade Services.

Chapter IV was written by Dale Squires of the NMFS Southwest Fisheries Center. Chapter V was written by staff of the Northwest Fisheries Center and Northwest Regional Office, respectively. Staff of the Alaska Regional Office consisting of Lewis Queirolo, Aven Andersen, Jim Brooks, Tamra Faris, William Heard, Janet Smoker, and John Hamilton wrote Chapter VI and Appendix III. Kenneth L. Beal of the Northeast Regional Office prepared Chapter VII. James P. McVey of NOAA's National Sea Grant College Program wrote Chapter VIII.

The NMFS Fisheries Analysis Branch, under the direction of Milan Kravanja, prepared Appendices I and II. Appendix I was written by William Folsom, with assistance from Michelle Miller. Appendix II was coauthored by Dennis Weidner and Paul Niemeier.

## *DEFINITIONS*

**Salmon aquaculture** is the partial or complete cultivation of the species in hatcheries or the sea. It includes at least two different processes: pen-farming and ocean-ranching. Pen-farming is the commercial production to marketable size in total capitivity. Ocean-ranching is the private or government production of salmon in captivity to a certain stage at which it is released into the wild.

**Shrimp aquaculture** is the production of shrimp involving control of one or more phases of their biological cycle and/or control of the environment in which they develop. Management systems may be extensive such as large seminatural or natural marsh impoundments or rice fields (low stocking rates and little or no feeding or water exchange), semi-intensive such as large drainable ponds (medium stocking, feeding and water exchange), and intensive such as small, totally controllable ponds (high stocking rates, water circulation/exchange, and nutritionally complete diets). Indoor raceways would exhibit the highest degree of technology with control of nutrition and environmental requirements for year-round growth.

# CONTENTS

# SUMMARY

## RISING DEMAND FOR SEAFOOD

Consumer demand for seafood products in the United States has grown steadily in the 1980's. Between 1980 and 1986, U.S. per capita consumption rose from 12.8 pounds (5.8 kg) to 14.7 pounds (6.7 kg), an increase of almost 15 percent. Annual growth in per capita consumption averaged 2.1 percent over this period compared to a 1.3 growth rate between 1960 and 1980. Factors that led to the rise in consumption include increases in income, changing lifestyles, and a greater awareness of the health benefits of seafood.

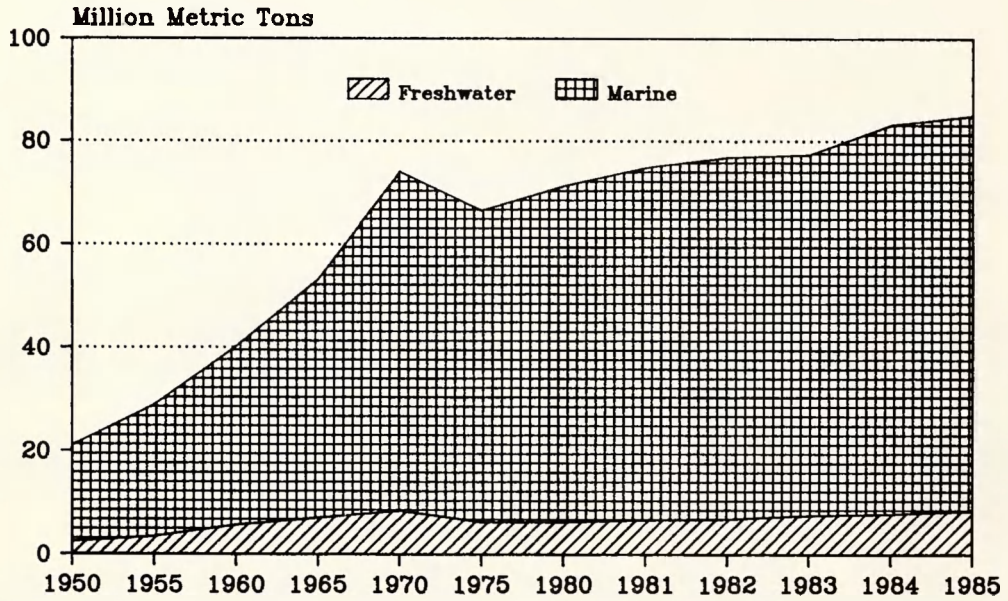
America's growing appetite for seafood is satisfied by domestic supplies and imports. As U.S. catches of its mainstay fisheries of groundfish, salmon, and shellfish such as shrimp, lobsters, and crabs have approached or exceeded their maximum biological limits, seafood imports from capture fisheries and aquaculture have satisfied the increase in fish consumption. The net result is a persistent fishery trade deficit that gets larger each year, growing from $ 1.8 billion in 1980 to $ 3.5 billion in 1986.

If the upward trend in seafood demand continues, the United States is going to need new sources of fishery supplies in the 1990's. Based on recent projections by the U.S. Department of Agriculture, it appears that per capita seafood consumption may increase 5 percent to 17 percent above the 1986 base by the year 2000.1/ This would boost per capita consumption to between 15.5 pounds (7.0 kg) and 17.2 pounds (7.8 kg). Under this scenario, supplies of edible seafood products for the total U.S. market will need to increase by 18 to 31 percent above the 1986 level.

**Global Trends**

More than three decades ago, the oceans were thought to contain an enormous untapped supply of marine fishery resources. Between 1950 and 1970, the world catch increased from 21.1 million metric tons (mt) to 66 million mt (Figure i-1). Per capita consumption grew from 8.4 kilograms to 17.8 kilograms over the same period, as the annual growth rate in catch outpaced world population increases.

## Trends in World Catch
### Freshwater and Marine




After 1970, however, this situation reversed itself. From 1970 to 1985, world catch increased 29.4 percent, while world population grew 33.2 percent. The Food and Agricultural Organization of the United Nations projects that global demand for fish (all aquatic species) could reach 114 million mt by the year 2000.2/ Production is estimated at 94 million mt, resulting in a shortfall of 21 million mt. These numbers suggest that the supply of seafood products will need to grow at rates well above those of recent years to keep pace with anticipated increases in demand. This has important implications for U.S. seafood markets.

Given the need for new supplies, what are the potential sources? Catch trends for the world's principal fishery resources indicate that they are at or close to their biological limits, or that certain stocks have been overfished. Additions to future supplies, therefore, must come from rebuilding depleted stocks, or tapping stocks that are yet to be discovered. It is also possible that a future increase in demand for seafood products can be met, in part, by aquaculture.

Growing pressures on seafood supply sources raise a number of questions that need to be addressed by U.S. fishery managers in industry and government. The study addresses the issues in the context of salmon and shrimp markets which are most likely to be affected by competition between capture fisheries and aquaculture. The suggested issues are as follows.

What seafood products will experience the greatest increase in consumer demand?

Will the additional supplies come from domestic or foreign sources?

Can catches be increased significantly from the traditional U.S. fisheries?

Will the political, economic, and social framework of U.S. fisheries allow the appropriate management measures to rebuild stocks currently below their maximum biological levels?

Will the additional supplies come from capture fisheries and/or aquaculture?

Does the United States need an organized aquaculture industry to compete with foreign aquaculture companies for the domestic seafood market?

Does a domestic aquaculture industry represent a threat to traditional U.S. capture fisheries?

Should aquaculture be part of the overall U.S. trade policy to reduce the trade deficit in fishery products?

## COMPETITIVE OUTLOOK FOR SHRIMP: CAPTURE FISHERY AND AQUACULTURE

* Demand for shrimp in the United States has exceeded the harvest potential of wild shrimp in U.S. waters for the last 20 years. Reliance on imports has increased accordingly. Imported shrimp in 1986 accounted for 67 percent of the total U.S. supply. Cultured shrimp, from sources principally in Central and South America, represent a growing share of U.S. imports.

* This report suggests that, at least for shrimp, the wild and cultured products are substitutes. With domestic landings expected to be relatively stable, and with limited investment in domestic aquaculture operations, imports of shrimp products, including aquaculture, will moderate any upward trend in product prices caused by an increase in consumer demand.

* Private, for profit, shrimp aquaculture enterprises in the United States are not extensive. At present, they are currently located in Hawaii, South Carolina, and Texas. Total production estimates are not available.

* World catch of shrimp from wild or capture fisheries has been stable for the last 10 years at around 1.6 million metric tons. Aquaculture production, however, grew from 78,300 metric tons in 1982 to 216,000 metric tons in 1985.

* World production of cultured shrimp is projected to reach 490,000 metric tons by 1990. Aquaculture thus could account for 28 percent of total world shrimp production if landings remain stable. Major producing countries are expected to be: China, Taiwan, Ecuador, Indonesia, and the Philippines.

* The outlook for the U.S. market indicates that U.S. consumption for shrimp will continue to grow. It is unlikely that the U.S. harvesting sector can increase its share of the domestic market because U.S. shrimp catches are approaching their biological limits. Thus, the implication is that imports will play an increasingly important role in the U.S. shrimp market. These imports are further encouraged by the fact that they enter the United States free of duty.

* The need for shrimp imports could be lessened if shrimp farming operations expand in the United States. At present, the Federal government provides limited technical assistance, but no direct financial support, for the development of a U.S. commercial shrimp aquaculture industry.

## COMPETITIVE OUTLOOK FOR SALMON: CAPTURE FISHERY AND AQUACULTURE

* Consumer demand for salmon products appears to be growing both in the United States and abroad. The introduction of a new product such as pen-raised salmon has added to world supplies, and thus has probably helped to ease any upward movements of product prices triggered by increases in demand.

* Since the early 1980's, imports of fresh pen-raised salmon have established a solid position in the U.S. market, and now account for most sales of fresh salmon during the winter months. It is not clear that consumers distinguish between wild salmon (Pacific Ocean species) and cultured (Atlantic and Pacific) salmon. This issue needs further study.

* U.S. imports of fresh, farmed salmon rose from 726 metric tons in 1980 to more than 12,700 metric tons in 1986. Import value rose from $3.9 million to almost $78 million.

* In 1980, world production of pen-raised salmon — Atlantic and Pacific — amounted to 6,880 metric tons. World production reached 70,000 metric tons in 1986. By 1990, total world output of pen-raised salmon could reach 226,000 metric tons.

* Presently, Atlantic salmon is the predominant species produced by culture operations. By 1990, farmed salmon (all species) could account for an estimated 26 percent of world salmon production (capture and culture operations combined).

* The two species of Pacific salmon from capture fisheries believed to compete with pen-raised salmon are chinook and coho. Over the past decade, world landings of these species have been relatively stable. If current trends continue, world output of pen-raised salmon in 1990 will continue to exceed the landings of chinook and coho from the capture fisheries.

* Major producers of pen-raised salmon are expected to be Norway, followed by Canada, the United Kingdom, Japan, Chile, and Ireland.

* Although the U.S. catch of salmon increased 60 percent between 1970 and 1986, the quantity of salmon available for the domestic market declined because of growth in salmon exports. Over the period, exports jumped from 12,800 metric tons to 160,000 metric tons.

* In 1986, the United States was the second largest market for Norwegian exports of salmon, accounting for 23 percent. France was the largest market with a 25 percent share. The size of the U.S. market and the expected future production in Norway indicate that the U.S. will probably become the largest market.

* Fresh salmon imports may help reduce seasonal swings in supply. Landings of Pacific salmon fisheries peak in the summer months. Fresh salmon imports generally peak in the December to March period. The natural production cycle for wild salmon, coupled with management regulations, does not lend itself to providing significant quantities of fresh salmon during the winter months.

* U.S. producers are at a disadvantage in world salmon markets. U.S. exports of salmon products face generally higher trade barriers in foreign countries than foreign salmon exports to the United States encounter.

* The United States is no longer the leading exporter of salmon to the European Community. In 1986, Norway shipped 23,800 metric tons of fresh and frozen salmon to this market, compared to U.S. shipments of 18,400 metric tons of fresh and frozen salmon.

* In 1986, Norway replaced the United States as the leading exporter of fresh salmon to Japan.

* Commercial pen-reared salmon aquaculture operations have begun recently in Maine, Oregon, and Washington. The future production outlook suggests that Norway, Canada, and other foreign nations will continue to dominate the fresh salmon market in the United States.

* In the State of Alaska, there is a moratorium on site permits for pen-reared salmon facilities until June 30, 1988. Public hearings will evaluate the benefits/costs of allowing these operations in state waters.

* The Federal government provides some funding for salmon rearing operations that involve salmon ocean ranching activities. Federal funding of salmon aquaculture research involving pen-raised salmon is very limited. Foreign governments are believed to provide economic and financial aid to their domestic aquaculture industries. However, no additional Federal funds are requested in the President's FY89 budget because aquaculture is inherently a private sector activity.

* The United States has a trade surplus in salmon products (i.e., exports exceed imports). If the demand for fresh salmon continues to grow, and the domestic capture fishery cannot meet the demand now being filled by imports of cultured salmon, it appears that the trade surplus will diminish.

* Lucrative markets exist in the United States and abroad for fresh salmon on a year-round basis. If the U.S. industry is unable to produce more fresh salmon year-round, significant income producing opportunities will be lost.

**RECOMMENDATIONS**

In summary, the National Aquaculture Improvement Act of 1985, Section 1735 (C), requires the Secretary of Commerce to assess whether existing capture fisheries in the United States are adversely affected by competition from products by commercial aquaculture enterprises and, if so, to propose measures to ameliorate such effects. The study indicates that dockside prices received by U.S. fishermen are lower than they would be otherwise in the U.S. market. By the same token, U.S. consumers enjoy the benefits of lower salmon and shrimp prices that are the result of unrestricted foreign import supplies. Furthermore, U.S. salmon and shrimp fishermen are at a competitive disadvantage to foreign imports of cultured salmon and shrimp that enter the United States duty free, while U.S. seafood export opportunities are hindered by foreign trade barriers.

On balance, the National Oceanic and Atmospheric Administration (NOAA) of the United States Department of Commerce believes that despite the present otherwise competitive disadvantages, the domestic salmon and shrimp capture fisheries do not require any type of Government grants since these are commercial activities and should not be subsidized by the Federal government. Nevertheless, NOAA will continue to monitor economic and environmental conditions within these sectors of the U.S. fishing industry and respond with appropriate actions when needed.

CHAPTER I

# *THE ECONOMICS OF AQUACULTURE AND CAPTURE FISHERIES*

## INTRODUCTION

Recent strides in aquaculture have raised troublesome questions for commercial fishermen. At issue is whether gains in aquaculture output will disrupt markets now supplied principally by the traditional "capture"-type commercial fisheries. Cultured salmon and shrimp already have won important market positions, particularly in the United States and Western Europe. Advances in aquaculture technology promise success for other species.

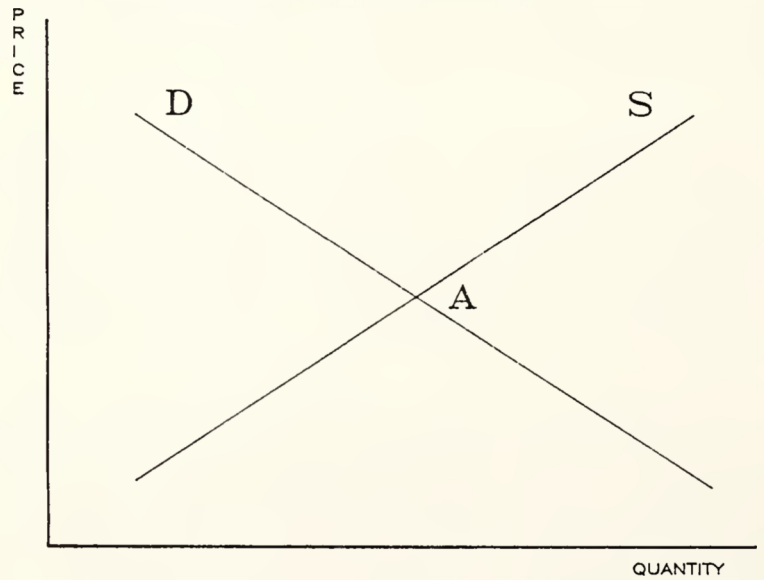
Much is at stake for commercial fisheries. Salmon and shrimp, for example, dominate the upscale seafood market, and both have been among the leading revenue producers for commercial fishing throughout the world. In the U.S., salmon and shrimp together account for over 40 percent of the annual value of all commercial landings. Salmon also are the principal U.S. fisheries export. Abroad, varieties of shrimp are an important source of export earnings for many developing countries.

The impacts of aquaculture will be reflected in prices at all market levels for species that are supplied from both commercial fishing and aquaculture sources, such as salmon and shrimp. There is speculation that a surge in supplies of cultured products will devastate the market and jeopardize traditional suppliers. The salmon/shrimp experience is still too new to use as an empirical basis for determining whether cultured products are a significant threat to the interests of commercial fishing. Nonetheless, the issue can be examined within the framework of conventional economic theory, drawing upon what is known generally about the nature of contemporary seafood markets.

## THEORY AND NATURE OF SEAFOOD MARKETS

Before projecting a scenario for aquaculture impacts on seafood markets, it is useful to review some familiar basic concepts from economic theory and the general characteristics of seafood markets. Market exchanges (sales), it will be recalled, occur when the quantities consumers are willing to take at a given price coincide with the quantities suppliers are willing to place on the market at that price. Graphically, this market "equilibrium" point is demonstrated by an intersection of supply (S) and demand curves (D), or "schedules", as shown in Figure I-1. The schedules show quantities consumers and suppliers are willing to buy or sell at various prices. Point (A) in Figure I-1 designates where the equilibrium price and quantity are established.

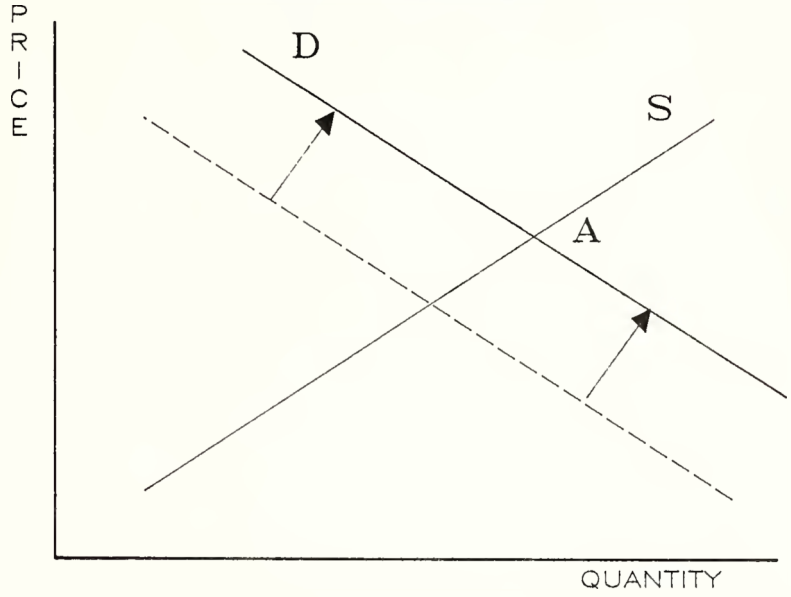
Figure I--1. Supply (S) and demand (D) equilibrium occurs at point A.




The slope and direction of the (S) and (D) curves show that the higher the price, the more producers are willing to place on the market, but the less consumers are willing to purchase. The shape and position of these curves are subject to change. Demand is influenced by factors such as tastes or preferences, personal income, and the price of substitute products; supply is influenced by production costs and resource availability, among other factors.

U.S. demand for seafood has grown significantly in the last few years. In our simple model, the increase is seen graphically as a shift in demand, with the (D) curve moving up and to the right. Note that, after the shift, at every price the quantity of seafood demanded is higher (Figure I-2). There is a new, and higher equilibrium price.

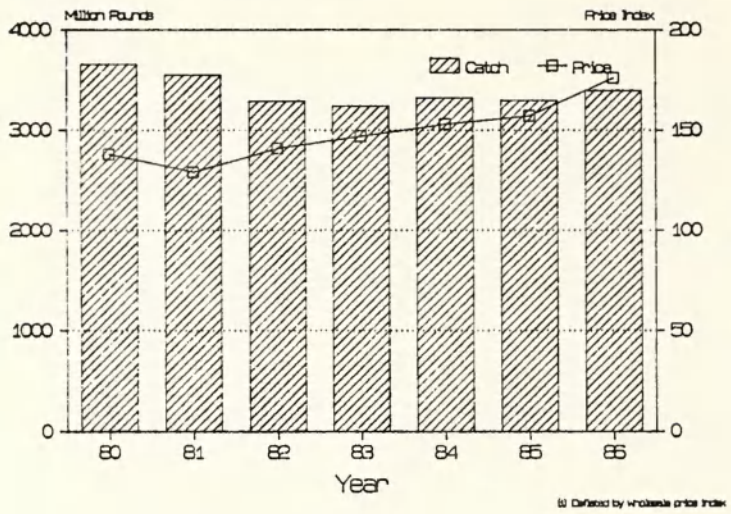
Figure I-2. An increase in demand results in a higher price and a higher quantity consumed.




The extent of any price rise, however, will not rely on demand alone; the slope and shifting of the (S) curve will help determine how high prices will go. It is generally accepted that the U.S. supply of fish from domestic capture fisheries is relatively inelastic, i.e. the supply curve is steep. Even at higher price levels domestic fishermen are unable to offer significantly larger quantities because most of the popular species are fished at or near their maximum sustainable yield. The same holds true on a global scale.

Figure I-3 compares U.S. commercial landings of edible fish from 1976-1986 with an index of wholesale fish prices adjusted for inflation. Although fish prices have risen greatly over the period, U.S. landings, after subtracting joint ventures, have remained virtually flat. Without aquaculture, domestic seafood producers are unable to respond to higher prices by increasing their output.

Figure I-3. U.S. Edible Fish Landings and Wholesale Price Index (1)




The implication of static domestic fish supplies in the face of increasing demand is that fish prices will rise at a rapid rate. There are no compensating increases in supply from domestic sources to dampen the price impacts of an increase in demand. This is especially important because it is projected that seafood demand will continue to rise in the future. As mentioned earlier, increasing population, increasing incomes and changing demographics could lead to as much as a 30 percent increase in U.S. seafood consumption by the year 2000 if supply can expand to keep prices at current levels. If the supply curve does not shift, the increasing demand can be expected to lead to over a 20 percent increase in seafood prices (assuming no increase in imports).

Initial expectations are that seafood prices will rise above today's level. Below we show the mechanism by which imports and aquaculture lower exvessel and consumer prices (all other factors held constant). By this we mean that prices will rise at a slower rate than if there were no increases in aquaculture and imports. It is an empirical matter whether the rate is slowed to the point where the actual price does not rise or even decreases.

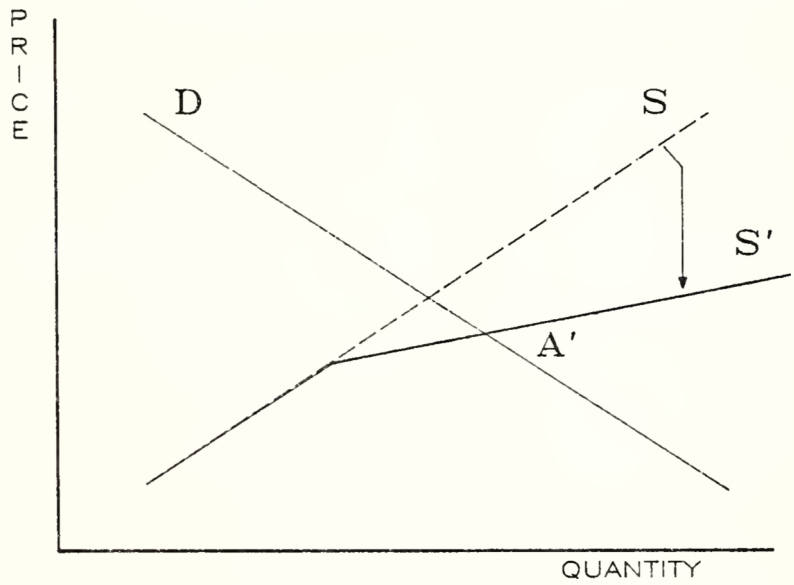
## THE ROLE OF IMPORTS IN THE U.S. MARKET

Traditionally, shortfalls in U.S. production of marketable fishery products have been made up for by imports. Nearly two-thirds of the U.S. supply of edible fishery products, by volume, are imported from scores of countries throughout the

globe. This heavy import trade reflects the strong demand and prices for fishery products in the U.S. market. It is almost axiomatic that a foreign country will export if it can sell its fish to the U.S. at a higher price than it can receive by selling in a purely domestic market or other foreign market, barring political expediency.

The effect of these U.S. imports can be seen in Figure I-4. The supply curve (S) kinks at the price level where imports begin entering the domestic market, and shifts to the position (S'). The shift begins at the price where U.S. and foreign prices are the same. The greater the positive difference between U.S. and foreign prices, the more is imported.

Figure I-4. The availability of imports shifts the supply curve down to S'.



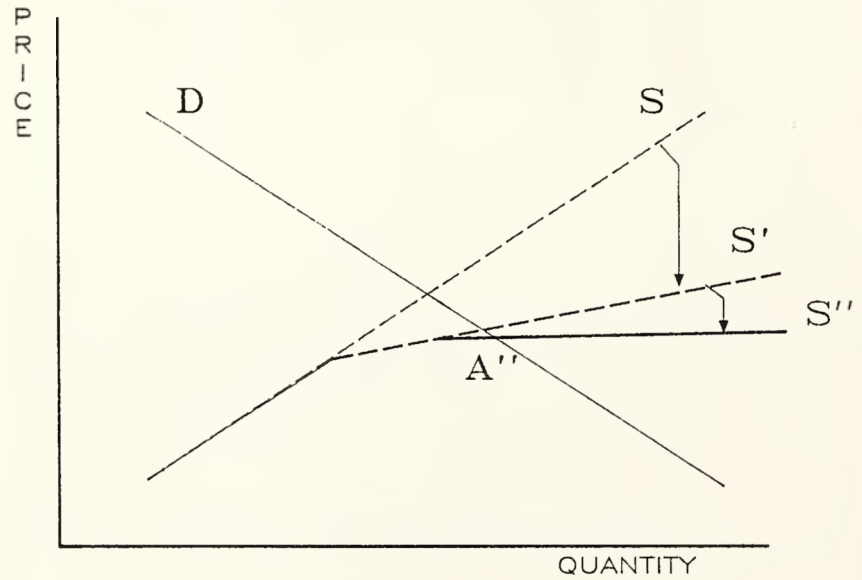

The overall effect is a lower U.S. market price with imports than without, with the sharpest impacts felt at the exvessel level. At higher market levels (e.g., wholesalers and brokers) where both domestic and imported product are being handled, the dealer pays less for the product, receives a lower price, but enjoys the revenue benefits of a higher sales volume. With imports, the final consumer has more seafood available at a lower price.

The flexibility to increase U.S. fishery supplies through imports, however, is limited. The same restrictions that limit U.S. landings limit world landings. While in any given year, it may be possible to increase a particular country's supply of fish products through imports, this is accomplished at the expense of supply in other countries as shipments are diverted from the weaker to the stronger markets.

## Substituting Shrimp Imports and Domestic Landings

U.S. imports of shrimp (wild and cultured) have the same effect on supplies and prices as described in the previous section. At the price where aquaculture becomes feasible (see Technical Note A), there is another kink and shift downward in the supply curve. The new market equilibrium is at a lower price than before the cultured product became available (Figure I-5). Fishermen get an even lower price for their product, but the consumer is again the big gainer by getting more at a lower price.

Figure I—5. Aquaculture shifts the supply curve further down to S".




## Cultured Salmon as a Substitute Product

Products are considered substitutes when an increase in the price of one increases the demand for the other. When market conditions change for a product, this affects the market for all other substitute products through a complex series of interactions. These interactions are described in Technical Note (B) at the end of this section.

For example, if pen-reared Norwegian salmon is viewed as a substitute for "wild" Pacific salmon, the availability of the Norwegian salmon will lower the demand, and hence, exvessel price of Pacific salmon. The closer the Norwegian product is

perceived as a substitute and the lower its price, the more the Pacific salmon price will be lowered. At the other extreme, if Norwegian salmon is not perceived as a substitute by consumers, its presence will have no effect on Pacific salmon prices.

## SUMMARY

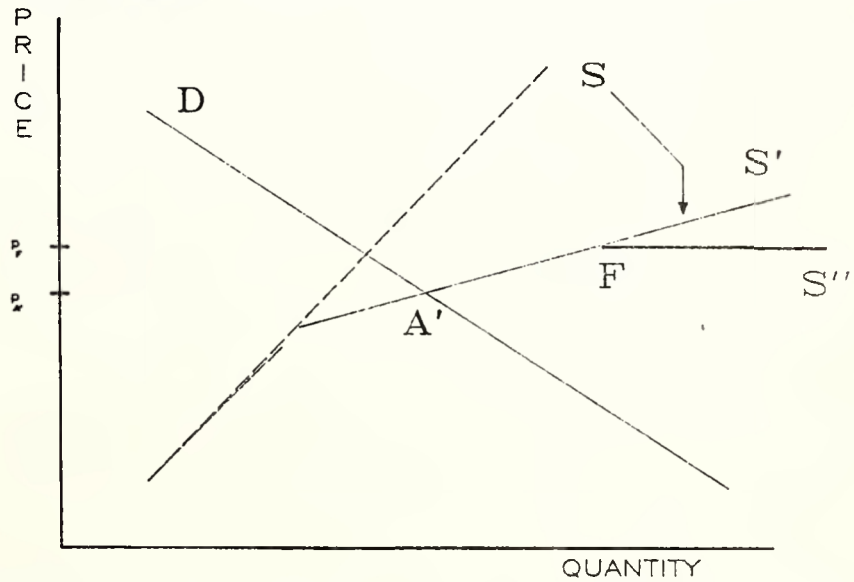
The following three factors point to an increasing role for aquaculture in U.S. seafood markets: (1) limitations on U.S. landings and world supplies of seafood products; (2) increasing U.S. and world demand for seafood; and, (3) technological advancements in aquaculture production. These factors interact through the marketplace and affect the market for capture fisheries. The aquaculture product either enters the market directly or as a substitute product. In either case, the price of the capture product is lowered (all other factors held constant). Degrees of impact will vary between products, depending upon differences in factors that influence supply and demand for various species.

## TECHNICAL NOTES

### Note (A): Illustrating the Economic Feasibility of Aquaculture

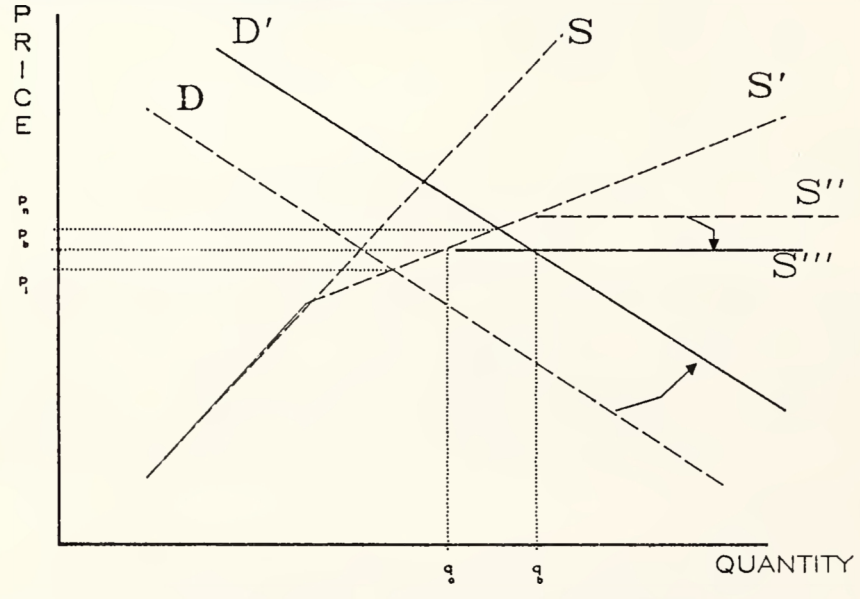
Until recently, aquaculture was not economically feasible for many products. Graphically, economic infeasibility is shown in Figure I-6. The shift in the supply curve due to aquaculture begins at a price above the current market price determined by supply and demand from capture fisheries. Point (F) on the graph, at price $p_F$ is the point where aquaculture would become economically feasible. At prices above $p_F$ the market for the product would be shared by capture fishermen and aquaculturists.

Figure I–6 Aquaculture is not feasible because the market price is to low ($p_A < p_A$).



Two factors make it likely that aquaculture will become economically feasible for most seafood products in the future. One is the increasing demand for seafood. In Figure I-7, increasing demand is shown to shift the demand curve (from D to D') to a level above point (F). The second factor is technological advances in aquaculture such as genetic engineering, disease control, etc. These advances translate into economic terms as a shifting down of the aquaculture section of the supply curve (from S"to S'"). Thus the amount that demand has to rise to make aquaculture feasible is less when there is technological advancement.

Figure I–7 Aquaculture becomes feasible with higher demand (D') and technological change (S'").




The impact of aquaculture on capture fisheries can be derived directly from these price-quantity diagrams by comparing prices and quantities with and without aquaculture. With seafood demand at (D'), the price of seafood will be $p_B$. The total quantity produced and consumed will be $q_b$, $q_c$ of which is produced by the capture fisheries and $q_a=q_b-q_c$ produced by the aquaculture industry. As drawn, $p_b$ is higher than $p_1$, the price before demand shifted to (D'), but lower than $p_n$, the price the capture fishermen would receive with increased demand if there was no aquaculture.

If technological advances are significant enough, it is possible that the supply curve will shift down to a point where the entire increase in demand is absorbed by the aquaculture industry so that no price rise occurs for the capture fishery. An

even greater shift in the supply curve due to aquaculture could result in a situation where the price to the capture fishery is lower even though demand has increased (Figure I-8).

An additional case is where aquaculture production is significantly less costly than capture fisheries, and the capture fisheries play an auxiliary role in the market. This is illustrated in Figure I-9. Now the supply curve to the left of point (F) is aquaculture production, and the feasible price for capture fisheries is reached at point (F). The tail of the supply curve labeled (S') is lower than (S) due to the presence of capture fisheries. The roles are reversed and the presence of capture fisheries lowers the price that aquaculturists would receive without capture fisheries.

**Note (B): The Economics of Substitute Products**

Two products are considered substitutes when an increase in the price of one increases the demand for the other. This is demonstrated in Figure I-10. The supply curve for product (A) is shown with two demand curves. The first demand curve (D) represents demand when the price of substitute product (B) is $p_B$. The second demand curve (D') is the demand when the price of product (B) is $p_B'$, where $p_B < p_B'$. The demand curve shifts up and to the right due to the higher price for the substitute (B). The amount that the demand curve is shifted will depend on how closely the consumer perceives the attributes of product (B) to be similar to product (A). The closer the products resemble each other, the greater the shift in the demand curve.

The price of product (B) is determined in its own market by supply and demand which in turn depend on product (A). Postulate product (A) as a purely domestic product and the substitute product (B) as obtained through imports. Figure I-11a shows an initial equilibrium for the markets for product (A) and (B). In Figure I-11b the supply of product (B) increases due to strong recruitment, lowering the price of B to $p_B'$. The lower price for product (B) has the effect of decreasing the demand for product (A) and lowering its price.

The lower price for (A) decreases the demand for (B), forming a new price, $p_B'' > p_B'$. The cycle continues until a new equilibrium is reached between the two markets. The net effect of the increase in the supply of the substitute is that both products have a lower price.

Figure I–8. With a large enough supply shift to S''' the price is lower than before demand increased.

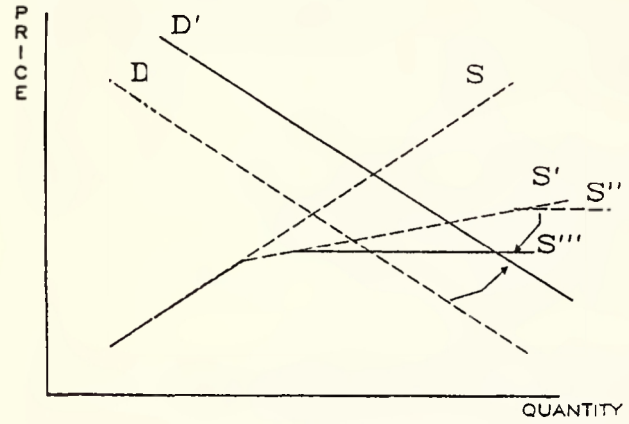



Figure I–9. Now aquaculture is the dominant industry supplemented by capture fisheries.

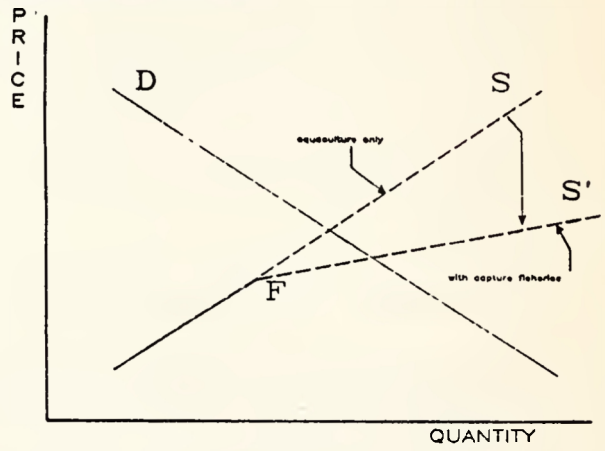



Figure I–10. The demand for product (A) is higher when the price of product (B), a substitute, is higher.

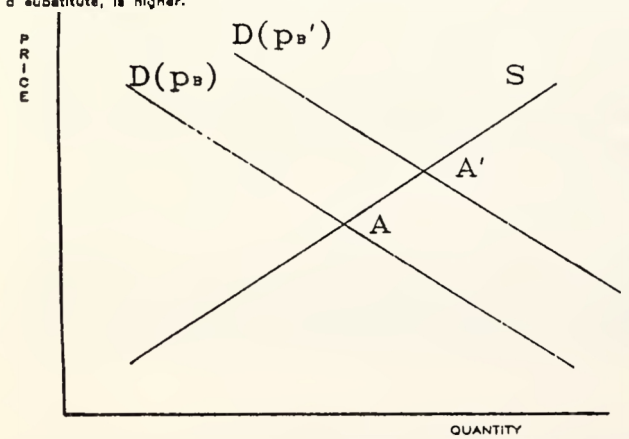
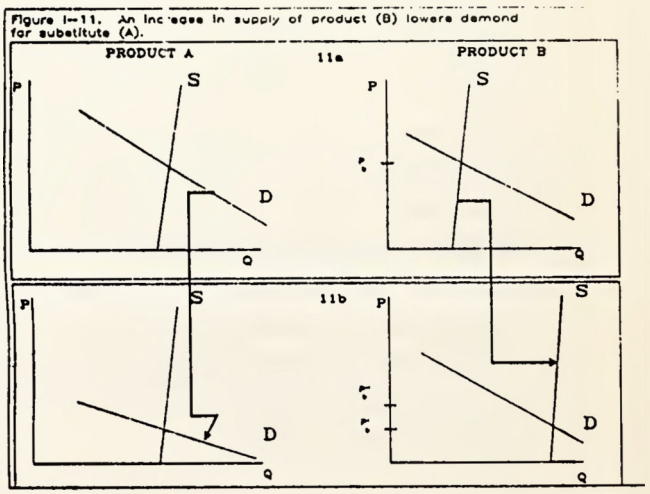



Figure I–11. An increase in supply of product (B) lowers demand for substitute (A).



## CHAPTER II

# *U.S. SALMON MARKETS: DEMAND FOR WILD AND CULTURED PRODUCTS*

Historically, the world supply of salmon has come from the capture of wild salmon in the oceans or in river systems where salmon return to spawn. Salmon capture fisheries occur primarily in the Pacific Ocean, where most of the fishing effort focuses on chinook, coho, sockeye, pink, and chum. In 1985, for example, 94 percent of the world supply of salmon from capture fisheries was caught in Pacific Ocean areas.

Aquaculture is another source of salmon products. Pen-raised products (as opposed to ocean ranching) appeared in world markets around 1980. (Pan-size salmon, produced in "pens" or "race-ways" entered the market in the mid-1970's.) Norway was the first country to successfully export pen-raised salmon. Consumer demand for the product grew rapidly in the United States and Europe. Norway is now the preeminent supplier of fresh Atlantic salmon in the world. Recently, Ireland, England, Scotland, New Zealand, Canada, and Chile and a host of other countries have begun to produce cultured salmon.

This chapter examines world trade flows in wild and aquaculture salmon for the major international markets. The analysis focuses on trends in world salmon landings, and on projections of aquaculture production. The expected increases in world supplies of farmed salmon in the United States and abroad have generated concerns from U.S. producers of wild salmon about changes in their market shares.

This chapter, therefore, will also investigate the seasonal pattern of salmon supply, and also briefly examine the interaction of U.S. salmon exports and farmed salmon in Western European and Japan.

## WORLD SALMON PRODUCTION

### Production Trends

From 1979 to 1985, the world output of salmon (chinook, coho, sockeye, pink, chum, and Atlantic) was relatively stable, fluctuating about 10 percent around the six year average of 765,000 mt (Figure II-1). Of the six species included in the total, only chum, pink, and sockeye salmon showed any appreciable upward trend (Figure II-2). In 1985, significant increases in pink and chum catches led to a record total world production of 787,000 mt for the six salmon species.

The species of wild salmon likely to compete in the same markets as farmed salmon are chinook, coho, and Atlantic salmon. Catch trends for "wild" chinook and coho appear stable, while Atlantic salmon catches from capture fisheries, according to recent FAO statistics, are slowly increasing. (Note: the FAO statistics do not distinguish between production from capture and culture operations. Thus, the increase in Atlantic salmon catch probably is due to the increased output of cultured Norwegian Atlantic salmon.)

Figure II-1

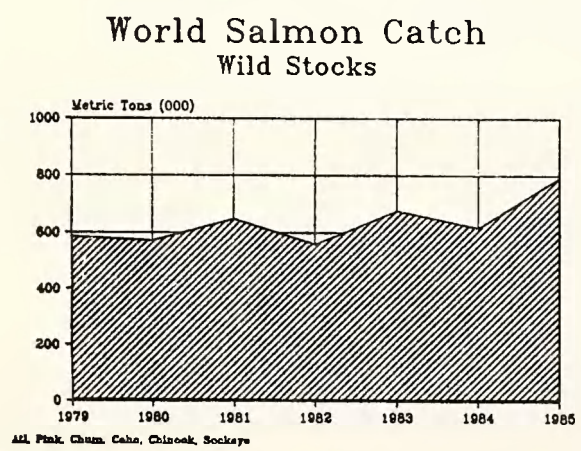
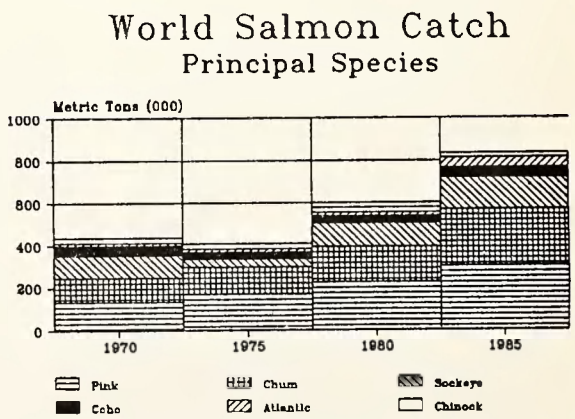



Figure II-2



**Pen-Raised Salmon**

Total world production of pen-raised salmon (Atlantic and Pacific) has expanded rapidly, rising from 7,200 mt in 1980 to an estimated 70,000 mt in 1986 (Table II-1). In 1980,farmed salmon accounted for 1.2 percent of world production (wild and aquaculture). By 1985, this share rose to 5.3 percent, and in 1986, it could approach 10 percent if the catch of wild salmon remains stable.

By 1990, the National Marine Fisheries Service estimates that world production of farmed Atlantic and Pacific salmon could approach 226,000 mt (Table II-2). Norway is the world's leading producer of farmed Atlantic salmon, and it probably will continue in this role. Norwegian output is forecast to grow from 46,000 mt to 100,000 mt between 1986 and 1990. Other leading producers of farmed Atlantic salmon are expected to be the United Kingdom and Ireland, with a combined yield of 35,000 mt (Figure II-3). Furthermore, by 1990, farmed salmon could account for an estimated 26 percent of world production (aquaculture and wild), using the aquaculture estimate in Table II-2 and the average wild catch for the 1980 - 1985 period.

Figure II-3

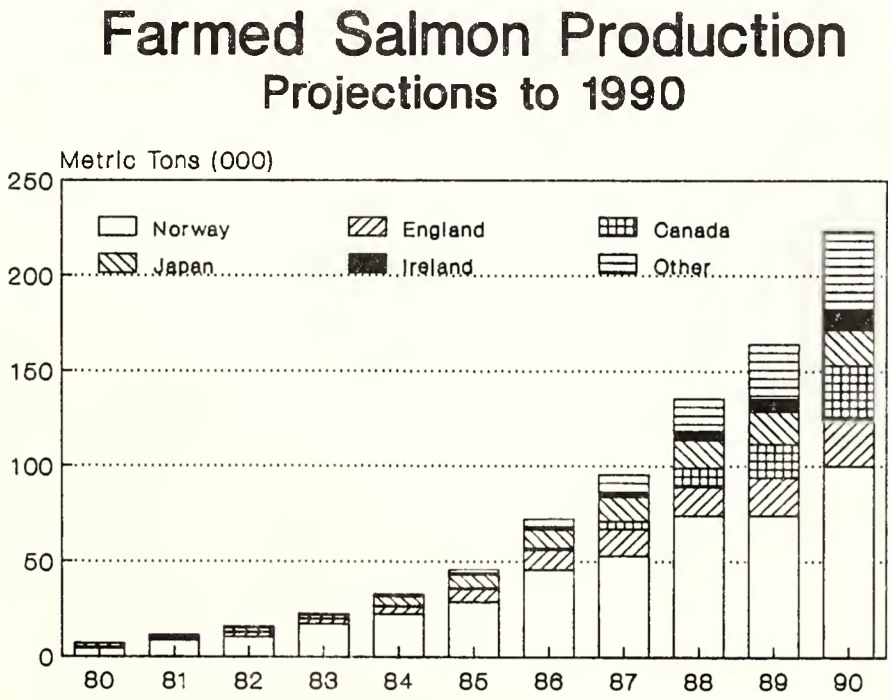


Table II-1 World Farmed Salmon Production, 1980-86

| COUNTRY | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|---|---|
| | | | | Metric Tons (live weight) | | | |
| EUROPEAN COMMUNITY: | | | | | | | |
| France | 30 | 40 | 40 | 40 | 50 | 60 | 200 |
| Ireland | 21 | 35 | 100 | 257 | 385 | 722 | 1,500 |
| Spain | 0 | 0 | 0 | 0 | 100 | 150 | 150 |
| U.K. | 598 | 1,333 | 2,136 | 2,536 | 3,912 | 6,921 | 10,338 |
| TOTAL | 649 | 1,408 | 2,276 | 2,833 | 4,447 | 7,853 | 12,188 |
| NON-EC EUROPE: | | | | | | | |
| Faroe Islands | 0 | 0 | 60 | 105 | 116 | 470 | 1,370 |
| Finland | 0 | 30 | 30 | 30 | 94 | 100 | 100 |
| Iceland | 0 | 20 | 30 | 50 | 107 | 91 | 123 |
| Norway | 4,143 | 8,422 | 10,266 | 17,000 | 22,300 | 28,655 | 45,675 |
| Sweden | 0 | 0 | 10 | 15 | 20 | 80 | 300 |
| TOTAL | 4,143 | 8,472 | 10,396 | 17,200 | 22,637 | 29,396 | 47,568 |
| NORTH AMERICA: | | | | | | | |
| Canada: | | | | | | | |
| Atlantic | 6 | 35 | 140 | 180 | 200 | 300 | 400 |
| Pacific | 157 | 176 | 273 | 128 | 107 | 120 | 600 |
| United States | 392 | 873 | 691 | 844 | 1,248 | 1,820 | 1,400 |
| TOTAL | 555 | 1,084 | 1,104 | 1,152 | 1,555 | 2,240 | 2,400 |
| OTHER: | | | | | | | |
| Chile | 0 | 1 | 184 | 94 | 109 | 500 | 1,144 |
| Japan | 1,855 | 1,150 | 2,122 | 1,760 | 5,049 | 6,430 | 8,000 |
| New Zealand | 0 | 2 | 5 | 10 | 10 | 250 | 500 |
| TOTAL | 1,855 | 1,153 | 2,311 | 1,864 | 5,168 | 7,180 | 9,644 |
| GRAND TOTAL | 7,202 | 12,117 | 16,087 | 23,049 | 33,807 | 46,669 | 71,800 |

Source: U.S. Embassy reports based on various official statistical tables or reports. Some 1986 figures are preliminary estimates. U.S. estimates are based on State and industry sources.

Table II-2 Projected Farmed Salmon Production, 1987-1990.

| COUNTRY | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| | | Metric Tons (live weight) | | |
| EUROPEAN COMMUNITY: | | | | |
| France | 200 | 200 | 200 | 200 |
| Ireland | 2,210 | 4,520 | 6,630 | 10,100 |
| Spain | 200 | 300 | 450 | 600 |
| U.K. | 13,949 | 15,000 | 20,000 | 25,000 |
| EC total | 16,559 | 20,020 | 27,280 | 35,900 |
| NON-EC EUROPE: | | | | |
| Faroe Isl. | 4,800 | 4,800 | 7,100 | 9,000 |
| Finland | 100 | 100 | 100 | 100 |
| Iceland | 800 | 1,750 | 2,500 | 5,000 |
| Norway | 53,000 | 74,000 | 74,000 | 100,000 |
| Sweden | 400 | 800 | 1,000 | 1,000 |
| Non-EC total | 59,100 | 81,450 | 84,700 | 115,100 |
| NORTH AMERICA: | | | | |
| Canada: | | | | |
| Atlantic | 800 | 1,600 | 3,200 | 5,000 |
| Pacific | 3,200 | 8,400 | 14,600 | 23,000 |
| United States | 2,500 | 3,800 | 5,600 | 7,700 |
| N.Am. total | 6,500 | 13,800 | 23,400 | 35,700 |
| OTHER: | | | | |
| Chile | 1,720 | 7,522 | 15,410 | 17,000 |
| Japan | 13,000 | 15,000 | 17,000 | 19,000 |
| New Zealand | 1,000 | 1,500 | 2,000 | 3,000 |
| Other, total | 15,720 | 24,022 | 34,410 | 39,000 |
| GRAND TOTAL | 97,879 | 139,292 | 169,790 | 225,700 |

Source: U.S. Embassy reports based on various official statistical tables or reports. NMFS believes the figures for Chile are too high while those for Norway are too low.

Production estimates for the United States are uncertain. Private salmon aquaculture operations recently have started in Washington and Maine, and several permit applications are under review by State agencies (see Chapters V and VII for a review of efforts in these states, respectively). NMFS estimates that by 1990, farmed output of Atlantic and Pacific salmon (in Idaho, Maine, Oregon, and Washington) could reach 7,700 mt. In Alaska, industry groups and the State legislature are debating the merits of allowing pen-culture operations (see Chapter VI for a detailed discussion of these issues for Alaska).

Atlantic salmon is the predominant species of salmon produced by pen-rearing (Table II-3). The ratio of farmed Atlantic to Pacific salmon rose from more than 2 to 1 in 1980 to about 6 to 1 in 1986. This ratio could drop back to about 2.5 to 1 in 1990 if Canada achieves its production goals for Pacific salmon (chinook and coho).

Between 1986 and 1990, production of farmed Pacific salmon — primarily chinook and coho — is expected to rise from 10,400 mt to 62,600 mt. Canada will probably be the leading producer, followed by Japan and Chile (Table II-4).

Table II-3 World Production of Farmed Salmon, by Species, 1980-1986 with projections to 1990.

| YEAR | ATLANTIC | PACIFIC | TOTAL |
|---|---|---|---|
| | Metric Tons (live weight) | | |
| 1990 | 160,600 | 65,100 | 225,700 |
| 1989 | 117,930 | 51,860 | 169,790 |
| 1988 | 104,470 | 34,722 | 139,192 |
| 1987 | 77,059 | 20,820 | 97,879 |
| 1986 | 60,006 | 10,394 | 70,400 |
| 1985 | 37,399 | 7,450 | 44,849 |
| 1984 | 27,184 | 5,375 | 32,559 |
| 1983 | 20,213 | 1,992 | 22,205 |
| 1982 | 12,812 | 2,584 | 15,396 |
| 1981 | 9,915 | 1,329 | 11,244 |
| 1980 | 4,798 | 2,012 | 6,810 |

Source: U.S. Embassy reports based on various official statistical tables or reports. NMFS believes the figures for Pacific salmon for 1988-1990 are too high while those for Atlantic salmon in 1990 may be too low.

Table II-4. World Production of Farmed Atlantic and Pacific Salmon, By Species, Projected to 1990

| Country | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| | (Metric Tons, Live Weight) | | | |
| ATLANTIC SALMON | | | | |
| Canada, Atlantic | 800 | 1,600 | 3,200 | 5,000 |
| Faroe Islands | 4,800 | 4,800 | 7,100 | 9,000 |
| Finland | 100 | 100 | 100 | 100 |
| France | 200 | 200 | 200 | 200 |
| Iceland | 800 | 1,750 | 2,500 | 5,000 |
| Ireland | 2,210 | 4,520 | 6,630 | 10,100 |
| Norway | 53,000 | 74,000 | 74,000 | 100,000 |
| Sweden | 400 | 800 | 1,000 | 1,000 |
| United Kingdom | 13,949 | 15,000 | 20,000 | 25,000 |
| United States | 800 | 1,700 | 3,200 | 5,200 |
| Total Atlantic | 77,059 | 104,470 | 117,930 | 160,600 |
| PACIFIC SALMON | | | | |
| Canada, Pacific | 3,200 | 8,400 | 14,600 | 23,000 |
| Chile | 1,720 | 7,522 | 15,410 | 17,000 |
| Japan | 13,000 | 15,000 | 17,000 | 19,000 |
| New Zealand | 1,000 | 1,500 | 2,000 | 3,000 |
| Spain | 200 | 300 | 450 | 600 |
| United States | 1,700 | 2,000 | 2,400 | 2,500 |
| Total Pacific | 20,820 | 34,722 | 51,860 | 65,100 |
| GRAND TOTAL | 97,879 | 139,192 | 169,790 | 225,700 |

## U.S. SALMON LANDINGS

The United States is the world's leading producer of wild (ocean/river caught) Pacific salmon. U.S. commercial salmon landings ranged from 91,400 mt in 1975 to 330,000 mt in 1985 (Figure II-4). In the 1980's, however, wild catches stabilized, hovering between 276,000 mt and 330,000 mt. (Note: in the Pacific northwest and Alaska, the "wild" salmon catch consists primarily of natural runs, supplemented by ocean ranching operations.)

The quantity of Pacific salmon sold domestically has declined as salmon exports have grown. Between 1970 and 1986, U.S. exports of salmon (fresh, frozen, and canned) increased more than tenfold, from 12,800 mt to 160,000 mt. Despite the 60 percent increase in the U.S. salmon catch between 1970 and 1986, the amount of salmon available for the U.S. market (based on annual landings and excluding inventories) declined from 0.85 kilograms (1.89 pounds) to 0.57 kilograms (1.23 pounds) per capita. Thus, the growth in U.S. landings has not been sufficient to allow U.S. per capita consumption of salmon to increase, while at the same time support a growing export market.

On a species basis, catches of chinook and coho since 1970 have fluctuated between 10,000 - 16,000 mt and 13,000 - 27,000 mt, respectively (Figure II-5). Catches of pink, chum, and sockeye have followed an upward trend and, therefore, have been the major contributors to the increase in U.S. salmon catches.

Figure II-4

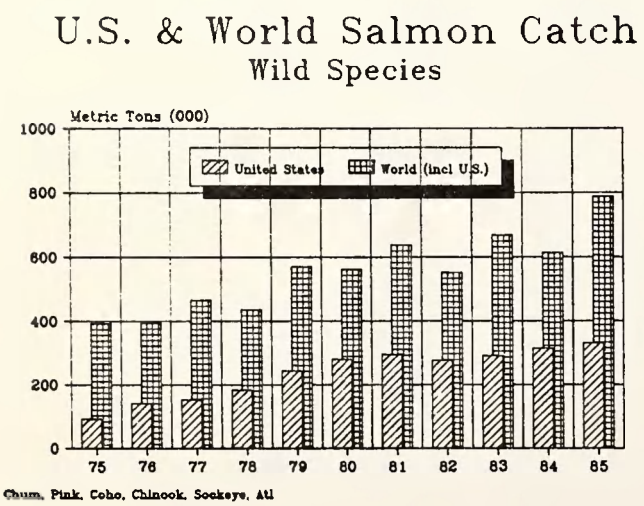
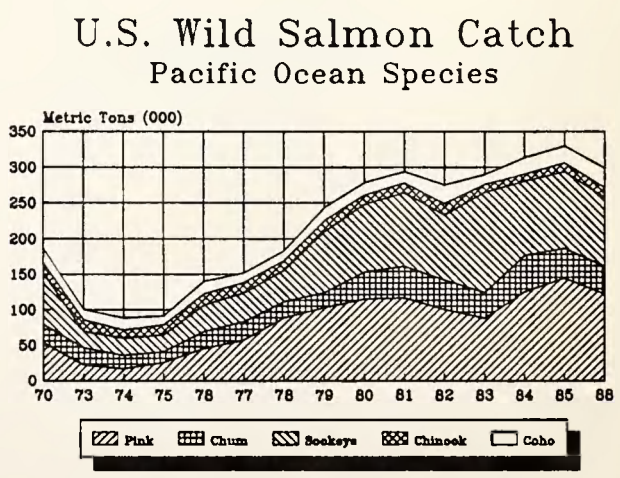
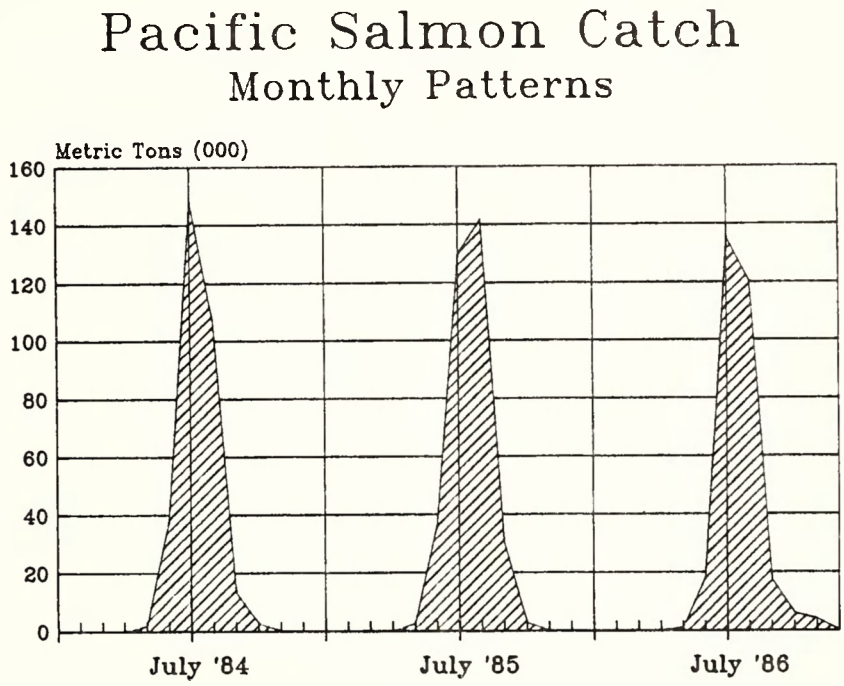



Figure II-5



Landings of Pacific salmon have a distinct seasonal pattern (Figure II-6). The U.S. Pacific salmon fishery generally occurs during the months of May to September, with the peak catches coming in June, July, and August. In Alaska, there is a small commercial troll fishery in the winter months. Thus, most of the fresh salmon from the capture (wild) U.S. fisheries appear on the U.S. market in the late spring to late fall.

Figure II-6

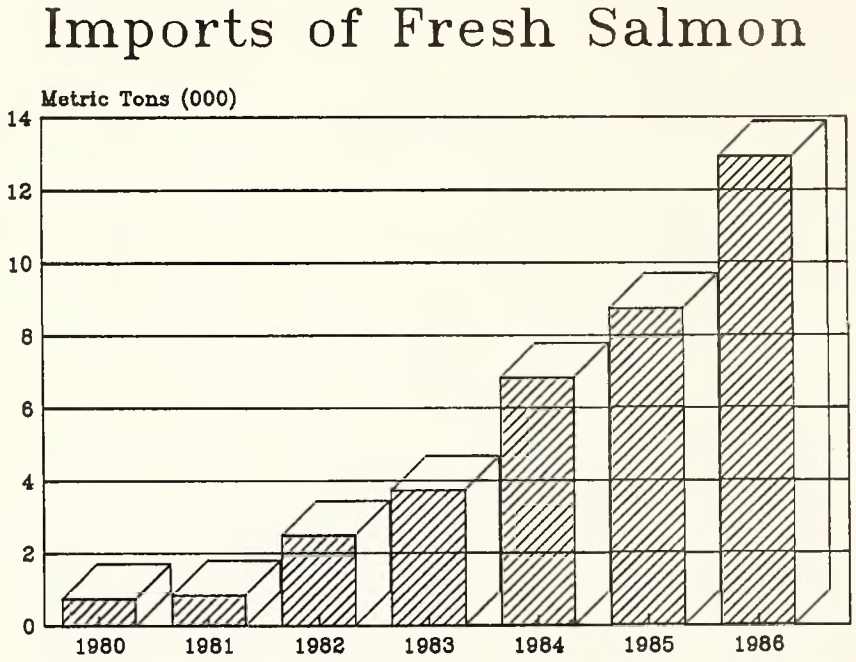



**SALMON IMPORTS**

Fresh pen-raised salmon first appeared on the U.S. market in significant quantities in 1979/1980. Not long after its introduction, it became one of the most widely sought after specialty seafood products by U.S. restaurants. Imports of fresh, farmed salmon rose from 726 mt in 1980 to more than 12,700 mt in 1986 (Figure II-7). The import value jumped from $3.9 million to almost $78 million.

If the import trends continue, the United States should become the major market for Norwegian pen-raised salmon. In 1982, Norway shipped 29 percent of its salmon exports to France, whereas the United States had an 8 percent market share. By 1986, while France was still the largest market accounting for 25 percent

Figure II-7




of Norway's salmon exports, the U.S. share had risen to 23 percent. In view of the size of the U.S. market, and the estimates of future farmed salmon production, it appears that exporters feel the U.S. market for farmed salmon will continue to be strong.

Norway dominates the U.S. fresh salmon import market. In 1986, it accounted for 69 percent of U.S. imports, followed by Canada (19%), Chile (5%), and the United Kingdom (3%). Norway and the United Kingdom exported fresh pen-raised Atlantic salmon, while the other countries shipped Pacific cohos or chinooks.

Port of entry for the farmed salmon imports appears to be correlated geographically with the exporter. For example, in 1986 Norway shipped 78 percent of its exports of fresh Atlantic salmon to east coast markets. A similar pattern holds for the United Kingdom. On the other hand, Canada sends its farmed salmon produced in British Columbia into Seattle and other west coast markets. New Zealand and Chile also ship to these areas. Table II-5 shows the market areas supplied by the exporters of fresh, pen-raised salmon.

The largest market area in the United States is the Mid-Atlantic region. This includes New York City, Philadelphia, and Washington, D.C. (Figure II-8) In the southwest, the primary market area is Los Angeles (Figure II-9). Seattle is the

Table II-5 U.S. Imports of Fresh Salmon
By Region and Country, 1986
(Metric Tons)

| Country | NE | MA | SA | GF | SW | NW | MW | TOTAL |
|---|---|---|---|---|---|---|---|---|
| United Kingdom | 170 | 176 | 0 | 2 | 16 | 2 | 0 | 367 |
| New Zealand | 2 | 5 | 0 | 0 | 103 | 50 | 0 | 161 |
| Norway | 2196 | 4720 | 21 | 284 | 1374 | 140 | 117 | 8853 |
| Chile | 9 | 179 | 0 | 61 | 307 | 107 | 16 | 679 |
| Canada | 126 | 13 | 0 | 1 | 33 | 2247 | 59 | 2480 |
| Other | 44 | 127 | 8 | 5 | 134 | 8 | 54 | 379 |
| Total | 2546 | 5220 | 30 | 353 | 1967 | 2555 | 246 | 12198 |

Regions
Northeast - ME, NH, MA, RI, CT
Mid-Atlantic - NY, PA, DE, NJ, MD, VA
South Atlantic - NC, SC, GA
Gulf - FL, LA, AL, TX
Southwest - CA, HI
Northwest - AK, OR, WA, ID

Figure II-8

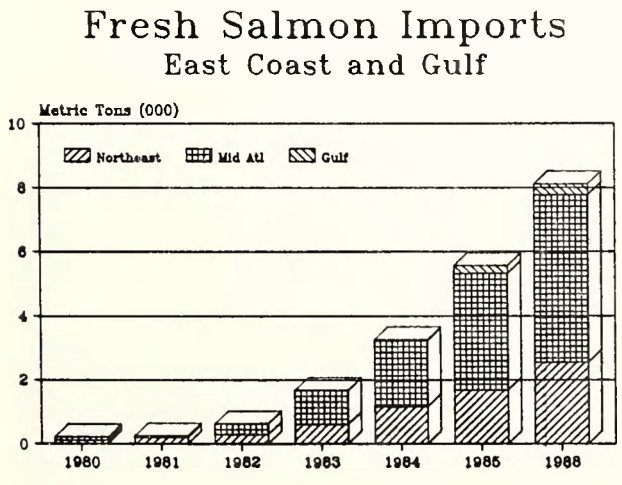
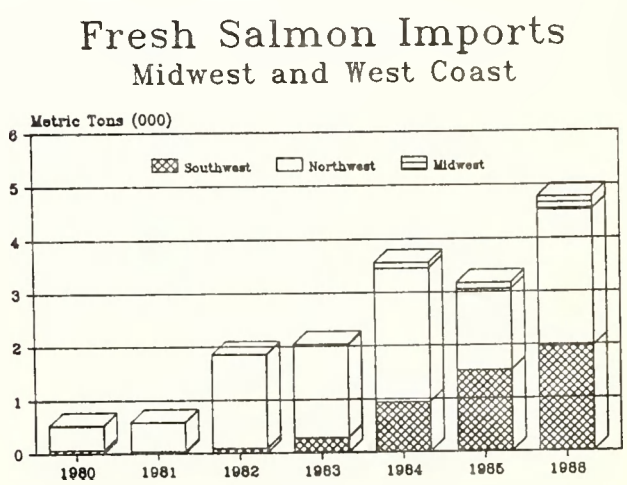



Figure II-9

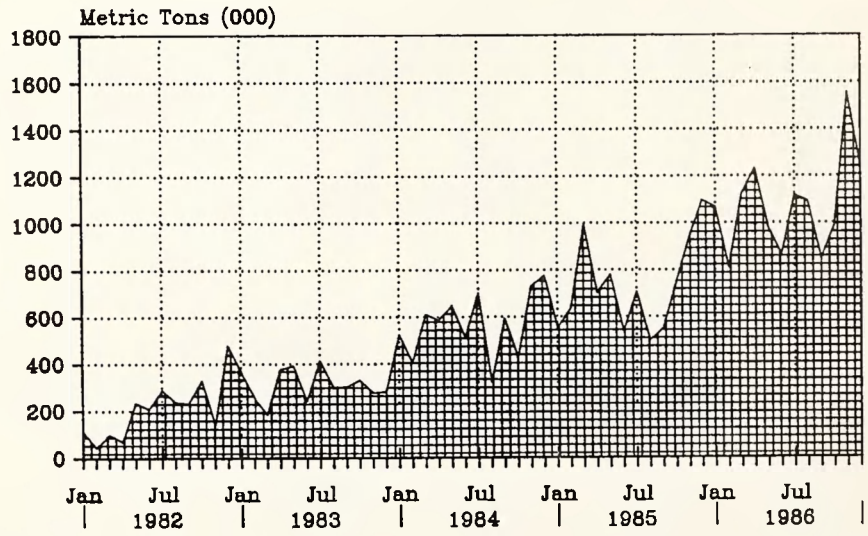


largest west coast market for imported salmon due to its proximity to the major salmon production centers in the United States and British Columbia, Canada.

Although the domestic market for farmed salmon is relatively new, imports appear to follow a fairly regular seasonal pattern. Fresh salmon imports peak in the December to March period (Figure II-10). In comparison, landings of Pacific salmon in the capture fisheries peak in the summer months. This suggets that pen-raised salmon are filling a demand niche created because of the scarcity of wild salmon in the winter months.

Figure II-10

Monthly Import Patterns
Fresh Salmon




**ARE ATLANTIC AND PACIFIC SALMON SUBSTITUTES?**

With the increasing consumer demand for fresh salmon, especially in the winter months, an unresolved empirical issue is whether farmed salmon (Atlantic and Pacific) are strong substitutes for wild Pacific salmon. (This issue has been addressed in a theoretical context in Chapter I). Alternatively, do fresh farmed salmon and fresh wild Pacific salmon compete in the same markets? The question can be further complicated by asking whether fresh pen-raised Atlantic salmon (from either domestic or foreign producers) compete with pen-raised Pacific salmon (chinook and coho) and which may also compete with wild Pacific salmon (chinook

and coho) from the capture fisheries? And finally, can fresh farmed salmon produced in the United States compete with fresh farmed salmon produced abroad and sold in the United States?

A few studies have addressed some of these questions. A recent study by Rogness and Lin explored whether pen-raised Atlantic salmon were substitutes for wild Pacific salmon.1/ The study was based on a survey of 120 seafood wholesalers and distributors in Boston, New York, Chicago, Los Angeles, San Francisco, and Seattle. Of the 62 firms that sell fresh, pen-raised Atlantic salmon, 49 indicated it was a substitute for fresh wild Pacific salmon. These distributors also felt that fresh pen-raised Atlantic salmon and frozen wild Pacific salmon were not substitutes. Although this and other studies suggest that the products may be substitutes (under certain conditions), more research is needed to clarify the issue.2/

The market for fresh salmon in the United States is at least 12,700 mt and still growing, if gauged by 1986 import statistics. What the data imply is that the U.S. market can absorb the current production of farmed salmon shipped to the United States as well as the U.S. catch of wild Pacific salmon that is sold fresh. Other nations believe the United States is a good market based on their respective production plans (see Appendix I). It is also important to note, as previously discussed, that landings are not growing fast enough or cannot increase because of biological, ecological, and regulatory constraints to meet the projected increase in U.S. seafood demand.

There are several other questions beyond the scope of this study that should be addressed before any definite conclusions can be reached on competition between pen-raised and wild salmon.

* Are fresh pen-raised Atlantic salmon and wild Pacific salmon equally substitutable in the winter (when wild Pacific salmon is less readily available) and in the summer months?

* Given an equal choice, what do restaurants prefer?

* Is the market growing sufficiently to absorb the projected increases in farmed salmon production? This question also applies to Japan and the salmon markets in Western Europe.

Appendix I will provide an overview of production trends outside the United States.

## TARIFF/TRADE BARRIERS AFFECTING SALMON PRODUCTS

Countries use nontariff trade barriers to restrict imports of fishery products. These practices include: import quotas, restrictive licensing, standards testing, labelling, and domestic content or service requirements.

This section describes nontariff trade barriers for salmon products in the United States and its major export markets. In developing U.S. trade policies it is necessary to know whether U.S. salmon products are treated the same in foreign markets as are foreign salmon exports to U.S. markets.

### United States

U.S. tariff and non-tariff barriers on salmon imports are minimal. Imports of fresh and frozen salmon, whether whole or in fillet forms, enter free of duty. In 1986, imports amounted to $105 million. Salted or pickled salmon, which the U.S. imports in small quantities, has a 3 percent ad valorem duty. Smoked salmon is dutied at 5 percent ad valorem. Canned salmon in oil carries a 12.5 percent ad valorem duty while canned salmon not in oil has a tariff rate of 3 percent. Imports of canned salmon were valued at $13 million in 1986.

U.S. exports of salmon products face generally higher trade barriers in foreign countries than foreign exports encounter in the United States. Major U.S. markets for fresh and frozen salmon are Japan and the European Community (EC). These markets absorb 93 percent of the total value of U.S. fresh and frozen salmon exports. Exports amounted to $546 million in 1986.

Principal markets for canned salmon are in the European Community. The United Kingdom particularly, is an important buyer. Exports of canned salmon to the EC amounted to $73 million in 1986. U.S. total exports of canned salmon were valued at $101 million in 1986.

### Western Europe

The common external tariff of the EC applies to imports from the U.S. The member countries are Belgium, Denmark, Federal Republic of Germany, France, Greece, Italy, Ireland, Luxembourg, Netherlands, United Kingdom, and the two new members, Spain and Portugal. The accession of Spain and Portugal into the European Community has involved changes in the tariff rates of these two countries, including fishery items. Spain and Portugal have implemented tariff reductions of 12 percent annually on fishery items until the year 1993 by which time common tariff rates for all European Community member countries shall be achieved.

Currently, with the exception of Spain and Portugal, fresh, chilled, and frozen salmon (whole, headless, fillets, or in pieces) carries a tariff of 2 percent ad valorem. Spain's tariff on live and fresh salmon is 0.5 percent and 10.4 percent on frozen forms. Fresh or chilled salmon fillets carry a 4.5 percent ad valorem duty while other forms are dutied at 15 percent. Portugal carries a tariff of 18.5 percent on fresh, chilled, and frozen salmon (whole, headless or in pieces). Fresh or chilled salmon fillets are taxed at 22.5 percent while frozen forms carry a 21.8 percent ad valorem duty.

The EC external tariffs on processed salmon are considerably higher than tariffs on fresh, chilled, and frozen forms. Whole, headless, or pieces of salted salmon carry a tariff of 11 percent while fillet forms have a tariff of 15 percent. Spain carries a tariff rate of 4.5 percent on salted and brine salmon while Portugal's duties are 17.8 percent for whole, headless or gutted.

The EC external tariff does not apply to trade among the member countries. Thus for example, Scottish or Irish farm grown salmon enters France or other EC countries duty free. Norway, as a member country of the European Free Trade Association (EFTA), enjoys reduced tariffs (primarily on industrial items) in the EC. However, Norwegian fishery exports are subject to normal EC tariff rates as levied on non-EFTA members with the exception of salmon fillets which carry a 3 percent duty if a settlement is made with regards to the reference price. The EC reference price system does not include salmon.

### Japan

In Japan, the tariff on fresh, chilled or frozen salmon is 5 percent ad valorem. The tariff on salmon roe is currently 5 percent. Japan's tariff on salted and dried salmon is 12 percent while smoked salmon is 15 percent. Canned salmon carries a tariff of 7.2 percent. There are no quota restrictions on salmon imports in Japan.

## FOREIGN MARKETS FOR U.S. SALMON PRODUCTS

### Western Europe

Earlier in this report, the question was raised whether wild and cultured salmon compete against each other, and whether the U.S. market is growing fast enough to accomodate the expected increase in production. The same questions apply to the markets in Western Europe, to which the United States has been the major supplier of salmon products.

The demand for imported salmon in the EC has grown significantly since the late 1970's (Figure II-11). Over the 1979 - 1986 period, EC imports of fresh and frozen products rose from 35,500 mt to 67,073 mt, an increase of 89 percent. However, imports of fresh salmon (primarily pen-raised) increased 627 percent (4,200 - 26,500 mt), compared to a 30 percent rise for frozen salmon (31,300 - 40,600 mt).

The United States has been the leading supplier of salmon products to the European market, followed by Canada (Table II-6). Between 1984 and 1986, U.S. exports of frozen salmon (as classified by the European Community's import sta-

Table II-6 Major Salmon Suppliers to the European Community

| Year | Canada | U.S. | Norway | Other | Total |
|---|---|---|---|---|---|
| | | | **Fresh** | | |
| 1979 | 18 | 74 | 2,935 | 1,199 | 4,226 |
| 1980 | 0 | 34 | 2,454 | 1,583 | 4,071 |
| 1981 | 0 | 0 | 4,528 | 1,582 | 6,110 |
| 1982 | 13 | 0 | 6,195 | 1,915 | 8,123 |
| 1983 | 32 | 88 | 8,602 | 2,680 | 11,402 |
| 1984 | 0 | 72 | 10,424 | 3,871 | 14,367 |
| 1985 | 24 | 112 | 11,890 | 6,219 | 18,245 |
| 1986 | 0 | 0 | 18,785 | 7,715 | 26,500 |
| | | | **Frozen** | | |
| 1979 | 11,287 | 14,992 | 1,358 | 3,634 | 31,271 |
| 1980 | 11,473 | 14,075 | 1,185 | 4,399 | 31,132 |
| 1981 | 10,302 | 13,782 | 1,889 | 4,373 | 30,346 |
| 1982 | 10,353 | 15,233 | 1,472 | 5,098 | 32,156 |
| 1983 | 12,466 | 15,699 | 2,586 | 3,434 | 34,185 |
| 1984 | 10,700 | 16,148 | 2,389 | 4,032 | 33,269 |
| 1985 | 10,420 | 17,212 | 2,666 | 5,663 | 35,961 |
| 1986 | 11,851 | 18,425 | 3,985 | 6,312 | 40,573 |

tistics) have grown at an average annual rate of almost 6 percent. This increase in exports was probably due, in part, to the depreciation of the U.S. dollar.

However, in 1986, Norway became the leading exporter of salmon to the EC. Norway shipped 22,700 mt of salmon, of which 18,800 mt were fresh, compared to total U.S. exports of 18,400 mt.

In the EC, France is the largest market for both fresh and frozen salmon products (using import data as a proxy for consumption) (Figures II-12 and II-13). Imports of frozen salmon in the leading consuming nations in the EC countries have been relatively stable over the 1979 - 1986 period, while imports of fresh salmon have increased sharply.

It is difficult using only import data to determine how fresh and frozen salmon products compete in the western European market. A detailed study is necessary to analyze prices, exchange rate effects, and consumer preferences for each product at different prices as the quality and texture vary.

It is possible that the small increase in demand for salmon in the Western European market may have been tempered by a shift towards fresh salmon. Alternatively, the two markets could be entirely separate at the current price level. It may even be possible that fresh pen-reared salmon competes directly with other high-priced seafood products.

**Salmon Imports by Japan**

During 1977 - 1986, Japan's imports of frozen salmon overshadowed fresh salmon imports (Figure II-14). The United States has been the major supplier of frozen salmon products to the Japanese market, followed by Canada.

In 1986, Japan imported 864 mt of fresh salmon compared to 113,000 mt of frozen salmon. However, Norway has become the leading supplier of fresh salmon with exports of 588 mt in 1986. The import market in Japan mirrors that of the United States and the EC. The United States supplies the majority of the frozen salmon, while Norway is positioned to become the chief source of imported fresh salmon. On the other hand, as the discussion in Appendix I indicates, Japan has its own programs to culture salmon for its domestic market.

Figure II-11

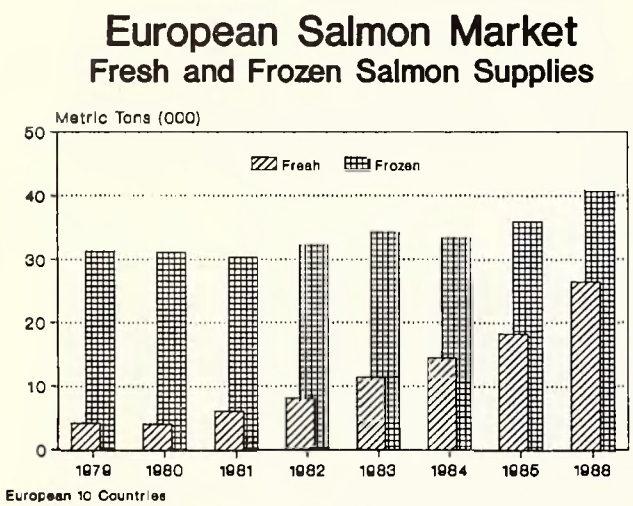



Figure II-12

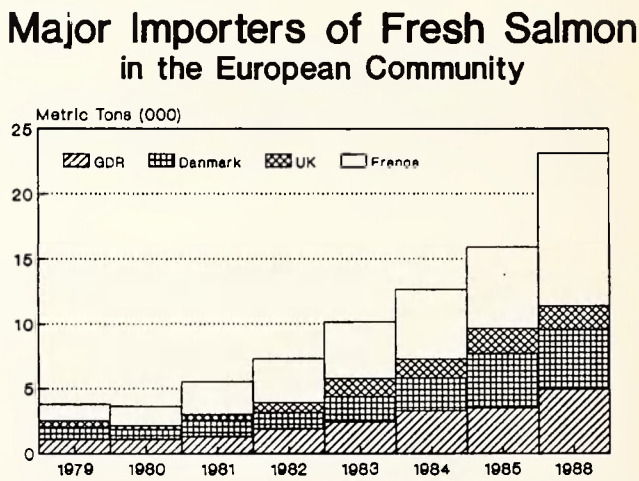



Figure II-13

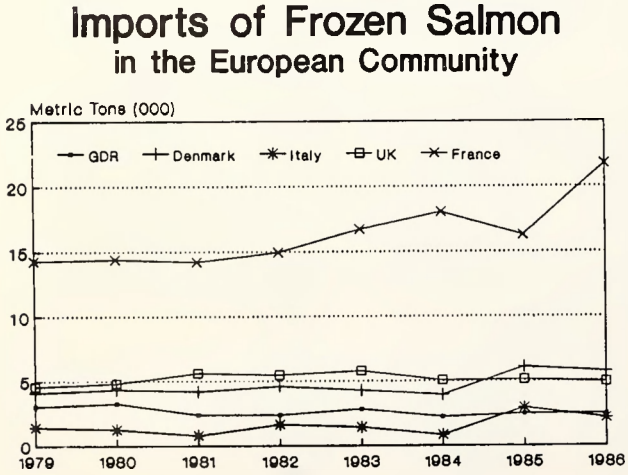
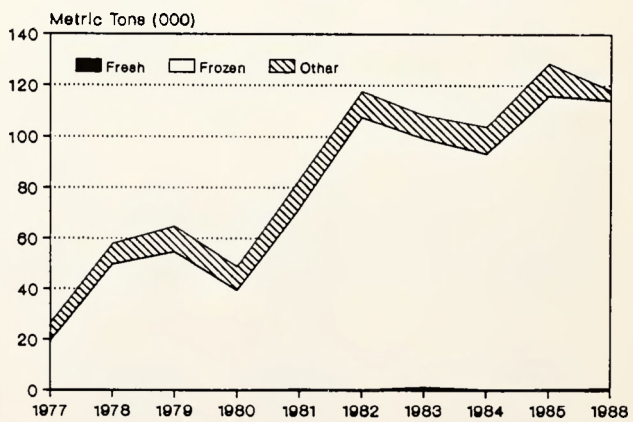



Figure II-14



## CHAPTER III

# *SHRIMP PRODUCTION: CAPTURE FISHERIES AND AQUACULTURE*

The shrimp market in the United States is supplied by products from capture fisheries (domestic and foreign) and aquaculture (primarily foreign). This Chapter reviews the world production situation for shrimp and also examines the role shrimp imports play in the U.S. market.

### WORLD PRODUCTION TRENDS

Over the past 15 years, the world landings of shrimp (wild and aquaculture) have almost doubled. Between 1970 and 1985, landings grew from 1.08 million mt to 1.90 million mt (Figure III-1). However, the increase in production has not kept pace with population growth worldwide. During this period, per capita landings of shrimp dropped from 0.413 kilograms to 0.388 kilograms.

In the late 1970's and early 1980's, the world catch of shrimp leveled-off in the 1.57 to 1.67 million mt range. The increase in catch to the 1.9 million mt level is due primarily to the success of shrimp aquaculture operations. Figure III-2 shows that world catch of shrimp from wild or capture fisheries has been stable for the last 10 years, fluctuating around 1.6
million mt.

In contrast, aquaculture production grew from 78,300 mt in 1982 to 216,500 mt in 1985, and accounts for almost 13 percent of total world shrimp production. Trends in the FAO catch data by management area suggest that the world catch is not likely to increase significantly in the near future.

Figure III-1

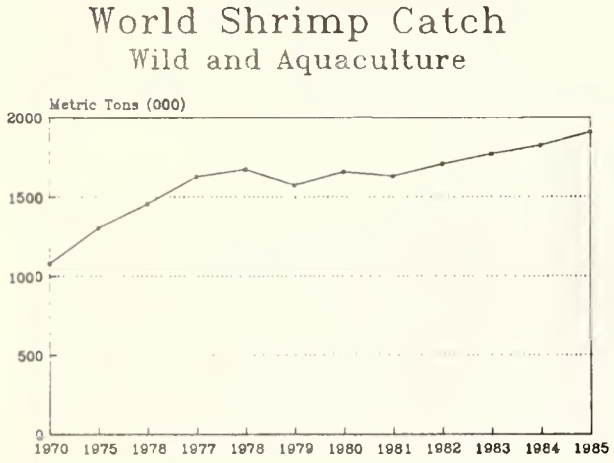



Figure III-2

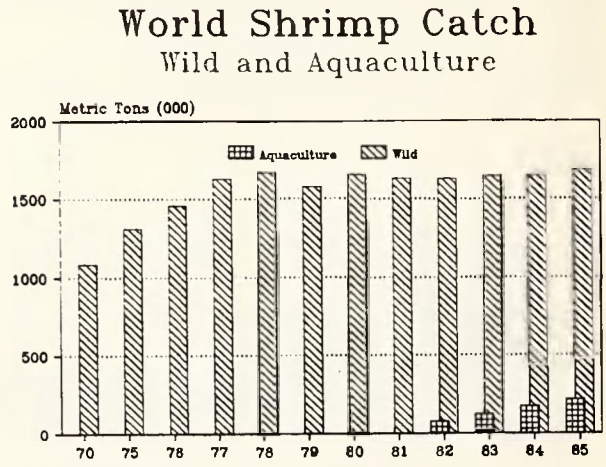



Figure III-3

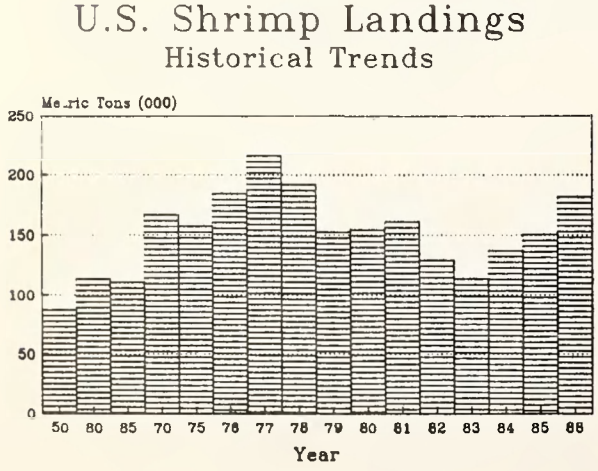
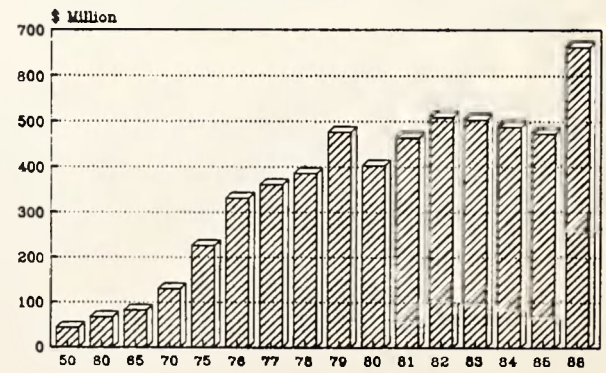



Figure III-4



## U.S. SHRIMP LANDINGS

In 1986, the U.S. fleet harvested 182,000 mt (liveweight) (111,000 mt heads-off weight) valued at $663 million (Figure III-3), which is 24 percent of the total value of U.S. commercial landings. Between 1950 and 1977, U.S landings followed an upward trend, rising from 87,200 mt to 216,100 mt (Figure III-4). This growth could not be sustained, and landings over the 1978-1986 period ranged between 113,300 mt to 191,800 mt.

The demand for shrimp in the United States, at least for the past 20 years, has exceeded the harvest potential of wild shrimp in U.S. waters. As a consequence, the domestic market has become increasingly dependent on shrimp imports. For example, in the 1960's, imports accounted for, on the average, a little more than 50 percent of U.S. supplies. In the 1980's, the import share was more than 60 percent, and peaked at 73 percent in 1983.

Countries in Latin America and Asia are the major suppliers of shrimp to the United States. In 1986, the U.S. imported 223,000 mt (heads-off weight) (181,000 mt product weight) of shrimp valued at $1.4 billion. Mexico, Ecuador, Taiwan, Panama, Brazil, Thailand, and China accounted for 71 percent of the total value. Imports from all of these countries, except for Mexico and Panama, have increased substantially since 1980 (Table III-1). As will be shown in the this chapter and in Appendix II, the growth in shrimp imports from these countries comes from cultured shrimp production.

Table III-1 Major Suppliers of Shrimp to the United States, 1980 and 1986

| | 1980 | 1986 |
|---|---|---|
| | (Metric Tons) | |
| Mexico | 34518 | 33747 |
| Ecuador | 9163 | 28123 |
| Taiwan | 2449 | 15694 |
| Panama | 6214 | 9888 |
| Brazil | 3992 | 9026 |
| Thailand | 3992 | 10932 |
| China | 454 | 9389 |

## POTENTIAL AQUACULTURE PRODUCTION

Since shrimp landings, not only in the United States but worldwide, have stabilized, and with the demand for shrimp continuing to grow, where are the additional supplies going to come from to satisfy the market demand? Current trends suggest that aquaculture is expected to provide much of the new supply source for shrimp in the United States and abroad. FAO estimates indicate that world aquaculture production rose from 78,300 mt in 1982 to 217,000 mt in 1985. Over this period, the aquaculture share of world production (wild and aquaculture) rose from 4.6 percent to 11.4 percent.

In 1990, world production of cultured shrimp is projected to reach 490,000 mt (Table III-2). If the world catch of wild shrimp stays at the 1980 - 1985 average level, by 1990 aquaculture could account for 28 percent of world shrimp production, compared to 5 percent in 1982. Appendix II contains detailed descriptions on aquaculture operations for the countries listed in Table III-2. As the Table shows, countries that are the primary producers of cultured shrimp are also the leading exporters of shrimp to the United States.

## SEASONALITY OF U.S. LANDINGS AND IMPORTS

A brief attempt was made to determine graphically whether there was any seasonal relationship between shrimp landings and imports. Figure III-5 shows monthly U.S. shrimp landings for the South Atlantic and Gulf regions. There is a strong seasonal pattern, with landings peaking in June and July.

Imports of fresh and frozen shrimp appear to have a less pronounced seasonal component than landings (Figure III-6). A major peak occurs in the fall months, as U.S. landings of shrimp begin to decline from their summer highs. In view of the size of the U.S. market, there seems to be a trend towards less seasonality for imports. As the demand for shrimp continues to grow, and with U.S. landings stable, aquaculture imports have been used to smooth out seasonal peaks and reduce inventory costs.

Since 1979, shrimp inventories, according to NMFS data, have declined steadily from an average of two months supply to one month (Figure III-7). Discussions with shrimp industry representatives indicate that a stable supply of aquaculture products has enabled them to avoid large cold storage holdings. But as indicated in Chapter I, imports tend to dampen prices at the exvessel level.

Table III-2

World cultured shrimp production, by region and country, 1982-1987, and projection for 1990.

| Region/Country | Year | | |
|---|---|---|---|
| | 1982 | 1986 | 1990P |
| | —Metric tons (live weight)— | | |
| **Asia** | | | |
| China | 7,079 | 79,054 | 100,000 |
| Taiwan | 9,575 | 51,003 | 75,000 |
| Indonesia | 11,313 | 41,000 | 60,000 |
| Philippines | 4,100 | N/A | 40,000 |
| India | 15,000 | 20,000 | 30,000 |
| Thailand | 10,371 | N/A | 35,000 |
| Bangladesh | N/A | N/A | 24,000 |
| Japan | 2,025 | N/A | 2,600 |
| Burma | - | 300 | 1,500 |
| Malaysia | 157 | 269 | 2,000 |
| Korea, South | 109 | 133 | 500 |
| Singapore | - | N/A | 300 |
| Fiji | - | N/A | 200 |
| Pakistan | - | 8 | 200 |
| Australia | - | N/A | 30 |
| New Zealand | - | - | 300 |
| New Caledonia | - | N/A | 60 |
| Asia | 59,729 | 104,032 | 373,490 |
| **Western Europe** | | | |
| Italy | - | N/A | 2,000 |
| Spain | - | - | 100 |
| France | - | N/A | 25 |
| W. Europe | - | N/A | 2,125 |
| **Africa** | | | |
| Gambia** | - | - | 500 |
| Ivory Coast** | - | - | 200 |
| Kenya** | 2 | 2 | 25 |
| Madagascar** | - | - | 50 |
| Nigeria** | - | 5 | 50 |
| Senegal** | - | 5 | 50 |
| South Africa** | - | - | - |
| Africa | 2 | 12 | 875 |

World cultured shrimp production, by region and country, 1982-1987, and projection for 1990.

| Region/Country | Year | | |
|---|---|---|---|
| | 1982 | 1986 | 1990P |
| | —Metric tons (live weight)— | | |
| Latin America | | | |
| Ecuador | 21,500 | 43,600 | 85,000 |
| Brazil | 200 | N/A | 4,000 |
| Mexico | N/A | 1,400 | 4,000 |
| Peru | 600 | 1,015 | 3,500 |
| Columbia | - | 140 | 3,500 |
| Panama | 1,500E | N/A | 3,000 |
| Honduras | 250 | 1,100 | 3,000 |
| Guatemala | 100 | 620 | 1,500 |
| Venezuela | - | 5 | 1,500 |
| Dominican Rep. | - | 216 | 750 |
| French Guiana | - | 36 | 700 |
| Belize | - | 4 | 500 |
| Puerto Rico | - | 50 | 350 |
| Martinique | 50 | 50 | 300 |
| Jamaica | 25 | 35 | 300 |
| El Salvador | N/A | 100 | 250 |
| Bahamas | - | N/A | 250 |
| Costa Rica | - | 5 | 150 |
| Guadeloupe | N/A | 45 | 100 |
| Cuba | - | 25E | 50 |
| Suriname | - | - | 50 |
| Guyana | - | 50 | |
| Dominica | - | N/A | 25 |
| Nicaragua | - | - | 25 |
| Others | - | - | 100 |
| Latin America | 24,225 | 52,121 | 113,000 |
| Other | - | N/A | 500 |
| Grand Total | 83,956 | 308,754 | 489,990 |

p - Projected.
e - Estimated.
N/A - Data not available.
* - Where country shrimp culture data was not available for 1986, the previous year's data was used in calculating the totals.
** - No Actual harvest data are available for these countries,

Figure III-5

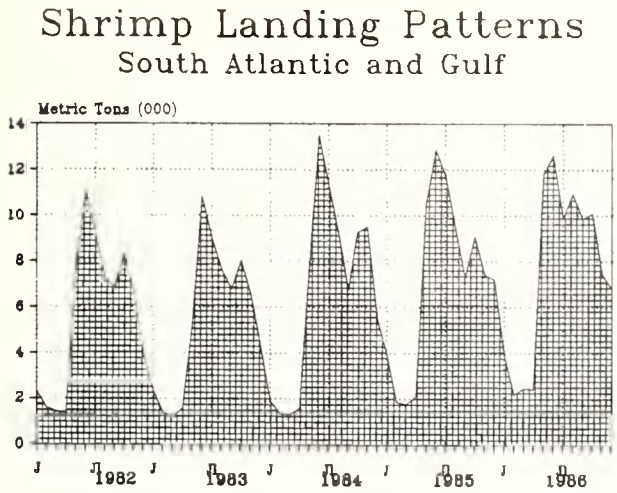



Figure III-6

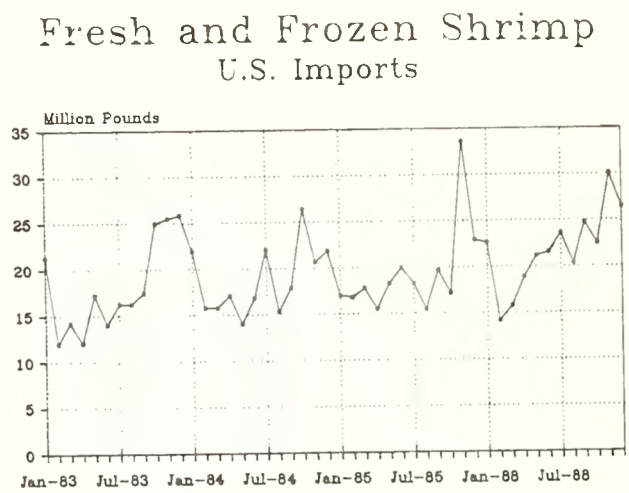
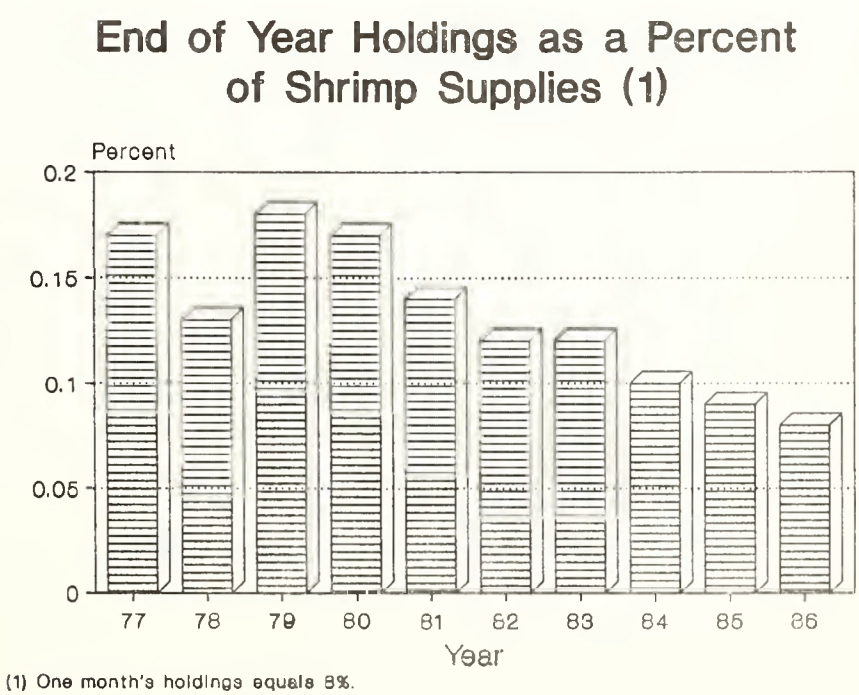



Figure III-7




(1) One month's holdings equals 8%.

## TARIFF/TRADE BARRIERS

Earlier sections of this chapter indicated that the United States is a net importer of shrimp products. Shrimp exports are minimal compared to imports. Nontariff barriers, therefore, are potential policy tools that can affect the volume and relative prices of U.S. shrimp imports.

### United States

The tariff schedule of the United States (TSUS) show that shrimp in all forms enter the United States free of import duty. The duty-free status applies to any country of origin, except Cuba, North Korea, Kampuchea, and Vietnam. All imports to the United States from these countries are prohibited.

Although there are no nontariff barriers on shrimp imports, there are some U.S. regulations and laws which can restrict imports under certain conditions. For example, the FDA rejects or detains imports of shrimp which are decomposed or infested with salmonella or other filth. Automatic detention is used when shipments from certain sources violate U.S. health standards.

Unfair methods of competition or increased imports causing hardship to a domestic industry may be reasons for import restrictions. Under present U.S. law, three avenues for import relief could be pertinent here: a section 201 or "escape clause" action, a countervailing duty, or an antidumping action.

Under the section 201, "Escape Clause" provisions of the Trade Act of 1974, the President may increase or impose duties, establish quotas, or tariff rate quotas, negotiate orderly marketing agreements, or order expedited domestic adjustment assistance if there is evidence that imports of a specified product are coming in such increased quantities as to be a substantial cause of serious injury to the domestic industry.

The U.S. shrimp industry initiated an investigation under the "Escape Clause" as recently as 1976. Although the investigation determined that the industry was injured because of import, the finding did not result in increased trade barriers. The President ordered expedited domestic adjustment assistance instead. The United States is an advocate of free trade and the tendency of the Government is to assist the industry, in case of hardships caused by international competition, through such measures, rather than to restrict imports.

Section 303 of the Tariff Act of 1930, as amended by Section 101 of the Trade Agreements Act of 1979, provides that whenever a subsidy is paid or bestowed by a foreign country on production or export of any article produced in such a country, a countervailing duty, equal to the net amount of the subsidy, is to be levied upon the importation of such articles into the United States. A material injury test has been added to the U.S. law with regard to countries under the Subsidy/Countervailing Duty Code negotiated in 1979 during the Tokyo Round of the Multilateral Trade Negotiations. The major exporters of shrimp to the United States (Mexico and Ecuador) are not signatores of the Code, and therefore the injury test is not required. Meaningful subsidies in these countries may be, however, difficult to find.

The antidumping provisions are currently included in the Tariff Act of 1930, as amended by Section 101 of the Trade Agreement Act. An antidumping duty may be imposed if an investigation determines that imports are being sold in the United States below the cost of production or the home market price of foreign producers, and because of those imports an industry in the United States is being threatened with injury, or its establishment is being retarded. The duty is calculated as the amount by which the foreign market value exceeds price of the product "dumped" in the United States.

There are no countervailing or anti-dumping duties on shrimp imports from any country, and no investigations under these provisions are presently taking place.

As the above discussion shows, the U.S. import market for shrimp is relatively free from any barriers. It is important to point out that other major markets for shrimp are not as free. Each country may have its own health requirements but so far high tariff rates remain as the major trade barrier.

**Western Europe**

The European Community has an import tariff of 18 percent ad valorem on shrimp except those belonging to the Pandalidae family which carries a 12 percent tariff for the Most Favored Nations. Spain has a tariff of 10 percent on shrimp other than live ones, full scale or semi-full scale, used for breeding, which are levied a 4.5 percent tariff rate. Portugal's tariff rate on shrimp is 23.3 percent ad valorem.

**Japan**

The tariff on fresh, chilled or frozen shrimp in Japan is currently 3 percent ad valorem. Smoked shrimp is dutied at 4.8 percent while shrimp that are salted, dried or in other conditions are levied a 6 percent duty. Chilled and frozen shrimp after simply boiled in water have a 4 percent duty and those that are salted, dried, or in brine after boiled in water carry a 4.8 percent ad valorem duty.

## CHAPTER IV

# *MARINE AQUACULTURE IN CALIFORNIA AND HAWAII*

Chapters IV - VII provide summaries of the "state" of marine aquaculture in the United States. These chapters are organized according to the geographical regions of the National Marine Fisheries Service.

Marine aquaculture activity varies among the regions and, to a large degree, is governed by the local climate and ecological conditions. Salmon aquaculture is conducted in the more northern areas, while shrimp and other shellfish are grown in warmer climates. The descriptions will show that aquaculture, at least for salmon and shrimp, are in the early stages of development in the United States.

## INTRODUCTION

This chapter summarizes the aquaculture industries of Hawaii and California, while emphasizing the interactions between the commercial capture and culture fishing industries of the two states. The Hawaii material is drawn from discussions with John Corbin of the Hawaii Aquaculture Development Program, Hawaii Department of Land and Natural Resources. The California material is based on discussions with Fred Conte of the University of California aquaculture extension.1/

## HAWAII

The Hawaii aquaculture industry is comprised of two sectors: (1) commercial production and (2) services such as research, extension, and consulting. It differs from most other U.S. aquaculture industries because of Hawaii's unique geographical and climatical situation. This unique status has allowed the industry to develop the important service component.

In 1986, the commercial sector of the industry produced 499 mt of products with a wholesale value of $3.6 million. The single most important species produced was marine shrimp worth $1.6 million. The other species were worth $2.7 million. The next three most important species were freshwater prawns, tilapia, and seaweed.

Other cultured species include Chinese carp, Chinese catfish, milkfish, abalone, algae, rainbow trout,ornamental fish, mullet, microalgae, frogs, bait fish, clams, oysters, salmon, and lobster.

The commercial sector is organized into approximately fifty farms, most of which are less than 10 acres. Several farms are from 10-50 acres, and one farm is 100 acres. The commercial sector tends to be either small family farms or large-scale corporate farms. Only a few farms are mid-sized. The large- scale farms practice intensive cultivation methods. Many have been largely experimental, but full commercial production is beginning.

No serious adverse interactions exist between culture and capture fisheries. Two major reasons account for this. First, the commercial capture fisheries is not large enough to satisfy demand. Second, the Hawaiian market is very specialized and segmented. Ethnicity, price, and product form are all important factors determining market structure.

The capture and culture fisheries do not intensively compete in these specialized markets. The capture fishery concentrates more on producing frozen products than does the culture fishery. Moreover, tuna and mahi-mahi are the two most important capture fishery species, while all aquaculture species other than shrimp are exotics. The capture shrimp catch is also too limited to be affected by cultured shrimp (although frozen imports could be affected). Little direct competition therefore exists.

**CALIFORNIA**

The California aquaculture industry is comparatively small and undeveloped with a 1984 value of around $20 million. The cultured freshwater species include trout, channel catfish, crayfish, and macrobrachium. The cultured saltwater species cultured include salmon, oysters, clams, mussels, scallops, penaeids, lobster, abalone, sturgeon, and striped bass. Production is predominantly small-scale, organized into small family corporations simultaneously involved in production, processing, if any, and marketing.

Salmon is the only cultured species that could provide serious competition for capture marine fisheries. The other species are either largely experimental, too small in scale relative to market demand, or occupy different market niches. Even salmon currently does not offer serious competition. Only one salmon ranch exists, which is experimental and on a small scale. The ranch is in Davenport Landing and raises silver and king salmon. It is the only ranch allowed by law.

## CHAPTER V

# *AQUACULTURE IN THE PACIFIC NORTHWEST*

### INTRODUCTION

Salmon aquaculture in the Pacific Northwest (Washington, Oregon, Idaho, and portions of northern California) takes two forms: (1) public and private sea ranching and (2) salmon farming. Sea ranching is defined as the rearing of juvenile fish in freshwater hatcheries and then releasing these fish to the ocean to grow, unprotected, on natural foods. As adults, these fish return to the coastal waters of their origin and are harvested in the common property fishery. Salmon farming is the captive rearing of salmon in floating sea cages (net-pens) or land-based raceways to marketable size. Both of these forms of salmon aquaculture make significant contributions to U.S. domestic production. The following chapter is a brief description of these culture systems, how they operate and concerns and issues relating to the development of the newly emerging salmon farming industry in the Pacific Northwest.

### SALMON SEA RANCHING IN THE PACIFIC NORTHWEST

Public sea ranching was developed in the 19th century and since the late 1950s has played a prominent and important role in the enhancement of the common property salmonid resource in the Pacific Northwest. Public sea ranches have existed in most Pacific rim nations since the late 1800s. The first effort in artificial propagation of Pacific salmon was a hatchery on the McCloud River in California in 1872. In the 1970s, private sea ranches were permitted in some coastal regions of California and Oregon. These private sea ranches added substantially to the salmon migrants already being released by public sea ranches in Canada, Japan, USA, and USSR.

Modern scientific fish culture in the Pacific Northwest began with the development of commercial salmon fisheries in North America. As native salmon runs declined under intensive fishing, artificial propagation was developed to sustain or increase run sizes. Hatcheries were established along the west coast of North America in the 1880s and 90s. Much of the early propagation was of ova and fry, and by the 1920s, it was apparent that such hatchery production contributed little to maintaining runs. Soon

the economic feasibility of hatcheries was questioned, and some hatcheries were closed after production records indicated unacceptable costs per fish returned. From the 1930s to the 1950s, hatcheries were subordinated to the enhancement of natural reproduction through improved fish passage, predator control, and development of spawning channels. Beginning in the 1950s, advances in the knowledge of feeds, diseases, and the early life history of Pacific salmon led to improved survival of hatchery fish and increased management's reliance on hatchery fish. Because hydroelectric development resulted in the loss of wild runs, new mitigation hatcheries were constructed on the lower Columbia River to replace the lost fish. Production from these very large hatcheries elevated coho (Oncorhynchus kisutch) and chinook (O. tshawytscha) salmon to the leading sea ranched species in North America. In the 1970s, public sea ranches expanded rapidly and were augmented by private corporate sea ranches in Oregon and California.

Coho salmon enhancement in the Pacific Northwest increased in the 1950s following the initiation of the Columbia River Fisheries Development Program. By the early 1980s more than 150 million migrants weighing 4.45 million kilos were released from 150 hatcheries in Washington, Oregon, Idaho, and California. Federal, state, and Indian tribal hatcheries in Washington rear over half the coho salmon released into North Pacific waters. Ten coho salmon smolts were released from North American hatcheries for each adult caught in 1982. Although catch remains high, recent trends in yield (adults caught/smolts liberated) in the Oregon Production Index area, which includes the Columbia River, show an alarming decline. This has led to speculation that the ocean carrying capacity of this region has been reached or exceeded.

Hatchery production of chinook salmon also increased in the 1950s and 60s much like coho salmon. Today chinook salmon is the major sea ranched species in the Pacific Northwest. Of the 260 million smolts (2.83 million kilos) released in 1982, 160 million were produced in Washington. The recent decline in wild chinook salmon populations in the Pacific Northwest has caused concern among fishery managers. Overexploitation in ocean fisheries and loss of freshwater habitat have been major causes. Wild stocks of bright chinook salmon that spawn on the upper Columbia and Snake rivers, above the hydroelectric dams, have shown an especially rapid decline and large-scale enhancement programs are planned to counter this trend. Currently, more than 60 smolts are released for every adult caught in North America.

Steelhead trout (Salmo gairdneri) is the third most important species released from sea ranches in the Pacific Northwest but fall far behind coho and chinook salmon in numbers of fish released. No substantial public or private sea ranching exists for chum, pink, or sockeye salmon in the Pacific Northwest.

Private for-profit sea ranches were made legal in Oregon and California in the 1970s, but only Oregon developed a sizeable industry. In Oregon, a substantial proportion of the coho salmon released from sea ranches in coastal regions are fish from corporate

ranches. Fishermen oppose private sea ranching, fearing eventual corporate control over the common property resource. Although legalized in two states, Washington commercial fishermen have successfully lobbied against private sea ranching. The outlook for legalization of private sea ranching in Washington State remains dim for the forseeable future. The major difference between public and private sea ranches is in harvest management. Public hatcheries expect releases to be exploited at a high rate by the fishery sometimes hundreds of miles from that site (e.g., the coastal troll fishery of Washington and Oregon). State and federal agencies program the smallest possible escapement to meet the egg-take requirements for hatcheries. Private sea ranches strive to return a maximum of bright adults to the land-based release site.

## SALMON FARMING IN THE PACIFIC NORTHWEST

### Geographical Setting

The Pacific Northwest is an ideal area in which to establish a salmon farming industry using both Pacific and Atlantic salmon species. The environment is similar in its physical and climatic characteristics to very successful growing areas of Norway. Numerous coastal inlets, fjords, and embayments provide sheltered areas for floating salmon farms. Annual surface water temperatures range from 6° to 16°C and are within the optimal temperature range for salmon culture. These ideal temperatures produce better than 80% of maximum attainable growth for Atlantic salmon (Salmo salar) for 12 months each year--conditions that exceed the best sites found on the U.S./Canada eastern seaboard or Alaska. These optimum growing conditions extend from northern California to southern British Columbia.

Because the Pacific Northwest is the site of one of the largest salmon-fishery enhancement efforts in the world, there is an existing infrastructure in the region to support a large salmon farming industry. It is estimated by the Washington Salmon Growers Association that Puget Sound (870,000 surface acres) alone is capable of supporting at least 300 acres of farms that could generate $225 million in revenue annually. But, despite these obvious advantages, the industry in Washington faces major constraints.

### Farm Production

In 1987, the four Pacific Northwest states produced 2,154 metric tons of farmed salmon or 87% of the U.S. total.

Both Atlantic and Pacific salmon are grown in farms in the Pacific Northwest. Two species predominate. Pan-sized coho salmon ranging in size from one-half to three-quarters of a pound are produced in floating marine net-pens or in ponds and raceways. Atlantic salmon introduced from eastern North America or Western Europe are grown in marine net-pens in Puget Sound and are usually marketed in size ranges of 4-6, 6-9, and 9-11 pounds per fish.

Washington is the major U.S. producer of farmed salmon. Of 2,472 metric tons of farmed salmon produced in 1987 in the U.S., 1,819 metric tons or 74% was produced in twenty Washington farms. Oregon produces pan-size coho salmon in freshwater production hatcheries or at coastal farms where land-based raceways are supplied with pumped seawater.

Additional species grown in the Pacific Northwest are steelhead trout and chinook salmon. Steelhead are cultured in marine net-pens at the Squaxin Island farm operated by the Squaxin Tribe. A few chinook salmon are grown by one Oregon company in seawater raceways and net-pens where they attain 5- to 6-pound size.

California produces a small amount of pan-size coho salmon as does Idaho in several trout farms in the Hagerman Valley.

**Technology for Farming Salmon in the Pacific Northwest**

The biology of salmon and trout is perhaps better known than that of any other group of cultivated fishes in the world. This scientific insight is used advantageously for manipulating and advancing the aquaculture of these species. The diversity of species and life histories, ease of artificial breeding, and high market value make them an ideal cultivar for marine and freshwater farming.

Initiation of the production cycle is generally limited to the time of adult spawning in the fall and winter. Limited success has been obtained, experimentally, in altering the time of spawning using photoperiod (day length) and gonadotropic hormones, but these techniques have not been employed widely by the industry. Harvest cycles are therefore extended or contracted through temperature control of growth during freshwater rearing. The beginning of the production cycle for Atlantic salmon begins when eggs are taken in October, for coho salmon when eggs are taken in November.

Each production cycle consists of four phases irrespective of whether eggs are obtained from wild adults of captive brood fish: 1) stripping of eggs and freshwater incubation of ova, 2) rearing of fry and fingerling in freshwater hatcheries, 3) saltwater growout of smolts, and 4) harvesting and processing.

**1. Stripping of eggs and freshwater incubation**

Adult Pacific salmon are transported in October/November by tank truck from cage farms to freshwater hatcheries where they are allowed to "ripen" for a few days to a few weeks. After salmon are returned to fresh water, they undergo a progressive deterioration of physical and physiological condition, similar to aging in other animals. The brood fish usually cease feeding and their immune system deteriorates, leaving them increasingly vulnerable to external fungal infections and bacterial

diseases. Also like other animals in the reproductive mode, the brood fish direct most of their energy and body reserves to the production of viable gametes. Most Pacific salmon will survive until spawning, but all fish die shortly thereafter as part of the normal life cycle.

Atlantic salmon and steelhead undergo a similar regression in their physiological condition, but they do not always die after spawning. Fish that successfully avoid fungal or bacterial infections may survive and be returned to the seawater farms. But in practice, the costs involved in transportation and freshwater space requirements for reconditioning are high and most farmers do not attempt to recondition spawners, choosing instead to kill the brood animals immediately prior to spawning.

Upon completion of final maturation, eggs are taken from salmon and steelhead by manually stripping the eggs from gravid, ripe females. Semen for fertilization is milked from males. Eggs are allowed to water harden after fertilization and within a few minutes are distributed into incubation units. These are usually trays, boxes, or baskets fitted with mesh bottoms and/or walls. The trays may be horizontally or vertically stacked with the water flow directed upward through the eggs. Temperature affects the rate of development and can be used to accelerate or delay the hatching of eggs, and through these techniques, the farmer is able to ultimately extend his harvest time to meet market demands. When eggs develop to the "eyed" stage, a physical shock is applied to kill weak embryos that would die later.

**2. Rearing of fry and fingerling in freshwater hatcheries**

The time from fertilization to hatching varies with each species and is strongly temperature dependent. Generally, about 60 days are required for hatching. When fry reach the "swim up" or feeding stage, they are transferred to troughs or starting tanks. As they grow, the fingerlings are moved to large circular tanks or rectangular concrete raceways. Growth to the smolt stage requires from 6-18 months depending on species, but rearing time will also vary depending on water temperature. At transfer to sea cages, the fingerlings will range from 20 to 50 g, depending on the species.

Rearing of fingerlings often involves maintaining high density populations in warm water and is accompanied by disease patterns that are typical of such culture systems. Any failure to adjust flow to compensate for temperatures, oxygen, or density changes will lead to stress and, ultimately, to disease. Managers carefully monitor water conditions for oxygen, temperature, and ammonia throughout the production period. Treatments for disease will involve the addition of therapeutants to the water (as flow-through baths or a flush treatment) or incorporation of drugs into the diet (medicated feed).

The freshwater rearing stage lasts from about early February or late March of the first year of life until April/May of the second. At this time, the fingerlings undergo a transformation--a metamorphosis where body shape and coloration change. This process is called smoltification, a physiological process that allows the salmon to regulate its ionic content in the more saline marine environment. At this time, the farmers transport the smolts by truck and barge to the sea farming sites where they are grown from 9 months (coho) to 3 years (Atlantics) depending on the species and the desired market size.

**3. Seawater growout of smolts**

Salmon are usually farmed in clusters of net-pens (cages) anchored offshore in sheltered seawater inlets. Although nearly one-half of the production of pan-size coho salmon in Washington is from freshwater farmers, most large farmed salmon in the United States and worldwide are grown in the sea--the great majority in net-pens. Other marine structures have been tried for the culture of salmon such as fixed tidal enclosures in bays and inlets but floating net-pens provide many advantages over fixed structures with few disadvantages. They are free from tidal-height changes, small units are amenable to cleaning of fouling organisms and sorting of fish, and enclosed populations of fish are easily fed.

The sea farms are floating structures of from 1 to 160 individual net-cages with adjacent walkways for work space. The pens are serviced mainly by boats which bring smolts, feed, and other supplies. Some farms are connected by walkways to the shore or are moored next to docks. All farms are supported by on-shore sites where feed is stored and fish are processed.

Fish are fed commercially formulated pelleted diets containing 40-50% marine proteins, fish and vegetable oils, vitamin and mineral packs, and binders. The feed may be provided either by hand, through demand feeders (feed delivery triggered by fish behavior), or through automatic feeders (feed delivered at preset times and in predetermined quantities). Salmon are typically fed 2% of their body weight per day, although this may vary depending on size of the fish and water temperatures. A feed conversion ratio of 2:1 is commonly achieved on pelleted feeds, meaning that 2 kg of feed are required to produce 1 kg of salmon.

The net-pen operator must protect against loss of fish through disease. Mortality due to disease can be minimized by proper husbandry practices (e.g., reducing stocking density), vaccination, or addition of therapeutic agents (e.g., antibiotics) to the feed.

Infectious and non-infectious diseases are responsible for losses in salmon populations held captive in marine net-pens. Many of these diseases are amenable to chemotherapy, however; the legal arsenal of drugs is severely limited. Salmon held in marine net-pens for eventual harvest or as brood stock suffer mortality from many of the freshwater diseases that are carried over into the seawater environment.

During seawater growout, farmers expect to lose no more than 20% of their Atlantic salmon before they reach a marketable size of 10 pounds and no more than 40% of their coho salmon before they reach pan-size at one-half pound. These losses may be due to a combined effect of disease, predation, physiological maladaptation to seawater, escape from the cages, handling stress, and poor environmental conditions.

Grow-out strategies are aimed at producing fresh products year-round, but most fish are marketed during the off season of the Pacific salmon fishery. The year-round availability of farmed salmon is one of the most attractive features of the product. Another attractive feature is that quality can be controlled: freshness, size, flesh color, fat content, and body conformity are all variables that can be programmed.

## PROBLEMS AND CONCERNS

In the Pacific Northwest, there is a wide range of views on the potential interactions between existing capture salmon fisheries and salmon aquaculture. Some commercial fishing groups oppose salmon farming because they feel it may cause environmental damage, may introduce diseases into wild fish populations, and may cause adverse economic impacts. Upland residential owners in bays, suitable for salmon farming, voice concern over possible environmental affects of farm systems and visual pollution. This section provides a discussion of the major issues.

### The Issues

Pacific Northwest salmon fishermen are concerned how pen-rearing will affect their industry. The rapidly expanding production of Norwegian farmed salmon, the vast majority of which is exported, will mean increased competition for U.S. fishermen in both domestic and foreign markets. Some fishermen and industry groups, therefore, oppose the development of a domestic aquaculture industry. They view salmon farming as a threat to native stocks and apply pressure at the local-level (e.g., the Washington Shoreline Management Act permit process). Their major concerns are: environmental damage to sea beds from organic wastes produced by floating net-pens; genetic deterioration of native stocks from interaction with escapees from net-pens; and introduction of exotic diseases from introduced, non-native species.

Opposition from upland owners on Puget Sound in Washington stems from a desire to maintain a pristine marine view uncluttered by floating salmon farms. In Washington farm lease holdings are issued by the Department of Natural Resources, and upland owners lobby the State to deny leases by claiming that the farms cause environmental degradation.

**Potential for Environmental Alterations**

In Japan, Norway, Scotland, and the U.S., there have been cases where a buildup of organic material from pens has caused a loss of benthic life and deteriorated water quality in enclosed bays with poor flows and low turnover rates. To avoid similar severe cases in Washington, growers have worked with state and local agencies to locate their pens in areas of good tidal flows and in such a way to minimize environmental and visual impact. In 1986, the state agencies in Washington developed a set of interim guidelines for siting of salmon farms to avoid significant adverse environmental effects from net-pen operations, pending completion of an Environmental Impact Statement.

Potential environmental alterations resulting from salmon farming have been extensively reviewed from the world literature by Donald P. Weston of the University of Washington and our review relies heavily on his work.[1]

In general, concerns can be divided into three categories. First, adverse changes to the environment that are highly probable. Second, effects on the environment that are highly dependent on site-specific conditions and whose potential magnitude cannot be predicted. Third, potential environmental alterants for which there is inadequate data for conclusive determination of significance.

**Category I** Highly probable environmental alterations associated with floating salmon farms.

Floating salmon farms generate large amounts of solid wastes in the form of feces and uneaten feed. The effect on underlying sediments is increased oxygen consumption and increased levels of organic carbon, sulfides, nitrogenous compounds, and phosphates. In some cases of heavy organic waste accumulations, the community of bottom-living organisms intolerant of organic enrichment are destroyed. While there are profound effects on sediment chemistry and biota, these effects are very localized, typically extending no more than 30 m from the culture structure. The rate and extent of such organic accumulations are dependent on water depth, flow, size of farm structure, and density of salmon being grown in the farm. The effect of organic wastes on the invertebrate community in the sediments can be more or less mitigated by siting farms in areas of deep water and good tidal exchange.

**Category II** Effects on the environment that are highly dependent on site-specific conditions and whose potential magnitude cannot be predicted.

A floating salmon farm placed in the marine environment will reduce current velocity particularly in the downstream direction. Reduced current velocity will impair dilution and dispersal of wastes downstream from the operation. This "shadow" effect is not likely to be significant except in cases of intensive culture and very large farm structures or in areas of restricted natural circulation. Porous bodies such as net-pens will typically influence current velocity for up to 50 diameters (of the object) downcurrent, and although it is possible to derive rough estimates of downstream influence, the complex flow patterns actually found in most estuarine environments complicate efforts to quantify the effects of a maricuture structure.

Cultured salmon and husbandry practices alter the chemistry of the water passing through the salmon farm, most notably increasing ammonia concentrations from metabolic wastes and decreasing oxygen concentrations from fish respiration. However, the concentration of nutrients in water passing through a salmon farm is very dilute compared with most discharges to the marine environment. Field studies have typically shown little or no changes in water quality outside the farm structure in well-flushed areas. Adverse effects would be anticipated only in areas of extremely limited tidal exchange or very intensive farming activity.

Floating salmon farms could produce nutrients that might enhance the blooming ("red tides") of certain toxic or noxic species of phytoplankton. But in most of Puget Sound, for example, nutrients are not limiting to phytoplankton growth. Thus, additional input attributable to mariculture should have no effect on productivity. Finfish culture in Japan has been implicated as a potential contributing factor in producing phytoplankton blooms, but no direct field observations have demonstrated a quantitative relationship between farm nutrient output and phytoplankton blooms.

Culture operations in Washington have required the importation of non-native Atlantic salmon from the eastern United States and Europe. Farmed fish may escape the farms and establish self-sustaining wild populations, potentially becoming pests or eliminating native species. But deliberate attempts to introduce Atlantic salmon into Washington, Oregon, and southern British Columbia have failed, and no self-sustaining wild populations have ever been established. While there appears to be little genetic risk with this species, the potential introduction of exotic diseases with further importations represent a significant threat and requests for future introduc-

tions should be carefully evaluated.

**Category III** Potential environmental alterations for which there is inadequate data for conclusive determination of significance.

There are several potential effects of salmon mariculture that are of concern but have not been demonstrated. The existence of such effects remains largely speculative and data for their clarification are inadequate or entirely lacking. The following are typical concerns:

- The environmental effects of antibiotic and other drug usage.

- Alteration of wild gene pools through introgression of escaped farm fish.

- The capacity for a salmon farm to serve as a disease reservoir for the infection of wild fish stocks.
- The potential for proliferation of human pathogens in the vicinity of salmon farms.

**Lack of Government Support**

Countries that have succeeded in producing large quantitities of salmon through aquaculture have been able to offer farmers substanial financial or technical assistance.

Caution by governmental agencies in the Pacific Northwest has been perceived as lack of support and has constrained the industry. However, in Washington, for example, there is growing support from the various governmental agencies (Departments of Fisheries, Ecology, Natural Resources, Wildlife and Agriculture). In 1987, Washington's Governor, Booth Gardner, issued a public policy in favor of salmon aquaculture and noted that the aquaculture industry already generates $35 million annually. However, little research and development aid exists to provide farmers with husbandry information and financial aid programs (local or federal) are not readily available.

## CHAPTER VI

# *AQUACULTURE IN ALASKA*

## INTRODUCTION

Pacific salmon aquaculture in Alaska occurs in two general categories: (1) ocean ranching, and (2) pen-rearing. Ocean ranching is conducted both by public agencies, particularly the Fisheries Rehabilitation, Enhancement, and Development Division of the Alaska Department of Fish and Game (FRED), and by private nonprofit aquaculture associations (PNP).

Pen-rearing of salmon in Alaska occurs only on an experimental basis at this time. Commercial pen-rearing of salmon is the subject of an intense public debate in this state and and a moratorium has been imposed at least until July 1, 1988.

## COMMERCIAL PEN-REARING OF SALMON: ECONOMIC AND SOCIAL ISSUES

On June 15, 1987, the Governor of Alaska signed a bill imposing a moratorium on the issuance or granting of licenses, permits, leases, or authorization for the construction or operation of a commercial finfish farm in the state. The moratorium expires on June 30, 1988. The moratorium allows the public time to discuss the merits of salmon farming and to develop recommendations for the next state legislature, which begins in January 1988.

### Arguments Raised In Support Of Commercial Salmon Farming

Advocates contend that commercial salmon farming will create year-round employment opportunities, particularly in areas of Alaska where employment is difficult to obtain and often seasonal. A study conducted for the Alaska State Legislature (Pierce 1987) estimates that about 1,920 jobs could be created as a direct result of salmon farming activity in the state, with an annual payroll of $48.8 million.1/ These jobs include occupations in fish farm construction, fish processing, transportation, distribution, and sales, as well as farm operation. Norwegian studies have estimated that for each person directly employed in salmon farming, an additional job is created elsewhere in the economy.

Furthermore, salmon farming could make all Alaskan salmon more competitive in the U.S. and world markets. Farmed salmon could be harvested during the winter and spring when the wild and ocean ranched fish are generally less available for harvest.

The supply of pen-reared salmon could be used to sustain the demand for Alaska salmon all year, and to extend the product to new markets. Also, if the quality of Alaska farmed salmon was equivalent to and the price competitive with foreign farmed salmon, Americans might be persuaded to buy Alaska salmon instead of the foreign product, thus improving the balance of seafood trade for the U.S.

Salmon farms will need a supply of fish food. Kerns (1986) reports that Norway's 1983 production of farmed Atlantic salmon and rainbow trout required approximately 200,000 mt of fish as ingredients for aquaculture feed rations.2/ Demand for raw materials for feed for Alaska's salmon farms might stimulate Alaskan fishermen and processors to enter the fish food production business. Much of the scrap from processed fish, which is now largely discarded, as well as unused species, could be converted to salmon feed.

Finally, it is pointed out that Alaska, with its largely undeveloped coastline, sheltered bays, and inlets, has prime locations for salmon farming. Thus, salmon farming could provide an economic base for rural residents and remote communities without the inherent conflicts with upland users identified with more highly developed areas such as, for example, the Puget Sound in Washington State.

**Arguments Raised In Opposition To Commercial Salmon Farming**

Some of the opponents of commercial salmon farming raise environmental issues. In summary, opponents present the following objections: (1) pen-rearing of fish "for profit" may encourage the introduction of nonindigenous and/or exotic species into Alaska's marine environment which, if they were to escape from holding pens, could pose a threat to native species; (2) introduction of alien diseases and parasites, or significant outbreaks of indigenous infectious diseases or infestations due to close confinement of fish in pen-rearing facilities, represents an environmental threat; (3) site pollution, including bottom deposition of fecal matter and unutilized feed resulting in eutrophication of important habitat for wild fish and shellfish; (4) introduction of artificial substances, e.g., antibiotics, into the marine environment; (5) disruption or destruction of normal flushing/flow patterns, thus reducing natural productivity; and (6) loss of scenic and wilderness value, represent significant potential environmental costs.

The economic arguments against salmon farming include the prospect, in particular, that Alaska farmed salmon would compete successfully with traditional salmon fisheries and ultimately drive down the price of all Alaska salmon.

It is argued that aquacultural operations would tax the limited existing infrastructure capacity in coastal communities (e.g., air transportation) and compete with traditional users of these services, thus increasing costs, restricting access, or both.

Another concern is that multinational corporations could take control of Alaska's aquaculture industry, developing highly automated "mega-hatcheries," owned and operated by non-Alaskans. The suggested result is that there would be little economic benefit to the local or state economies and removal of profits from Alaska.

Fear has been expressed that multinational pen-rearing will lead to multinational ocean ranching, and that, with the political and economic influence ascribed to these giants of world commerce, the ultimate result would be an effort to eliminate the existing commercial ocean salmon fisheries.

Some critics of pen-rearing argue that Alaska is "too late" to enter the salmon farming industry. They contend that Alaska's farmed salmon production would come on-line just as the world market for cultured salmon becomes saturated. The resulting economic "shakeout" will bring financial ruin to a developing salmon aquaculture industry. According to Kerns (1986), there is no doubt that Alaskan salmon farmers will be entering into a highly competitive industry.3/

Opponents of salmon farming note that the farms will preempt other uses of the bays and inlets selected as pen sites. These public waters presently serve as productive fishing grounds, secure temporary anchorages, recreational areas, and log transfer and storage sites.

Salmon farms could counteract the significant economic and political investments Alaska has already made in salmon enhancement and mitigation. Opponents are also concerned that a large salmon farming industry would represent a formidable lobbying interest. This would diminish the effectiveness of the traditional commercial fisheries lobby.

And finally, opponents argue that commercial salmon farming will lead to a new state government bureaucracy. This possibility is said to represent a threat to social freedom, an erosion of economic independence, and a further destruction of the "nontraditional" lifestyle associated with commercial salmon fishing in Alaska.

## OCEAN RANCHING

Alaska has 36 hatcheries producing Pacific salmon These cover a wide spectrum from world class facilities capable of incubating 150 million eggs per year to small private or research facilities handling less than one million eggs per year. Some hatcheries do only short-term rearing beyond incubation while others have extensive year round incubation and rearing capabilities.

### Current Production

Alaska's salmon culturing facilities collect over 1 billion salmon eggs per year. While egg-to-fry and fry-to-smolt survival values vary by hatchery, survivals from egg to release usually exceed 75 percent. In 1986, for example, 771 million juvenile salmon were released from about 950 million eggs collected either in 1984 or 1985.

The rate of survival from smolt to adult also varies considerably, depending on factors such as species, stock, release location, and the ocean environment. Overall, the survival rate is about 2 percent. Thus, from every million fertilized eggs placed in a hatchery, about 15,000 adults could return, of which 600 would be needed for obtaining the next one million fertilized eggs. Thus, for example, production from the 1986 release should amount to approximately 14,250,000 adult salmon.

### Planned Production

Salmon hatchery facilities in Alaska are presently operating at about 80% capacity. No large scale expansion in the existing hatchery program is planned, although changes in production strategies and operational modes could increase the capacity of present facilities. A few new hatcheries in special circumstances or settings could be built in the next decade. By 1995, Alaska will likely release 1.2 to 1.4 billion juvenile salmon from hatcheries per year and from these releases, harvest 25 million adult salmon each year.

## PEN CULTURE TECHNOLOGY

At present, because of the prohibition against pen culture in Alaska, the only pen culture of salmon in Alaska is being done on an experimental basis by NMFS out of its field station at Little Port Walter.

An earlier effort started in 1984, when a small-scale experimental salmon farm was established in southeast Alaska at Osprey Bay on Baranof Island. This project was a cooperative undertaking between three agencies: (1) the Fisheries Rehabilitation, Enhancement and Development (FRED) Division of the Alaska Department of Fish

and Game; (2) the Office of Commercial Fisheries Development of the Alaska Department of Commerce and Economic Development; and (3) the Auke Bay Laboratory of the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Department of Commerce. The project was established to gather preliminary information on the biological feasibility of raising chinook salmon to market size in netpens under southeast Alaska conditions.

Initial research at Osprey Bay involved six netpens and two ages of chinook salmon. Two diets, as well as different feeding rates, were tested and growth performance and survival of the chinook salmon were monitored. Osprey Bay is a relatively small research project, but it has shown promising results in the farming of chinook salmon. The project has raised a few chinook salmon to the 15-to-24 pound range and collected Alaska's first second-generation pen-reared brood stock.

The work at Osprey Bay resulted in nationally significant findings on the effect of the net antifoulant tri-n-butyltin on pen-reared salmon, and produced information on stress in cultured chinook, predator control, flesh pigmentation, and dietary responses. The primary thrust of the project now focuses upon brood stock development including comparisons of the four major chinook stocks now utilized in southeast public and private hatcheries. The NMFS research station at Osprey Bay has about 3,000 cubic meters of seapen rearing volume available and raises from 5 to 10 metric tons of farmed salmon per year.

Relatively little information currently exists with respect to the costs of salmon farming in Alaska. A study commissioned by the Sealaska Corporation provides some preliminary estimates of the capital and operating costs which might be associated with two possible Atlantic salmon pen-rearing operations hypothetically located in the Seattle/Vancouver B.C. area.

Based upon these estimated prices, and inflation factors intended to account for the higher material and labor costs since 1985 in Alaska, cost profiles were developed for hypothetical facilities (assuming that Alaskan urban construction costs exceed Seattle costs by, on average, 50 percent; and that Alaska remote construction costs exceed Seattle costs by as much as 130 percent) (Table VI-1).

## STATE REGULATIONS

### General

Alaska State regulations allow aquaculture production of marine organisms for scientific, educational, and commercial uses. However, production is limited for commercial operations. Ironically, the only species of marine organism for which unconditional approval has been given for commercial "for profit" production is the

Table VI-1 ESTIMATED CAPITAL COSTS: HYPOTHETICAL SALMON FARM IN ALASKA, 1985 DATA

| | 50 mt Atlantic salmon farm | | 200 mt Atlantic salmon farm | |
|---|---|---|---|---|
| | urban | remote | urban | remote |
| | (Dollars) | | | |
| Pens & nets | 45,000 | 69,000 | 187,500 | 287,500 |
| Anchoring | 3,000 | 4,500 | 12,000 | 18,400 |
| Feeders | 1,500 | 2,300 | 3,000 | 4,600 |
| Storage Facilities | 6,000 | 9,200 | 9,000 | 13,800 |
| Slaughterhouse & Equipment | 22,500 | 34,500 | 66,000 | 101,200 |
| Dock | 4,500 | 6,900 | 16,500 | 25,300 |
| Transportation Equipment | 7,500 | 11,500 | 39,000 | 59,800 |
| TOTAL | 90,000 | 137,900 | 333,000 | 510,600 |

*Based upon cost data for Seattle/Vancouver facility as presented in "Aquaculture: Opportunities and Constraints in Cultured Salmon Production Phase II," Sealaska Corporation, 1985.

nonindigenous Pacific oyster. Other species of shellfish, e.g., mussels, scallops, as well as aquatic plants, e.g., giant kelp, are in experimental cultivation or under consideration for potential "for profit" production.

**Ocean Ranching of Salmon**

The only genus of marine finfish which currently is of interest to Alaska aquaculturists, and simultaneously supports a significant directed commercial fishery, is the Pacific salmon. All five species of Pacific salmon are cultured in Alaska under statutory authority. Such production is limited to either small scale experimental, educational, research production, or public/private "nonprofit" ocean ranching.

Under Alaska State statute (AS 16.10.300 - 16.10.620), salmon ranching has been confined to State owned and operated enhancement facilities, or private nonprofit production facilities. Both types of facilities are explicitly intended, according to the authorizing statutes, to supplement and enhance the salmon fishing opportunities of commercial, sport, and subsistence users by producing salmon for the common property fisheries in the state.

**Public Programs** The first component of Alaska's state sanctioned salmon ocean ranching program, the Fisheries Rehabilitation, Enhancement and Development (FRED) Division of Alaska Department of Fish and Game (ADF&G), was established by the State legislature, and charged with the responsibility of planning and implementing a program that ensures the perpetual and increasing production and use of Alaska's fishery resource, (AS 16.05.092).

The division operates 20 hatcheries (representing approximately $80 million in capital expenditures) to produce salmon and trout for subsistence, commercial, and sport fisheries. FRED also oversees the permitting process for mariculture projects in the state and administers the second major component of Alaska's salmon ranching program, the Private Nonprofit (PNP) program.

**Private Nonprofit Programs** The PNP was established in 1974 by the Alaska legislature to assist ADF&G in carrying out its statutory and regulatory responsibilities pertaining to public and private aquaculture in Alaska. In 1976, the legislature authorized creation of regional aquaculture associations, comprised of representatives of commercial, sport, and subsistence fishing interests, as well as members of local communities (Section 1, ch. 161, SLA 1976).

Quoting from the enabling legislation, "It is the intent of this Act to authorize the private ownership of salmon hatcheries by qualified nonprofit corporations for the purpose of contributing, by artificial means, to the rehabilitation of the state's depleted and depressed salmon fishery. The program shall be operated without adversely affecting natural stocks of fish in the state and under a policy of management which allows reasonable segregation of returning hatchery-reared salmon from naturally occurring stocks " (Article 8 - Salmon Hatcheries Section 1, ch. 111, SLA 1974).

Several regional associations have been formed, to date. These associations assist ADF&G in developing and maintaining regional salmon production and in implementing salmon rehabilitation and enhancement programs (FRED 1987). To finance the capital costs and initial operating expenses of the PNP program, the legislature established the Fisheries Enhancement Revolving Loan Fund. Through

1986, approximately $41 million has been loaned by the state to PNPs for capital construction of salmon hatcheries and other salmon enhancement projects, with another $10.6 million for operation of the regional associations' facilities.

The impetus for the PNP hatchery system, as suggested by the language in the Act cited above, came from the desire of commercial fishermen to enhance the severely depressed salmon stocks of the early 1970s (Pierce 1987). The salmon industry's need for an extended payback period on capital and operating loans, coupled with the uncertainty of returns through the common property fishery are the primary reasons given for the State of Alaska's direct involvement in the financing of PNP hatcheries.

PNPs depend, in part, upon mandatory assessment taxes collected from commercial fishermen, and sales of salmon returning to special harvest areas, to sustain their operations and service their loans. The major difficulty faced by PNP hatchery operations has reportedly been to work out a reasonable harvest management scheme with fishery regulators to assure adequate cost recovery for the local nonprofit facility.

Private "for profit" aquacultural production of salmon in Alaska, either ocean ranching or pen rearing, is not authorized under State statutes at the present time. While considerable interest and debate has arisen, especially with regard to the economic potential and socioeconomic implications of salmon farming in the state, the Alaska legislature has been unable to fashion a compromise between the interests of proponents and opponents of "for profit" private salmon aquaculture.

Construction and operation of commercial "for-profit" salmon ranching facilities continue to be prohibited under State of Alaska law, with no expectation that this situation will be altered in the future. Given the existing system of FRED and PNP "ocean ranching" hatchery facilities, as well as the size and scope of the common property salmon fisheries in Alaska, it is unlikely "for profit" Pacific salmon ocean ranching will be of commercial interest in Alaska.

**Pen Rearing**

On June 15, 1987, the Governor of Alaska signed a bill imposing a moratorium, until July 1, 1988, on the issuance or granting of licenses, permits, leases, or authorizations for the construction or operation of a commercial finfish farm in the state. Should a political decision allow private commercial salmon aquaculture in Alaska, several other state statutory or regulatory constraints will have to be modified. These pertain to the legal acquisition, transportation, and disposition of salmon eggs, fry, etc. According to a report done by the House Research Agency,

Alaska State Legislative, February 1987, "If and when a salmon farming industry is begun, the availability of smolts will be a critical factor in how quickly development can proceed.

**Brood Stock Restrictions**

Acquisition of eggs and/or smolts for commercial production must involve one or more of the following. First, wild salmon stocks could be utilized as brood sources. However, under prevailing law, wild egg takes are tightly regulated and must be conducted in strict compliance with ADF&G Commercial Fisheries Division escapement goals for individual drainages. These regulatory constraints could severely limit the size, frequency, and geographic distribution of the egg take, and thus the availability of suitable raw material for commercial salmon farming operations. It could also intensify the conflict between users of the wild resource and private aquaculturists.

A second option, the importation of eggs, smolts, or brood stock from other states or countries, would necessitate extensive and costly quarantine provisions to assure compliance with current regulations intended to assure that nonindigenous diseases are not introduced into the state. Current Alaska State regulations on importation of nonindigenous species would have to be modified to permit the effective use of this source of supply.

Finally, eggs, smolts, and/or brood stock could be obtained by private salmon facilities from either FRED or PNP hatchery operations. This would require amendments of the Alaska statutes that authorized the creation of the FRED and PNP systems.

## CHAPTER VII

# *AQUACULTURE IN THE NORTHEAST*

### INTRODUCTION

In the northeast states, private aquaculture operators feel that release of any economic data could provide an unfair competitive advantage to other commercial enterprises. In general, state regulations do not require permittees to report production figures. Consequently, production figures from private operators are not available.

### CURRENT PRODUCTION

Leasing of estuarine bottomland for shellfish and finfish culture occurs in several states: Maryland 9,000 acres, Connecticut 40,000 acres, Maine approximately 900 acres, and Virginia 110,000 acres. The majority of these leases are for shellfish production, but interest in pen-rearing of salmon in Maine is growing rapidly.

In Maine, one operator has been in business for 5 years, and there have been 12 new applications in the past year. There is a strong indication that financial backing for these ventures is coming from Norwegian firms who have been satisfying the U.S. demand for Atlantic salmon.

In addition to the salmon and trout facilities, several state and federal hatcheries have been built, or are being built to raise striped bass; specifically, Maryland, Virginia, Pennsylvania, and West Virginia. Private striped bass hatcheries have also been built in New York and Maryland. Table VII-1 shows the number of private hatcheries in the northeast region.

### PLANNED PRODUCTION

For the same rationale expressed above, planned production, other than federal or state hatcheries is not available. New state hatcheries are being planned for Vermont and Ohio.

Although the U.S. Fish and Wildlife Service recently went through a period of

closing and phasing out several of its hatcheries, production now appears to be relatively stable. As noted above, there is strong interest in pen-raised Atlantic salmon, and it appears likely that many new firms will be operational within the coming year. An estimate of planned production for state and federal facilities is listed in Table VII-2.

## STATE REGULATIONS

Nearly all Northeastern states have regulations governing aquaculture facilities and operations. It should also be noted, however, that some states do not have strict regulations. Typically, state permits are needed for the construction of the facility, for diversion of running water, for discharge of water containing chemicals and elevated nutrients, for transporting fish or shellfish, and for importing eggs or other life stages.

A propagation permit and/or an aquaculture permit, and perhaps a commercial fishing license may also be required. Depending on the location and operation, other permits may be required for "consumption use" of ground-water, or for the use of publicly-owned lands for the aquaculture facility.

Due to the possibility of importing diseased eggs or fish, state regulations are becoming more and more stringent, requiring certification that the organisms are "disease-free". To receive this certification, the batch (eggs, larvae, fry, juveniles, smolts, or adults) must be tested prior to shipment by a qualified specialist who is acceptable to the receiving state. The objective of this policy is to prevent the spread of disease to uncontaminated areas and healthy stocks, including wild stocks.

## FEDERAL REGULATIONS

In general, federal regulations affecting aquaculture operations depend on the specific site. Corps of Engineers permits are needed for structures in navigable waters. U.S. Coast Guard permits are needed for causeways or bridges. Both the Corps and the Coast Guard are involved if the facility may cause a hazard to navigation. The Environmental Protection Agency issues permits for discharges.

## INDUSTRY CONCERNS

The most important point made by industry was the need for a reliable source of certified disease free organisms. Disease resistence tends to increase with successive life stages, so it may be advantageous for an aquaculture facility to purchase salmon or trout fingerlings rather than fry; or smolts rather than fingerlings. Although initial cost may be higher, survival should be greater and the

overall cost per fish should be less.

**ENVIRONMENTAL ISSUES**

Water quality and pollution, as well as the introduction of non-native species are of major concern. Most state regulations specify that aquaculture facilities cannot interfere with passage of native species in the stream or water body. While this normally is not a major problem, it can be the subject of debate in areas where new facilities are being planned.

Competing uses of the area frequently arise during public hearings on facilities, with objections not limited to fishermen who would like to pursue their own interests in the same location, but also objections from people who complain that the aesthetics of the area will be reduced by the new facility. One pen-rearing proposal for Atlantic salmon was withdrawn after extensive criticism of the aesthetics of the plan and the potential hazard to navigation in the area. And a planned State hatchery has been delayed by objections from certain segments of the public.

Aquaculture projects, though they are engaged in production of food, are not considered agriculture. Consequently, aquaculture operations do not enjoy the special perks which are extended to the agriculture industry.

**AQUACULTURE CAPITAL COSTS (Public Operations)**

Two states have estimated that it would cost $9 - $10 million to build a salmon/trout hatchery capable of raising 500,000 smolts per year. For pen-reared salmon, the estimate is $250,000 -$ 1,000,000 for the construction, placement and associated costs of 12 pens and a 5-acre ocean site. The cost of leasing marine bottomland from coastal states varies from $5 - $25 per acre per year. Leases are usually for 10 years, but can be renewed for subsequent 10-year periods.

Since the costs of leasing bottomland and constructing facilities vary considerably from state to state and among geographic regions, it is impossible to generalize on the overall costs of aquaculture production. Furthermore, private aquaculture facilities jealously guard all economic information, to preserve any advantage which they may have acquired at any of the stages of production.

Table VII-1. Estimated salmon and trout production in State and Federal hatcheries in the Northeast Region

| State | Production (1,000 lbs.) | | | | Costs ($1,000) | |
|---|---|---|---|---|---|---|
| | Current | | Planned | | Annual Operating | |
| | State | Federal | State | Federal | State | Federal |
| ME | 192 | 110 | 200 | 110 | 1197 | 598 |
| NH | 416 | 25 | 415 | 25 | 1255 | 134 |
| VT | 160 | 52 | 420 | 52 | 500 | 230 |
| MA | | 2 | | 2 | | 9 |
| RI | | | | | | |
| CT | | | | | | |
| NY | 1145 | | 1400 | | 3500 | |
| NJ | | | | | | |
| PA | 2508 | 178 | 2500 | 178 | 4921 | 531 |
| DE | | | | | | |
| MD | | | | | | |
| VA | 588 | | 740 | | 947 | |
| WV | | 165 | | 165 | | 290 |
| OH | 48 | | 48 | | 390 | |
| IN | 100 | | 96 | | 450 | |
| IL | | | | | | |
| MI | 850 | 232 | 1000 | 232 | 4500 | 782 |
| WI | | 76 | | 100 | | 398 |
| MN | 249 | | 249 | | 782 | |

Note: Capital construction costs not currently available.

Table VII-2. Private Aquaculture Operations by State in the Northeast Region, as of December 31, 1986.

| State | Number of Aquaculture Operations |
|---|---|
| Maine | 7 |
| New Hampshire | 14 |
| Vermont | 2 |
| Massachusetts | 5 |
| Rhode Island | |
| Connecticut | 80 |
| New York | 49 |
| New Jersey | 6 |
| Pennsylvania | 75 |
| Delaware | 2 |
| Maryland | 7 |
| Virginia | 9 |
| West Virginia | 4 |
| Ohio | 71 |
| Indiana | 27 |
| Illinois | 24 |
| Michigan | 44 |
| Wisconsin | 49 |
| Minnesota | 18 |

## CHAPTER VIII

# *AQUACULTURE IN THE SOUTHEAST*

### INTRODUCTION

The southeast United States has been the location of considerable investment in aquaculture over the past 20 years. Some of the first aquaculture ventures occured in Florida in the 1960's where several companies tried to grow pompano for the restaurant trade. One of the first shrimp farms in the U.S. was constructed in the early 1970's in Panama City, Florida. Most, if not all of these early attempts ended in failure due either to insufficient technology, economic factors or poor management skills.

Several key state and Federal research facilities in the Southeast have worked continuously to improve the technology and control over the life histories of important commercial species and it is now possible to reproduce many kinds of marine shrimp and fish in captivity. With these technical developments investors are being attracted to aquaculture enterprises.

There are now companies that produce marine shrimp, marine fish, clams, and oysters in addition to the more established crops of crawfish, baitfish, and catfish. Great interest is seen in redfish culture, particularly in Texas, South Carolina, and Louisiana and hybrid striped bass demonstration farms exist in Florida and Virginia and another has been attempted in South Carolina. Some shrimp farms are profitable. Catfish, baitfish, and crawfish already have substantial industrial with several hundred thousand acres devoted to their culture and with revenues in the tens of millions.

This report will concentrated on shrimp culture in the southeastern United States. However, the climate of the Southeast is conducive to a wide range of aquaculture activities, subject to economic and technological constraints.

## CURRENT PRODUCTION OF SHRIMP

National Marine Fiisheries Service figures show that South Carolina produced 80mt (176,135 pounds) of cultured shrimp valued at $396,000 while Texas produced 276 mt (606,000 pounds) valued at $1.4 million in 1986.

The Texas production came from at least four commercial farms: Laguna Madre Shrimp Farms, Inc. in Los Fresnos, Texas; Wolf Point Shrimp Farm, Port Lavaca, Texas; Mariquest Inc., Port Lavaca, Texas; Mariquest Inc., Port Isabel, Texas; and the King Ranch operation near Corpus Christi. Several other farms in Texas are either in the process of getting permits or starting up operations.

South Carolina production came from the Edisto Shrimp Co. near Charleston; Palmetto Aquaculture Corporation based out of Columbia; Richardson Plantation near Green Pond; Sand Creek Shrimp Farm at Isle of Palms; and the state research facility demonstration ponds at the Waddell Mariculture Center. There are also several companies seeking permits for new operations.

Puerto Rico is now being recognized as an excellent location for marine shrimp farming and there are plans for at least one large shrimp farm and hatchery. A successful freshwater shrimp farm already exists in Puerto Rico and shrimp are now being exported to New York and other mainland markets.

Some shrimp farming occurs in Louisiana where farmers control the water flowing in and out of old rice impoundments. Harvest may be in the form of trawls or nets at the water outflow gates.

In addition to the above growout facilities, there are shrimp hatcheries at Laguna Madre Shrimp farm near Bayview, Texas; Texas A&M facilities at Galveston; Waddell Mariculture Center at Bluffton, South Carolina; Continental Fisheries, Ltd. in Panama City, Florida; Florida Keys Aquaculture on Summerland Key, Florida; and Plantation Sea Farms, near Edisto Island, South Carolina.

Three methods of pond production are practiced in the southeast United States. Extensive culture, where stocking rates are from 1-10 shrimp per square meter; semi-intensive culture where stocking rates are form 11-40 shrimp per square meter; and intensive culture where stocking rates range from 41-300 shrimp per square meter. Extensive culture primarily occurs in the old rice impoundments found in South Carolina and Louisiana. Semi-intensive culture is the most common method given the high cost of most coastal land in the U.S. and occurs in both Texas and South Carolina farms. The researchers at the Waddell

Mariculture Center in South Carolina are now experimenting with intensive culture techniques which require more aeration, better water exchange, and more complete diets.

**SPECIES.**

In all of the above culture operations, the shrimp species of choice are exotics from the Pacific Coast of Central and South America. Native American species have not performed well under pond growout conditions. The most popular species is P. vannamei, which performs better in ponds and appears to have some natural immunities to shrimp viral diseases. Penaeus stylirostris has been used by some farmers as it attains a large size and is easier to reproduce in captivity. However, P. stylirostris is sensitive to shrimp virus diseases and therefore is not always a dependable pond production species.

Three other species: P. japonicus, from Japan; P. mondon; from the Philippines; and P. orientalis are also considered good candidates for shrimp farming. P. mondon is one of the largest shrimp but requires warmer waters and slightly less salinity for good growth. The other two species show promise for being tolerant of colder water temperatures which is one of the limiting factors in the U.S.

**PLANNED PRODUCTION.**

Increased production will probably occur in two ways: intensification and better management of existing facilities and addition of new facilities. Intensification is already beginning as most farms are stocking at higher densities, adding more and better feeds and providing increased water exchange and aeration. Several weeks can be added to the growing season in some areas by the use of greenhouse nursery systems to headstart the juvenile shrimp before placing in larger grow out ponds. It may even be possible to produce two crops per year in the southern U.S. if headstarting techniques are utilized. However, it may be better economically to produce one crop of very large shrimp rather than two crops of medium sized shrimp. If some of the present shrimp farms are successful, the USDA estimates of doubling production every 2-4 years is entirely possible over the next two decades.

**STATE AND FEDERAL REGULATIONS.**

Aquaculturists are faced with a maze of state and Federal regulations which change from state to state. Typically, state permits are needed for the construction of the facility, diversion of running water, discharge of water, transporting fish or shellfish, importing eggs or other life stages, general aquaculture activities, and perhaps a commercial fishing license. Other permits may be needed for use of ground water or for use of public owned lands. Federal permits needed generally

include permission from the Corps of Engineers to put structures in navigable waters. U.S. Coast Guard permits regulate causeways and bridges while the Environmental Protection Agency issues permits for discharges. The Federal regulations are fairly uniform between states but state regulations can vary considerably. Most states are now reviewing their regulations that influence aquaculture and some have already changed existing laws to allow the new aquaculture industry to develop.

**STATE AND FEDERAL SUPPORT TO AQUACULTURE**

The National Sea Grant Program presently funds 18 projects in marine shrimp research valued at $671K. The major program receiving this support is at Texas A&M but other projects in the southeast are funded through Florida and Louisiana. Hawaii and California also receive funds for shrimp research. Sea Grant also has several aquaculture specialists in the Marine Advisory Service that deal with the public on aquaculture technology.

The USDA supports a major program in shrimp research through the Oceanic Institute in Hawaii and the Gulf Coast Research Lab in Mississippi. Funding for this project stood at $2,236,000 for FY 88.

Most southeast states have supported research on aquaculture in the past. South Carolina has made the greatest commitment by building and operating the Waddell Mariculture Center. Texas supports shrimp work at Corpus Christi and Port Arkansas, as well as at the various state colleges. Alabama maintains the Claude Peteet Mariculture Center and Louisiana supports research on shrimp at their Coastal Fisheries Institute.

Both South Carolina and Texas see marine shrimp farming as holding great promise in their states and continued support can be expected.

## SUMMARY

The Southeast U.S., including Puerto Rico, appears to hold some promise for shrimp farming operations. Several commercial operations exist and some, but not all, are turning a profit. The profitable farms practice extensive culture with low capital outlay or, more recently, have gone to more intensive culture using aeration and better feeds. Shrimp farms that have had high capital costs to begin with and therefore high debt service have not done well. As the various techniques are developed, and successful management techniques are found, there should be increased production of farm-raised marine shrimp. Shrimp farms that will be successful in the U.S. will develop systems adapted to North America growing conditions, i.e., semi-intensive to intensive operations.

## APPENDIX I

# *WORLD SALMON AQUACULTURE*

**SUMMARY**

World production of pen-farmed salmon doubled from 33,800 metric tons (mt) in 1984 to 71,800 mt in 1986. The Foreign Fisheries Analysis Branch estimates that the production of farmed salmon will exceed 200,000 mt by 1990. Future production, however, will depend on economic and environmental conditions, disease control, the availability of smolts and feed, and consumer demand.

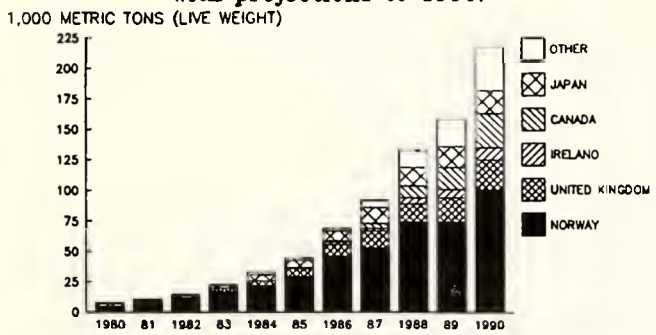
**I. OVERVIEW:**

During 1986, approximately 90 percent of the world's production of farmed salmon came from Norway, the United Kingdom (U.K.), and Japan. Ireland, Chile, and the Faroe Islands contributed about 6 percent of the world's production of farmed salmon. Norway's production of farmed Atlantic salmon (Salmo salar) has shown the most dramatic growth, increasing from 4,100 mt in 1980 to 45,600 mt in 1986, a ten-fold increase in just 6 years, accounting for about 75 percent of the world's production of farmed Atlantic salmon. The key to future world production of farmed salmon is Norway, which could produce as much as 100,000 mt of farmed Atlantic salmon by 1990. The United Kingdom replaced Japan as the second largest producer of farmed salmon in 1986. Production of pen-farmed salmon in Ireland, Iceland, the Faroe Islands, and Canada is expanding rapidly.

Farmed salmon production has doubled every 2 years between 1980 and 1986. If this trend continues, farmed salmon production will exceed 200,000 mt by 1990 (Table 1 and Figure 1).

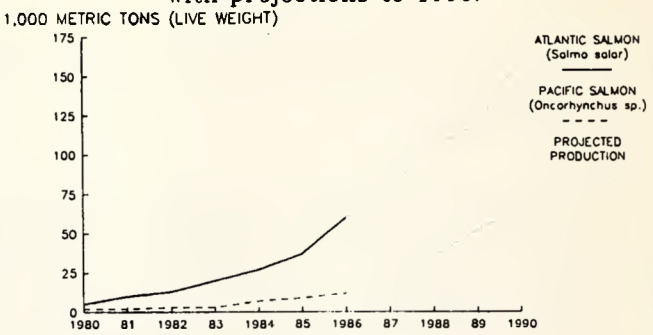
Production of farmed Atlantic salmon has shown dramatic growth since 1980 as compared with production of various Pacific salmon species; production of Atlantic salmon reached 60,100 mt in 1986 versus 11,700 mt for the Pacific species. By 1990, according to present trends, it is possible that world production of Atlantic salmon could exceed 160,000 mt while Pacific salmon production could exceed 65,000 tons (Table 2 and Figure 2). Salmon aquaculture in Pacific regions

**Figure 1.--WORLD. Farmed salmon production, by major producing countries, 1980–1986, with projections to 1990.**



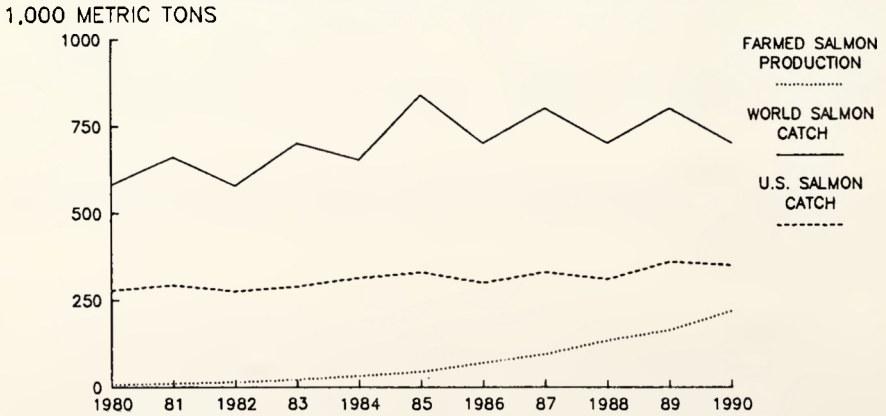

SOURCES: U.S. Embassy reports and various fishing industry publications.
Salmon#1

Figure 2. --WORLD. Farmed salmon production, by species, 1980 to 1986 with projections to 1990.




SOURCES: U.S. Embassy reports and various fishing industry publications.
File: Salmon#2.8

**Figure 3. -- WORLD. Farmed salmon production versus U.S. and world salmon catch, 1980–1985, with projections to 1990.**




SOURCE: FAO, Yearbook of Fishery Statistics, U.S. Embassy reports, and NMFS estimates.
File: Salmon#3

will include Atlantic salmon and several species of Pacific salmon. Currently, farms are using primarily coho salmon (Oncorhynchus kisutch) and chum salmon (O. keta), but other species are being studied for use in future culture projects.

During 1986, nearly 10 percent of the world's salmon supply came from salmon farms. By 1990, it is possible that 20 percent of all salmon could be farm-raised. Since 1980, the U.S. harvest of wild salmon has fluctuated between 275,000 mt and 330,000 tons. If present U.S. catch and world production trends are maintained, it is possible that world salmon production might exceed 50 percent of U.S. landings of wild salmon by 1990 (Table 3 and Figure 3).

**II. NORWAY:**

Norway is the world's most important producer of farmed-raised salmon, and is expected to remain in that position through 1990, when it could supply about half the world's farmed salmon. Norway's production of farmed Atlantic salmon increased from 170 mt in 1973 to 45,675 mt in 1986. In late 1986 and early 1987, approximately 300 out of 690 salmon farms were infected with a coldwater vibriosis (Vibrio salmonicida) commonly called "Hitra disease" (named for the Norwegian island where the disease first appeared in 1979). According to preliminary estimates, the disease resulted in the mortality or premature harvesting of 8,000 mt to 10,000 mt of salmon. As a result, it is likely that total production will be closer to 50,000 mt in 1987, than the 53,000 mt originally estimated. There are no official Norwegian estimates for 1990, but Ministry of Fisheries officials believe production will exceed 100,000 tons. Actual output will depend on several important factors, including availability of smolts, effective disease control, the ability to lower costs in the face of the declining value of the U.S. dollar, and Norway's ability to meet growing competition from salmon farmers in Scotland, Canada, Ireland, and Chile. Additionally, in order to significantly exceed 100,000 mt the Government of Norway will have to issue new licenses.

Norway's spectacular progress as a pioneer in the production of farmed Atlantic salmon is the result of an abundance of natural resources (protected fjords and ideal temperatures), a skilled labor pool, an excellent transportation system, government support, and close industry cooperation in all phases of salmon aquaculture. A decline in Norway's fisheries catch in the early 1970s, coupled with abundant revenues from offshore oil production, set the stage for the development of the salmon farming industry. To help farmers in depressed rural areas, the Government of Norway established a policy limiting salmon farms to 8,000 cubic meters of water, sufficient to produce 150 to 250 mt of salmon annually. This policy also led to the development of specialists in the manufacture of feed, the harvesting, packing, transportation, and marketing of salmon. The policy favoring small-scale producers has led large-scale producers to acquire small units or to look overseas for investment opportunities.

An important constraint to the growth of salmon farming in Norway during the early 1980s, was the inability of local firms to supply adequate numbers of salmon smolts. Initially, the answer was to import salmon smolts for stocking local farms. In 1985, the problem grew worse when diseased smolts imported from Scotland infected Norwegian fish farms. The situation pointed out the need for Norway to expand domestic smolt production. As a result, the Government of Norway imposed strict regulations on the importation of salmon smolts and encouraged the development of local smolt production by making it easier to obtain licenses for smolt production. Official regulations allow smolt producers to raise one million smolt per year. As a result, significant strides have been made in the past 2 years. In 1985 there were 322 firms licensed to rear 41 million smolts. By January 1987 there were 565 firms licensed to produce 153 million smolts. However, because of production problems and because many fish farmers are new to the business, output is not expected to exceed 30 to 40 percent of licensed capacity. Some Norwegian fish farmers have recently expressed concern that the rapid rate of smolt production might lead to an oversupply of salmon by 1988.

Most of Norway's farm-raised salmon is exported. Farmed salmon exports increased from 24,000 mt worth $152 million in 1985 to 39,000 mt worth nearly $230 million in 1986. During 1986, Norway exported 9,200 mt of farmed salmon worth $56 million to the United States, or about one-quarter of the country's total farmed salmon exports during that year. France, the Federal Republic of Germany (FRG), and Denmark were other important customers for Norwegian salmon (Table 4).

Fish farmers are eligible for loans and other benefits from various Government of Norway agencies. The largest source of aquaculture funds are district development banks which offer loans, loan guarantees, and investment grants. These banks are part of the Government's long-standing policy of supporting development in isolated regions where depopulation is a major concern. In 1984 (latest available data), $71 million was made available by the various district development banks. In addition, commercial loans were made by the State Industry Fund ($1.1 million), the State Fisheries Bank ($0.9 million), the State Industry Bank ($0.8 million), and the State Agriculture Bank and Development Fund ($0.09 million), as well as private banks and credit companies.

The Government of Norway also supports the fish farming community by providing scientific research, training, extension services, technical, veterinary, and breeding research conducted at a number of Norwegian universities or colleges. The rapid development of a vaccine to fight Hitra disease by the Foundation of Applied Research at the University of Tromsoe is an example of close cooperation between Norwegian universities and the fish farming community.

Future directions for Norwegian salmon farming include the possibility of increased salmon ranching — where smolts are released into the sea to feed and return to their native streams as mature adults to spawn. The high cost of feed in Norway is making salmon ranching more attractive, despite problems of uncertain returns. Norwegian researchers are also examining the possibility of using large oil tankers to transport live salmon to distant markets without the high costs of commercial air cargo. Researchers apparently have been able to overcome some of the problems involved in shipping salmon by ship, including the tendency of some fish to get "seasick" while being transported. Research is also being directed at the use of electrical currents or sounds to control the movement of farmed salmon, or keeping salmon inside "electric fences underwater" which will make much larger areas available for salmon production. Once the technical problems are resolved, there will, however, remain many social and legal issues to be settled. Norwegian scientists are also studying how to attract the fish to feed at the sound of noise. Greater efforts are being placed on increasing yields in closed systems through the application of new technology; most salmon farms are limited, by law, to 8,000 cubic meters of water. Because of improved technology, these same farms can now produce as much as 200 to 300 mt of fish per 8,000 cubic meters of water, an increase of 50 mt per farm. This high-density raising of fish, however, makes many farms vulnerable to fish diseases and many farms were quickly infected by Hitra disease in late 1986 and early 1987. Continued research into fish diseases and on the effect of fish farming on the environment will continue to be important areas of studies in the next few years. Finally, Norwegian fish farmers and companies have been investing overseas for quite some time where prohibitions on establishing large farms do not exist.

**III. UNITED KINGDOM:**

The United Kingdom (U.K.) ranks second, after Norway, as the world's most important source of farmed salmon. The U.K. salmon farming industry is centered in western Scotland and in the Shetland and Orkney Islands where clean water, isolation, and protected coastal inlets offer ideal conditions for salmon aquaculture.

Salmon farming in Scotland was begun by Unilever, the Dutch-English multinational corporation, which established a salmon farm in 1969. Following a period of slow growth, the salmon farming industry expanded rapidly; between 1983 and 1985, the number of companies farming salmon in Scotland doubled from 49 to 104 firms while the number of farms increased from 103 to 194; production increased from 2,500 mt to 6,900 mt during the same period. In 1986, Scotland's farmed salmon production increased to 10,338 tons.

It is likely that Scottish farmed salmon production will reach 25,000 mt by 1990, assuming an average growth of 4,000 mt per year between 1987 and 1990. Although the outlook for rapid growth of the Scottish salmon farming industry is excellent, some potential limits to growth have begun to surface. Many of the most choice sites have already been developed or reserved. Future expansion will probably have to occur from expansion of existing sites or development in more remote locations, such as in the Shetland Islands where 37 farms produced 1,500 mt of salmon in 1986 and where production of 8,000 mt is predicted for 1990.

Exports of Scottish salmon have nearly doubled in value during the past 3 years. Most of Scotland's fresh or chilled salmon exports stay within the European Community (EC), being shipped primarily to France, the Netherlands, and the FRG. Exports to the United States increased from $0.7 million in 1983 to $3.9 million in 1985 (Table 5).

Scotland's estimated smolt production is 15 million for 1987, and smolt production is expected to reach 22 million by 1988 (Table 6). Most smolts required by Scottish fish farmers are being raised domestically, but some smolts are still imported from Norway to help improve strains of Scottish salmon. Landcatch Ltd., 50 percent owned by Saga Seafoods, A/S of Norway, has imported salmon from Norway to improve their salmon ova, fry, and smolts. Landcatch's production capacity currently exceeds 10.0 million eggs and 1.4 million smolts.

BP Nutrition Ltd., which operates a worldwide network of companies involved in fish farming (including T. Skretting A/S of Norway, the Trouw group of Holland, and the Moore-Clark Company of Vancouver, BC, and Laconner, Washington, USA), is currently the largest manufacturer of animal feeds and premixes in the world. This followed the acquisition of Purina Mills Inc. in 1986. Total sales are expected to exceed 200,000 mt of feed in 1987. BP Nutrition recently opened a new specialty fish feed mill at Invergordon, Scotland. The mill's present capacity is 30,000 - 35,000 mt of feed (included pelleted salmon and trout feeds), but could easily expand this production to 100,000 mt a year.

Salmon farmers in the U.K. are able to benefit from various types of financial support. The U.K. Government, under the Fish Farming (Financial Assistance) Scheme of 1984, is allowed to grant farmers up to 5 percent of the costs of an aquaculture project. Grants may also be given to fish farmers in underdeveloped areas of Scotland under the Industrial Development Act of 1982, the Integrated Development Program for the Western Isles, and through the quasi-governmental Highlands and Islands Development Board (HIDB). The HIDB, an organization designed to encourage economic development in the region, offers grants of up to 30 percent of the cost of a project and will provide loans below commercial rates. Between 1975 and 1984, the HIDB awarded $17 million in grants and $7 million

in loans to support aquaculture in Scotland (including trout and shellfish projects). Salmon farmers have also received grants from the EC European Agricultural Guidance and Guarantee Fund (FEOGA), but the amounts are small (less than $130,000 in 1985). These EC grants cover between 25 and 50 percent of the capital costs of a project, and require the national government to provide between 5 and 25 percent of the total cost of the project.

**IV. JAPAN:**

Salmon propagation is not a new science to Japan. The country began experimenting with chum salmon culture in 1876, and the first national chum hatchery was built in Hokkaido in 1888. Japan's hatchery system expended rapidly, and by 1978 consisted of 230 hatcheries. In 1986, there were 270 private, 37 national, and 6 prefectural hatcheries operating in Japan.

Japan's salmon culture programs have operated under the Aquatic Resources Conservation Act (No. 313) since 1951. This act mandates that Japan's Ministry of Agriculture, Forestry, and Fisheries administer a national salmon hatchery program to ensure that Japan does not face the salmon shortages experienced during the period from 1920 to 1950, when salmon stocks were overfished. The act provides for subsidies to private hatcheries and requires that salmon fishermen contribute to the national hatchery program. The act has created a national salmon ranching program in Japan, with the fry and returning adult fish belonging to the Japanese Government. Japanese salmon hatcheries (both Government and private) released a total of over 2 billion fry (mostly chum salmon) in 1986.

Although Japan's salmon hatchery program is well established, commercial salmon farming is a relatively new phenomenon. The Nichiro Fisheries Company of Japan began to culture coho, chum, sockeye (Q. nerka), chinook (Q. tsha-wytscha), and pink salmon (Q. gorbuscha) in 1971 after its salmon factoryship became a victim of a vessel reduction program. Because coho salmon proved to be hardier than the other species, Nichiro began to concentrate only on coho farming in freshwater in 1973. After Nichiro discovered that coho salmon growth was slower in freshwater, the company turned to ocean cage culture in 1975. In 1978, Nichiro produced 450 mt of coho salmon with an 80 percent survival rate from smolt to adult. The Federation of Miyagi Fisheries Cooperatives and several large Japanese companies (including Taiyo and Nichimo) have also recently entered into coho salmon farming. Japan's salmon companies contracted out salmon production to about 350 farms in 1986 and plan to have nearly 400 farms in operation by 1987. Japan's coho production is expected to reach 19,000 mt by 1990.

In addition to coho salmon farming, the Nichiro company is also commercially farming small quantities of chinook salmon. The company began farming chinook in 1983, and harvested 21 mt of chinook salmon in 1986. Nichiro is also experimenting with raising sockeye salmon, but no data is available on the status of these experiments.

Feed production does not appear to be a problem for Japan. Japanese-produced feed for coho salmon consists of moist pellets made from 90 percent fish (sardine, mackerel, and filefish) and 10 percent formula feed (white meal, wheat and bread crumbs, soybean protein, and krill-like mysis).

Although the future of Japan's cultured salmon industry looks promising, there is a major constraint: egg supply. Japan must import all of the salmon eggs used in farming; mostly from the United States. Approximately 20 Japanese firms import and distribute eyed salmon eggs to smolt farms. In 1986, Japan imported 28 million eyed eggs (versus 19 million eggs in 1985, 12 million in 1984, 14 million in 1983, and 8 million in 1982). The only Government stipulation on the import of salmon eggs is that they be certified disease-free by the exporting country. The Japan Fishery Resources Conservation Association also inspects the salmon eggs to prevent possible carriers of a bacterial kidney disease from entering Japan.

The number of smolt farms in Japan is estimated at 200 to 300. Each is operated by a freshwater fish rearing cooperative which may also produce other salmonids, such as cherry salmon (O. masou), "amago" (O. rhodorus), char (Salvelinus pluvius), brook trout (S. fontinalis), and rainbow trout (S. gairdneri) at each facility. Production of coho smolt to the 100 to 300 gram sizes ranges from 2 mt to as much as 100 tons. There are no estimates available on the total number of individual smolts produced by all smolt production facilities in Japan.

Fresh farmed coho salmon is a new commodity for Japanese consumers, and it is well accepted by those already accustomed to salmon products. The pen-reared coho must be taken from coastal pens before high summer temperatures begin inflicting mortalities on the crop. Summer also brings competition from other fish products, such as skipjack tuna. Coho salmon not marketed by early summer are often salted for sale in the fall.

There are no programs or regulations designed to promote salmon imports or exports. Japan's overall demand for salmon products (in the 350,000 to 400,000 mt range in 1985) greatly exceeds local supplies of salmon (210,000 mt in 1985) of which Japanese hatchery production was 168,810 mt farmed coho production

was 6,990 mt and the highseas catch of wild salmon was 34,318 tons. Farmed salmon may eventually reduce Japan's need to import salmon, the majority from the United States. Currently, domestic salmon farming accounts for only about 2 percent of Japan's total salmon supply.

## V. CANADA:

### A. GENERAL:

Canada has a long history of managing commercial and recreational salmon fisheries. Only recently, however, have Canadians become involved in salmon farming. Production has increased from 163 mt in 1980 to an estimated 1,000 mt in 1986. The potential for rapid growth in the next few years appears excellent: Canadian government officials anticipate a sharp increase in production, which may reach 27,000 mt by 1990. Industry sources expect production could exceed 30,000 mt by 1990, based on "fish in the water". If this is achieved, Canada will become the third largest producer of farmed salmon in the world.

### B. ATLANTIC CANADA:

Atlantic Canada's first attempts at salmon farming began in the early 1980s. The first significant development occurred in 1984, when Stolt-Nielson Sea Farm A/S of Bergen, Norway, established a C$2.0 million salmon smolt hatchery at Lake Digdeguash near St. George, New Brunswick. The new company, Sea Farm (New Brunswick), initially expected to produce 500,000 smolts annually by 1986, representing potential production of 1,300 mt of adult Atlantic salmon worth C$8.0 million. Sea Farm (New Brunswick) later increased its smolt production capacity to 1 million smolts, constructed a smolt hatchery at Springdale with a capacity for 250,000 smolts, and is in the process of building a third smolt rearing facility at Oromocto Lake. In 1985, about 200 mt of Atlantic salmon, worth over C$2.2 million, had been raised in sea cages located in the Bay of Fundy. During that year, 13 additional entrepreneurs began operations. Each farmer received a Canadian Government grant of 30 percent of the project cost (limited to C$30,000 for first-time projects and C$70,000 for established operations). In 1985, Canadian Minister of Fisheries and Oceans, Tom Siddon, announced that the Canadian Government and the Government of New Brunswick were jointly investing C$1.3 million in a Salmonid Demonstration and Development Farm at Lime Kiln Bay, near Black's Harbor, New Brunswick, bringing the total investment to C$2.7 million. The facility was expected to provide commercial fish farmers with scientific and technological information about cage culturing salmon. In 1986, Connors Brothers Ltd. (a major sardine cannery) announced that it was establishing a sea-cage facility at Fair Haven on Deer Island at the site of one of their old

herring plants. The old facility was modified to raise salmon eggs for release into sea-cages. Connors Bros. Ltd. and Corey Feeds Ltd. worked together to produce C$2.9 million worth of salmon feed in 1986 at Beaver Harbor. There were reportedly 32 cage sites operated by 26 firms located in New Brunswick during 1986. It is expected that there will be 425 salmon cages in Atlantic Canada in 1987, producing an estimated C$8.0 million worth of farmed salmon. A moratorium on the establishment of new salmon farms on Canada's Atlantic coast was imposed during 1986, limiting the short-term growth of the industry.

**C. PACIFIC CANADA:**

Pacific Canada's salmon farming region is located in the province of British Columbia (B.C.), where the first salmon farm was established in 1972, using surplus eggs obtained from a Canadian Government salmon hatchery. The site operated until 1975, when 4 new farms were established using salmon eggs also obtained from the Government of Canada. Between 1975 and 1984, the industry remained undeveloped, attracting limited interest and producing only small quantities of salmon. During 1984, when there were only 10 salmon farms, Norwegian companies began to seriously invest in the Pacific salmon culture industry. Following Norwegian involvement, the number of salmon farms grew to 36 by 1985, and to approximately 69 salmon farms in 1986 (including 10 with Norwegian investment). B.C. authorities anticipate 125 sites by 1987 and 225 sites by 1988. Most of the sites are located along the Sechelt Peninsula and Vancouver Island, and employ a small staff of 3 or 4 people. These farms are expected to produce 200 to 300 mt of salmon per year. Production has increased from 120 mt in 1985 to 600 mt in 1986 (Table 7).

The British Columbia Provincial Government has identified aquaculture as an area for special emphasis. Incentives to establish fish farms have included concessional loans from the Provincial Economic Development Agency of up to C$150,000 as "seed" money, new venture tax relief equivalent to tax incentives offered traditional farmers, and access to the Province's Venture Capital Program which offers a 30 percent tax credit which can be transferred to other corporate activities.

Pacific Canada fish farmers have used some of these funds to raise coho salmon and chinook salmon. Earlier experiments that introduced Atlantic salmon to Pacific waters were generally unsuccessful, although three farms are still reportedly experimenting with Atlantic salmon (most are being raised at Crystal Water Sea Farms under strict quarantine conditions). Initially, production was based on coho salmon raised to "pan size" (250-300 grams), but in 1982, the production of chinook salmon was introduced, as restaurants and supermarkets in Canada and the United States began to ask for larger sized salmon; coho salmon are reportedly easier to raise, but chinook salmon earn higher returns.

B.C.'s salmon farming boom can be traced to the inability of Norwegian investors to develop similar farms in the State of Washington. To the province's benefit, the Norwegians reportedly invested C$9 million in 10 out of the 11 Canadian fish farms which have been established by foreign investors (the other farm was established by U.S. investors).

The B.C. fish farming industry relies on eggs made available from the Canadian Department of Fisheries and Oceans (DFO). Salmon eggs produced in excess of the DFO Salmonid Enhancement Program needs are turned over to hatcheries. In 1986, 30 million eggs were supplied to B.C. fish farmers (Table 8); 27 million eggs were of DFO origin and 3 million came from private producers using wild salmon stocks.

There is also a rapid growth in local smolt production; there was only one firm able to supply smolts between 1980 and 1983. Between 1984 and 1985, there were two smolt facilities which produced 2.5 million smolts. In 1986, the number of smolt farms increased by three, and smolt production increased to 8.5 million smolts. Most smolts are obtained locally. Atlantic salmon smolts must be imported; imported salmon smolts are subject to "extraordinary" screening to prevent health problems

Prior to the late 1970s, fish feed was imported from Washington state. Since 1978, however, B.C. feed producers have been supplying their own salmon farmers with feed. By 1984, B.C. manufacturers produced 410 mt (90 percent was from M&H Feeds Inc. of Surrey, B.C.) while the United States supplied 1,000 mt of fish feed. By June, 1986, there were six fish feed producers serving the B.C. salmon aquaculture industry.

The marketing strategy adopted by B.C. salmon farmers focuses on uniform size, quality, and the availability of cultured salmon when wild salmon are not available. Once consumers become "hooked" on these fish, the B.C. Salmon Farmers Association hopes that they will keep buying Canadian salmon the year round. The main advantage enjoyed by Canadian salmon exporters (on both coasts) is their proximity to the United States market. Fresh Canadian salmon can reach U.S. consumers in less than 36 hours by truck. This advantage makes Canadian salmon farmers increasingly competitive with other salmon producing nations. It is this advantage that is fueling the drive to produce 30,000 tons of salmon by 1990. B.C. exports, however, have been modest: 78 mt in 1984 and 39 mt in 1985.

Problems facing the B.C. salmon farming industry include the "gold rush" mentality of some investors, the hesitancy of Canadian bankers to provide loans to salmon farmers, and the lack of detailed knowledge on salmon-rearing tech-

niques, feeds, and diseases as they relate to Pacific salmon species; many salmon farmers in B.C. are experimenting with different growing techniques which may or may not prove profitable for several years.

**VI. CHILE:**

Chile has been trying for years to develop local fisheries for salmonid species. The first project began in 1905 when trout and salmon were first introduced into Chile. Salmonid species are not indigenous to the southern hemisphere and there are no native salmonid fisheries south of the Equator, even though climatic and environmental conditions suggest that the southern oceans could support wild salmon stocks. The remarkable genetic adaptability of salmonids is making it possible to introduce various species to the southern oceans. Chile's initial experiments with salmon were unsuccessful, but trout was introduced successfully. More recently, Chilean groups working with Japanese and United States experts have reported returns of wild salmon released in Chilean rivers. Researchers now believe that much of the work on salmon ranching was unsuccessful because the fingerlings and eggs were released too far north.

Investors are reporting increasing success with cage culture projects using various salmon species, especially coho salmon. Several companies are experimenting with other species, including Atlantic salmon. Chile's salmon culture industry is based on privately-owned farms located in the south near Puerto Montt, Chiloe Islands, Puerto Aysen, and Magallanes. Nearly 50 private companies have invested over $30 million in the industry. Several private companies are involved, but the most important are Nichiro Chile, Pesqueras Mares Australes, and Salmones Antartica (SA). Salmones Antartica is the largest single company and accounts for about 25 percent of Chile's salmon harvest. There is one Norwegian project to raise Atlantic salmon in Chile. The Fundacion Chile, a private development foundation, has played a key role in promoting the industry and has helped establish Salmones Antartica. The Instituto de Fomento Pesquero, a state-owned fisheries development corporation, has provided some assistance to farmers as have various local governments. The salmon aquaculture industry, however, has primarily been developed with private capital. According to statistics supplied by the Undersecretariat for Fisheries, Chile's farmed salmon production has gone from zero to 1,144 mt in 1986 and is projected to reach 17,000 mt by 1990. 1/

Chile reportedly imported 14.6 million salmon eggs and locally produced 4.5 million eggs in 1986. There are reportedly 22 firms raising smolts at 91 sites, but data on this production is not available. Chilean smolt production capacity is estimated at 25 million. The Undersecretariat of Fisheries in Chile is planning to enact a series of administrative procedures to regulate the salmon farming industry, including regulations designed to prevent disease transmission between aquacultural facilities and to prevent the importation or export of diseased eggs,

smolts, and salmon. The Government of Chile does not have any special policy, fiscal incentives, grants, or subsidies to develop salmon aquaculture. The rapid growth of Chile's salmon farming industry is partially due to a favorable investment climate in Chile along with favorable natural conditions.

The U.S. Embassy in Santiago estimates that about 80 percent of Chile's salmon production is exported, mostly fresh to the United States. Shipments during the 1986-87 season totaled about 1,000 mt valued at $4 to $5 million. Growers believe they might be able to increase shipments to over $430 million by 1990. Chile has an advantage over other salmon growers, in that the peak harvest period is during December to March when fresh wild salmon is not available in the United States. Theoretically, salmon farmers in other countries could also harvest during the same months, but farmers in the northern hemisphere report low yields during those months. Chilean farmers also believe that they can culture salmon at lower costs than in other countries. Chile has many advantages: inexpensive sites, low labor costs, and the availability of inexpensive feed. In addition, Chile's southern coastline stretches for about 2,500 kilometers south of Puerto Montt, offering a vast number of potential sites that the industry has just begun to utilize.

## VII. IRELAND

The growth in the Irish salmon farming industry may have been prompted by the country's declining catch of wild salmon, from 2,216 mt in 1975 to only 685 mt in 1981. Despite the decreased quantity, the value of the Irish salmon catch doubled between 1975 and 1985, stimulating interest in salmon farming.

In 1980, Ireland's production of farmed salmon amounted to a mere 18 tons. The following year, three salmon farms produced 35 mt of salmon. In 1985, Ireland had 10 salmon farms with a total output of 700 tons. By 1986, there were 12 major fish farms in Ireland producing 1,500 mt of farmed salmon (Irish industry sources report 1,675 mt in 1986). Most of these facilities use conventional cage culture, with two or three sites per farm. Annual production is forecast to increase from 1,500 mt in 1986 to 10,000 mt by 1990.

The Irish Government's involvement and support for salmon culture is fourfold: (1) support of research advisory services, (2) provision of veterinary services, (3) the issuing of fish farming licenses, and (4) the provision of grants for new projects. Part of the Irish salmon culture industry's rapid growth can be attributed to assistance programs administered by the Irish Sea Fisheries Board (BIM) and Udaras na Gaeltachta, the statutory agency charged with the economic, cultural, and linguistic development of the Gaelic speaking areas of Ireland. Both agencies offer capital subsidies ranging from 10 percent to 50 percent, with Udaras offering grants up to 60 percent towards the cost of fixed assets for small scale projects. Both agencies also provide the required national funds necessary to enable salmon

farming projects to qualify for EC European Agricultural Guidance and Guarantee Fund aid. Udaras reportedly has spent $5 million on aquaculture programs. In addition, the National Development Corporation (formerly the National Enterprise Agency), the Irish Aquaculture Association (IAA) and its Salmon Producers' Group have invested in the industry. Investments have also been made by private groups, such as the Food Venture Fund which includes Irish and Norwegian investment in specific fish farms. During 1986, about $9 million was invested in the Irish salmon culture industry.

There were 10 smolt farms operating in Ireland in 1986-87. These farms were operated by the Electricity Supply Board (ESB), a semi-state body (which owns 4 smolt farms and produced 220,000 smolts in 1985) and 6 other firms. Smolt production in Ireland is expected to increase very rapidly in 1987-88, as some trout farmers are now converting their existing trout production capacity to smolt production. A number of salmon farms are also building smolt units alongside their growout facilities and two Norwegian firms, Scanfarm and Osco, have proposed anchoring converted oil tankers for smolt production near Cork and Galway. A projected output of 3,000 mt per year has been cited, but the plan is being opposed by the Irish Aquatic Association and the Irish Fishermen's Organization. Ireland imports some smolts from Iceland, Norway, and Scotland. However, it is expected that Ireland will quickly become self-sufficient in smolt production and imports will not be required in the future.

There are two diseases which currently afflict Irish fish farms; furunculosis and Infectious Pancreatic Necrosis, a viral disease of salmonids. Also, Ireland will not accept fish from any country where Infectious Hematopoietic Necrosis is present. There is a ban on the import of eggs and live fish into Ireland, except under license granted by the State Fish Pathologists Office. Fish culture licenses are issued on condition that the farmer must notify the Fish Pathologists office of any suspected infection within 48 hours. There can be no movement of fish from one farm to another in Ireland without certification from the same office.

Feed is mostly imported from BP Nutrition, EWOS Baker, and Skretting. There is a majority Norwegian shareholding in each of these companies. Several Irish companies are establishing feed manufacturing operations and it is possible that Ireland could become self-sufficient in a few years. The ability of Irish fishermen to obtain EC quotas, however, for high-quality capelin for reduction into meal remains to be seen.

Irish farmed salmon is marketed through a variety of channels. Traditionally, Irish salmon has been sold primarily according to the standards and requirements of individual producers. For example, the ESB has always marketed its farmed salmon under the ESB label both domestically and internationally. Other Irish producers sell through associated processing and marketing organizations such

as the Irish Salmon Producers Group (ISPG), which is supported by the National Development Corporation and assistance from the BIM. Also, there are firms, such as Fanad Fisheries, who have chosen to market their salmon through Norwegian companies (in this case, A/S Mowi). A significant amount of Irish farmed salmon is used by domestic smokers to produce a high-quality product. Most of the salmon not used by smokers is exported, primarily to EC countries. Ireland exported a record 700 mt of salmon (both wild and farmed) during 1983 (Table 9).

**VIII. FAROE ISLANDS:**

Salmon culture on the Faroe Islands, a self-governing province of the Kingdom of Denmark, has grown considerably since it first began in 1980. Total production of pen-raised Atlantic salmon was 60 mt in 1982 and 1,370 mt in 1986. Marine farm production of Atlantic salmon is expected to approach 4,000 mt by 1987 and is projected to reach 9,000 mt by 1990 (Appendix-I-L). According to some reports, if hatcheries could supply more smolts, Faroese fish farms could surpass production estimates. There were 53 salmonid (both salmon and trout) farms in operation on the Faroe Islands at the end of 1986. These farms produced from 30 to 300 mt of fish per year. The average production of recently approved farms has been about 100 mt annually, a level expected to be maintained in the future.

The Faroese Home-Rule Government supports the salmon farming industry by providing technical assistance and investment loans to fish farmers. These preferential loans, provided by the Faroese Industrial Development Fund, are usually given for 10 years with a 2-year grace period and may cover up to 10 percent of the investment. The Government, concerned about the effects of marine fish farming on the environment, strictly regulates salmon cage farming.

In the early 1980s all smolts used for fish farming in the Faroe Islands were delivered from the public-owned P/F Fiskalling's three freshwater smolt farms. Two private farms were added in 1983 and by 1986 there were six smolt farms in operation in the Faroe Islands (Table 10). Some estimate that Faroese smolt production must increase by 1 million smolts annually if its farmed salmon production goal is to be met. Plans are underway to expand smolt production facilities to match the number of new licenses granted each year. All Faroese smolt demand is now being satisfied by domestic smolt production, as imports of smolts are prohibited.

Occasional outbreaks of whirling disease occurred on the Faroe Islands in the early years of marine farming. In 1970, the Faroe Islands imposed a ban on imports of live salmon, salmon eggs, and salmon fry to avoid diseases (legislation was later expanded to include all live fish, shellfish, and used farm equipment). Since then, no virus or infectious bacterial diseases have appeared in the Faroese fish farming sector. The Faroese Home-Rule Government has employed a veterinarian specifi-

cally for control of the fish farming industry. More inspectors are being considered as part of the rapid growth in Faroese salmon farming efforts.

Faroe Islands salmon farmers import some feed from Denmark and Norway, but these imports will be gradually phased out by 1988, with the exception of certain feed additives which cannot be produced locally. The major domestic supplier of feed is the fishmeal factory, Havsbrun, in Fuglefjor, which was significantly expanded in 1986. In view of the historically large Faroese industrial catch, future constraints on feed supplies appear unlikely. In addition, fish reduction facilities are being installed on many Faroese fishing vessels, which ensures not only fresher raw material, but also better utilization of the catch.

Shortly after the first private farm was established in 1981 (to raise steelhead trout), the Home-Rule government established a 4-member fish farm committee to plan the development of this new sector. The committee was replaced in 1985, by a Fish Farm Board with eight members and the following objectives:

- o Reserve as many suitable areas as possible for fish farming.
- o Expand smolt production to keep pace with the granting of new fish farm licenses.
- o Limit marine farming in certain areas vulnerable to environmental effects of fish farming.
- o Produce a general plan for the use of the limited freshwater resources.

The Fish Farm Board is also responsible for reviewing all applications for new licenses and applications for expansion of existing facilities. The Board is drafting new legislation for the fish farm sector, including the establishment of an advisory service and provisions for vocational training.

Faroe salmon exports (wild and farmed) in 1985 were 1,100 mt of which 97 mt were fresh or chilled farmed salmon, 902 mt of frozen salmon (mostly wild) and 100 mt of smoked salmon. In 1985, the Faroese catch of wild salmon was about 650 mt all of which was exported as either smoked or frozen product. In 1986, Faroese salmon exports increased to 2,000 mt of which 577 mt were fresh or chilled farmed salmon, 1,316 mt of frozen salmon (mostly wild), and 100 mt of smoked salmon (Table 11). The sharp increase in shipments of fresh or chilled farmed salmon was the result of the introduction of a fast catamaran service between the Faroe Islands

and Denmark, which reduced transport time to about 20 hours. In 1986, the Faroese catch of wild salmon amounted to about 600 mt all exported in frozen or smoked form. A significant portion of Faroese salmon exports to Denmark is reexported, primarily to other European countries.

Denmark serves as an important distribution center for Faroese salmon; much of Faroese salmon is either shipped out to other countries as fresh product or is smoked in Denmark and re-exported. Faroese salmon is slowly developing markets in a number of countries. The United States imported only $68,000 worth of Faroese salmon during 1986.

**IX. ICELAND:**

Icelandic aquaculture is a fairly recent phenomenon, owing to the success of its traditional fisheries. Until very recently, highseas fishing has more than provided Icelandic fishermen and processors with high quality raw material. However, the limited growth potential of traditional fish stocks has spurred interest in developing new fisheries. A ban on commercial salmon fishing in Icelandic waters since 1933 has provided an impetus for developing domestic sources of salmon. After years of leaving salmon culture to small individually-managed pilot operations, large companies (primarily Norwegian), are investing in large-scale facilities.

Iceland's Atlantic salmon production comes primarily from ocean ranching, or the release of salmon smolts into natural rivers and streams. Salmon ranching began at the state salmon hatchery near Kjollafjordur in 1961. Icelandic ocean cage or pen farming has not been as successful as it has been in Norway because Iceland lacks sufficiently protected fjords and water temperatures are too cold during the winter. Icelandic scientists are nonetheless continuing efforts to develop the pen farming of Atlantic salmon. Icelandic salmon ranching is expanding and may contribute significantly to future fishery exports. During 1986, the number of Icelandic farms culturing salmon grew from 18 to 50. Of these, 15 are land-based farms and 35 are sea-pens. Iceland's farmed salmon production has increased from 20 mt in 1981 to 123 mt in 1986.

The world's largest dry-land salmon farm recently opened in southwest Iceland, at Grindavik. The farm, Strandeldisstod Islandslax Ltd., is a joint venture between Samband (51 percent), and a Norwegian company, Norlax (Noraqua and Teleinvest, 49 percent). The firm was built with the help of the Nordic Investment Bank. The company started in 1984, when tanks for raising smolts were built. The eggs were first imported from Norway, but Islandslax is now self-sufficient in eggs. The firm expects to produce 300 mt of salmon for export to the United States and the United Kingdom in 1987. Production is expected to reach 700 mt annually by 1990. Also under construction by Islandslax Ltd., with help from the Nordic Investment Bank, is a farm designed to produce some 500 mt annually, eventually

reaching 5,000 mt per year. Islandslax also plans to export "super smolt" which weigh about 150 grams (as opposed to 50 gram smolts). The "super smolt" grow very rapidly in Iceland because of the abundance of naturally heated water from thermal springs. The smolts are shipped to Ireland where they are raised in sea pens, which results in a faster growing cycle. In 1986, of the one million smolts hatched by Islandslax, 0.2 million were used by the company and the remainder was exported. The firm has agreed to let the Marine Research Institute establish a research station at the farm to observe experimental programs, including the breeding of halibut.

Currently, salmon smolt production is the most valuable aspect of Icelandic salmon aquaculture, followed by ocean ranching, and farming salmon. During 1985, some 16 rearing units produced 821,700 smolts, an increase of 4 percent over 1984. There are reportedly 36 units in Iceland, with a total production capacity of 5.3 million smolts. Icelandic smolt producers have begun exporting sizeable quantities of smolts to Ireland and Norway, where prices for smolts have risen by 80 to 100 percent. During 1986, more than 1 million Icelandic smolts worth $2 million were exported to Norway and Ireland. Norwegian farmers imported 700,000 million salmon smolts and Irish fish breeders purchased 80,000 salmon smolts from Iceland in 1985. Because of the high prices offered elsewhere, Iceland has experienced a shortage of smolts for its own salmon culture industry.

As in other countries' salmon farming industries, the Norwegians have played an important role in Icelandic salmon farming. The Icelandic-Norwegian joint venture company (ISNO), at Oxarfjordur produced about 35 mt of farmed salmon in 1984 and 85 mt in 1985. The Fisheries Association of Iceland has operated an experimental station at the ISNO site since 1977. The site is located in a lagoon in floating pens. The facility is protected from severe weather and sea conditions by a sand bar with two openings to the sea. Heated freshwater from nearby springs located along the shore help maintain a constant temperature. Salmon grown in these pens reach 1.5 to 5 kilograms each in two years. The firm's partner is Mowi of Norway (45 percent ownership). The ISNO also releases small numbers of smolts into the sea as part of a salmon ranching operation.

A U.S. salmon farming company, in a joint venture with an Icelandic investment company, plans to eventually produce 2,100 mt of pen-farmed salmon annually in Iceland. The Icelandic Freezing Plants Corporation (IFPC), Iceland's largest exporter of fish and fishery products, is presently studying several farming and ranching projects, primarily involving salmon.

The Pathology Division of the Directorate of Veterinary Services (DVS), an agency supervised by the Ministry of Agriculture, has primary responsibility for disease control among fish farms. The U.S. Embassy in Reykjavik was told that Icelandic Government veterinarians routinely take samples from smolt farms and that if any

trace of disease is found, the farm is denied the right to export. Further, measures are taken to assure that diseased fish do not contaminate others around them. The movement of smolts from farm to farm is also controlled. Additionally, buyers of smolts invariably demand that the veterinary services approve the smolts they intend to buy. As a general policy, the DVS carries out random checks of farms for the purpose of disease control.

The agencies involved in salmon aquaculture are the Health Protection Agency (a consultative body under the Ministry of Health with the authority to issue operating licences), the Nature Conservation Council (an advisory body with the right to veto projects considered detrimental to the environment), the Directorate of Freshwater Fisheries (a government agency whose objective is to promote the growth of the salmon industry), and the State Veterinarian (operating under the Ministry of Agriculture).

The Icelandic Government operates some 40 salmon hatcheries and research stations, but does not provide financial incentives to salmon farmers. The Government of Iceland does not provide direct grants to the salmon farming industry. Loans are made by semipublic institutions, the Regional Development Fund, while the Fisheries Investment Fund guarantees loans. Total credit granted to the industry from 1981 to 1987, has been about $31 million. Credit and loans are also available from commercial banks, but commercial loans are limited to 30 percent of the insured value of the firm. The only other "incentive" given the salmon farming industry is the ability to purchase imported investment goods free of sales tax.

The major task facing the Icelandic salmon industry is to develop internationally recognizable salmon quality groupings and to apply standardized criteria to each. The large salmon farms, such as ISNO and ISLANDSLAX, which are seriously attempting to develop markets in Europe and the United States, apply strict quality controls.

Icelandic salmon farmers rely on the following companies for feed: Fodurblandan, Istess (both having some foreign participation), Mjolkurfelag Reykjavikur and Lysi-Sildar-OG Fiskimjolsverksmidjan. The first three firms produce dry feed while the last firm produces a wet feed. Special feed used for smolts and some small salmon is imported from Norway and Sweden, but there are plans to produce this type of specialty feed in Iceland in the near future. Iceland should be able to produce high quality feed from capelin, but capelin catches have fluctuated sharply in recent years.

## X. NEW ZEALAND:

New Zealand has no indigenous salmonid species. The Auckland Society introduced sockeye salmon to New Zealand's South Island in 1900 to establish a recreational fishery. The New Zealand Government later introduced chinook salmon, or quinnat, as it is called in New Zealand, in order to begin a commercial fishery. Chinook salmon is now found in major east coast rivers and lakes of the South Island and sockeye is restricted to the Waitaki River basin. Atlantic salmon is also present in New Zealand in several lakes and is being used in experimental sea-cage culture. Commercial production however, remained a dream until 1972, when limited ocean ranching was allowed (in order to enhance ailing wild salmon runs). By 1976, New Zealand had two large ocean ranching operations underway. One of these, Bubbling Springs Salmon Farm, became the country's first salmon farming operation in 1978. In 1983, the New Zealand Salmon Company became the first salmon farming concern to be listed on the New Zealand stock exchange. New Zealand salmon farmers produced 700 mt in 1985 and expect to produce about 3,500 mt by 1990.

In 1986, New Zealand had a total of 15 ocean-ranching farms, 19 pond-rearing, and 12 sea-cage farms. Most of these are located along the coast of Stuart Island. In 1985 there were also 11 smolt farms in operation. To date, the supply of salmon stock to New Zealand farmers comes essentially from wild populations, although returns from Government hatchery stock have become increasingly important in meeting this need. In 1984, the entire salmon stock requirement of farmers, beyond that met by brood stock production, came from Government hatchery returns. This trend is likely to continue in the future. Originally the New Zealand Government decided to supply two full cycles of chinook salmon to farmers, thereby ensuring a supply of smolts and eggs for up to 6 years and an induced return to the release facility. By 1980, there were six ocean ranching operations, requiring about 3 million eggs annually. New Zealand's wild stocks have been unable to sustain that level of egg removal so there have been some egg shortages. To counter this problem, farmers have been experimenting with maturing their own chinook brood stock to maturity in fresh water only, with mixed results. Farmers are not allowed to rear and sell wild stock given to them directly by the Government, hence the need to maintain their own broodstocks or obtain the surplus stock from other farmers.

The New Zealand Salmon Company's ranching operations are some of the most modern in the world. Its hatchery is capable of producing 8-10 million eggs per year. The company has also established a reliable adult salmon run at the hatchery. New Zealand Salmon's Christchurch feed plant provides feed for all phases of the culture operation. The heart of the company is on Stewart Island where approximately 120 ocean-pens are being used to raise salmon to market size

and harvest after 1 to 2 years in salt water. The Stewart Island operation has a production capacity of 350 mt and reached 200 mt in 1986. New Zealand Salmon has a ranching operation at Tentburn. The Tentburn operation apparently did not have satisfactory returns in 1986 and blames a "major ocean effect which is not yet understood" for the problem.

New Zealand farmers enjoy several distinct advantages over northern salmon producers. The country has an excellent supply of unpolluted fresh water (although a pending seapen anti-fouling issue might prove a roadblock to the ocean cage-farming sector of the salmon industry). New Zealand's salmon stocks are relatively disease-free (although the country did experience an outbreak of whirling disease several years ago). New Zealand also enjoys a market advantage in the Northern Hemisphere because harvests coincide with the off-season; New Zealand fresh salmon goes on sale when wild salmon is not available. Currently, Chile is the only other country that can offer direct competition on this point. New Zealand king salmon commands a premium price on foreign markets because of its quality and scarcity. In addition to the geographical advantages, New Zealand farmers have a cheap and plentiful supply of smolts available. Disease problems are minor, and technology is excellent.

One distinct disadvantage New Zealand may face in the long run is its location. Except for Australia (Tasmania), New Zealand is the salmon producing country located the greatest distance from major importing countries. As salmon culture develops in New Zealand's principle salmon markets, the United States and other importing countries, and products from these countries become competitive in their own markets, the cost of shipping fresh salmon may eventually price New Zealand out of the foreign marketplace. New Zealand has been exporting salmon to nearby Australia, but that country has only a small market for salmon.

The Fisheries Research Division of the New Zealand Ministry of Agriculture and Fisheries operates the Glenariffe Salmon Research Station on a tributary of the Rakaia River in Canterbury. The Station which carries out research on chinook salmon, began as a fish trap on the Glenariffe stream in 1985. Glenariffe has been a major supplier of eggs since ocean ranching began in New Zealand in the mid-1970s. Ocean ranches have a large demand for salmon eggs, because a large number of fish have to be released to obtain return. Only a small percentage survive to return to the release point (fish are captured and killed before their eggs ripen). The station has also been used to study the biology, life history, age structure, and juvenile survival and production of chinook salmon. In addition, studies on salmon nutrition and sex control are currently underway at Glenariffe.

Although cage farming has the advantage of year-round salmon production, salmon ranching has supplied New Zealand with the major source of product for world markets. Most ranchers also maintain cage culture operations. The future for ocean ranching appears promising if an adequate management program can be devised to prevent the "incidental" catch of ocean salmon by trawlers.

**XI. SWEDEN:**

Swedish aquaculture began approximately 200 years ago when farmers began raising trout, carp, and tench in small ponds. Most of this production remained small and isolated in underdeveloped rural areas. Aquaculture in Sweden began to expand in the late 1970s, focusing on the production of rainbow trout, salmon smolts (for release into the Baltic Sea), eels, sea trout, and blue mussels. Production of farm-raised salmon remains small. In 1982, Swedish salmon farmers reported producing 10 mt of farm-raised salmon (live weight). Production remained low in 1983 (15 t) and 1984 (20 t), but increased to 80 mt by 1985 and is projected to reach 300 mt in 1986.

The responsibility for aquaculture in Sweden rests with the National Board of Fisheries, which received formal responsibility for commercial fish farming in 1984. The National Board of Fisheries is responsible for the establishment of new fish farms, disease control, and the effects of fish farms on the environment. The agency estimates that about 500 salmon farms operated as family enterprises in Sweden in 1986, but large operations accounted for a significant portion of Sweden's smolt or salmon production. Sweden produces salmon smolts for release into the wild, for export, and for use in fish farming. A significant portion of Sweden's salmon smolt production has been used to restock rivers flowing into the Baltic Sea. The Swedish Water Law requires companies who build (or have built) hydroelectric dams to build hatcheries to compensate for the loss of natural waterways used by spawning salmon. In 1984, an estimated 4 million smolts were used to restock Swedish rivers (this includes brown trout). Swedish production figures are not available, but exports of smolts (salmon and trout) have grown rapidly from 10 mt in 1980 to a record 311 mt in 1985, before declining to 156 mt in 1986, when 173 firms were reported to be producing smolts. Swedish imports of smolts exceeded exports in 1980, but have since lagged behind similar exports (Table 12). The lack of statistical data for salmon, unfortunately, makes it difficult to clearly identify salmon smolts among the various possible imports and exports of salmon and trout.

The Government of Sweden has provided support to the aquaculture industry. Between 1980 and 1984, the Government provided $6.0 million in assistance, including $1.5 million to aquaculture farms in economically weak rural areas. The Swedish Government has also allocated about $0.5 million for aquaculture research, much of which is conducted at the Swedish University of Agricultural Sciences in Uppsala.

Export statistics indicate that Sweden shipped 409 mt of salmon worth $1.8 million in 1985, and 273 mt valued at $1.3 million in 1986 (Table 13). Since Sweden's total production of farm raised salmon was 80 mt in 1985 versus exports of 409 mt it can be safely assumed that the majority of salmon exports consisted of wild salmon in 1985. The situation in 1986, however is different; production of 300 mt of farm-raised salmon could account for a much greater share of the 273 mt exported in 1986. It is likely that Sweden will begin to export more farm raised salmon in 1987.

**XII. SPAIN:**

Salmon aquaculture is still in its earliest phases of development in Spain. Marcultura, with offices in Santiago de Compostella, is the only company currently engaged in salmon farming in Spain. Marcultura has been in business for 12 years and has been raising Pacific salmon since 1984. The firm initially farmed Pacific coho salmon, but began raising Atlantic salmon in 1987. They do not export salmon and do not plan to export, since they are currently providing only 10 percent of Spain's total demand for salmon. Production for 1987 is estimated at 200 mt of Pacific salmon. By 1990, Marcultura expects production to reach 600 tons (Appendix-I-P).

The U.S. Embassy in Madrid reports that several Norwegian companies plan to establish salmon farms in northern Spain in 1988. The number of sites and their production potential is not yet available, but it will expand Spanish salmon farming within the next 2 to 3 years. Salmon farming has not done well in Spain due to disease and high temperatures. Warmer waters enable salmon to reach sexual maturity at very low weights (1.5 to 2.0 kilograms apiece), forcing the fish to be harvested while they are still very small. The Norwegians reportedly have found a solution for both the disease and early maturation problems.

The Norwegians are attracted to Spain, because of a growing demand for salmon and because of attractive benefits for investors. Ten of Spain's 17 autonomous regions provide 40 percent financing in the form of grants to new aquaculture businesses through the "Consejeria de Pesca" (Fisheries Council) of each autonomous region. Investment incentives have included grants, tax exemptions, state loans, and grants for employment.

Spain is a net importer of salmon. Most of Spain's salmon is imported from Norway (1,700 mt in 1986). Imports of processed salmon are subject to a 12 percent import duty. The Norwegian Commercial Mission in Spain has a "vigorous promotion program for Norwegian salmon", staffed by three Norwegian officers. Spain could become an important new market for Norwegian farmed-raised salmon in the next few years.

## XIII. FRANCE

Historically, French aquaculture most often involved the farming of shellfish (oysters and clams). However, in recent years, the culturing of new (salmon, trout, seabass, seabream) and experimental (algae, flat fish, tropical fish) species has become more popular. Currently, farm-raised salmon represents only a small part of total French aquacultural production.

French salmonid (both salmon and trout) culture is concentrated in the northwest region of Brittany (Camaret and Le Conquet), where there are 10 operations producing about 500 mt of rainbow trout and coho salmon. These operations are handled under the technical supervision of the Breton Oceanological Center (government supported). Although the emphasis has been on trout farming, pilot production of coho salmon has reached 80 tons. By 1990, the annual production of farmed salmon could amount to 500 tons. French salmon farmers have reported problems in maintaining good survival rates due to high temperatures during the summer months. This, according to the farmers, prevents the production of salmon large enough to compete with imported farmed and wild salmon on the lucrative French market. French scientists from the National Institute for Agronomy Research (INRA) and the Institut Francais pour la Recherche et l'Exploitation de la Mer (IFREMER) are currently studying this problem at their three joint research stations in Camaret, Squirriou, and Rennes.

Overseas, the French Regional Association for the Development of Aquaculture (ARDA) and the ISTPM have established pilot production of trout and Atlantic salmon on the islands of St. Pierre and Miquelon, off Canada's Atlantic coast. In the southern Indian Ocean (Kerguelen Islands), INRA is reportedly getting good results from a salmon sea-ranching operation begun in 1983.

## XIV. FINLAND

Finland is not a major salmon farming country. It was not until post-World War II, when construction of hydroelectric power plants destroyed natural spawning grounds for salmonid fish, that efforts were begun to protect fish stocks. To compensate, the government established a hatchery system, producing smolts for release into coastal rivers and lakes for commercial and sports fishermen. The

culture of brown trout is the most common form of aquaculture in Finland. Atlantic salmon aquaculture is mostly restricted to smolt production, but small quantities of farmed salmon are raised for sale. There were 461 fish farmers in Finland in 1986. There is no specific government subsidization of fish farming in Finland. Farms located in "development areas" can obtain favorable loan packages from the Development Area Fund (KERA) for fish farm operations.

Finland's farmed salmon production began in the early 1980s. Between 1980 and 1983, approximately 30 mt of farmed salmon was produced annually in Finland. In 1984, the quantity of farmed fish (salmon and trout) amounted to 94 mt and by 1985 production of these two species reached 100 mt which is expected to remain constant until 1990.

In 1987, two Finnish firms, Savon Taimen OY and Hanka-Taimen OY announced plans to establish a joint venture fish farming operation in Scotland. The venture, established in January 1987, was named Risbond Fishfarms and was scheduled to import 400,000 salmon eggs from Finland for raising in Scotland (beginning in late February or early March 1987). The venture plans to raise 250 mt of salmon during its initial stages. The company's long-term plans call for the production of 1,000 tons. Salmon eggs will be sent from Finland starting in February 1987 (approximately 400,000 eggs will be shipped). Feed will be obtained from a Scottish fodder plant near the facility.

There were 126 Finnish smolt farms operating in 1986, and all were dependent on the Finnish Game and Fisheries Research Institute (FGFRI) for eggs, fry, and/or fingerlings, allowing the FGFRI to control the genetic composition of the parent fish. Salmon smolt production has flourished at the expense of adult salmon production because cold temperatures inhibit the growth of salmon. Smolt production increased from 1 million in 1980, to 1.6 million in 1984, to 2.3 million in 1985. The outlook for future smolt production is expected to grow at 10 to 20 percent per year through 1990.

Finnish salmon exports are small. In 1985, Finland exported 66 mt of fresh and chilled salmon worth $306,000 (this figure includes wild and farmed salmon). Exports in 1986 were only 1 mt worth $9,000, which was shipped to Switzerland, West Germany, and Italy.

**XV. AUSTRALIA:**

Australia's salmon aquaculture program is located on the island of Tasmania to the south of the Australian mainland where conditions are reportedly "ideal" for farming Atlantic salmon. In 1985, the Tasmanian Government's Foreign Investment Review Board and the Noraqua Group from Norway established a joint venture called Tassal Ltd. (79 percent Norwegian ownership and 21 percent

Tasmanian ownership) for the culture of salmon; Tassal Ltd. now controls about 40 percent of all salmon production. Tasmania Atlantic reportedly produces 11 percent of total production and about 17 other firms control the remaining 49 percent of Australia's salmon farm production.

Noraqua reportedly was attracted to Tasmania by the low variation in water temperatures, the cleanliness of the water, and because of the advanced infrastructure available. According to the Deputy Chairman of Tassal Ltd., Stal Svenning (who is also a Vice President of the Norwegian parent company), the Tasmanian operations are "the most promising of anywhere in the world." The time it takes from hatching to harvest, for a four to five kilogram salmon, reportedly is 27 to 30 months compared to 36 to 48 months in Norway.

Tassal Ltd. is planning to develop the Australian market for salmon. It has an entitlement to 40 percent of all salmon smolt in Tasmania through 1995 and will be able to market its salmon in Australia without fear of foreign competition; Australian quarantine restrictions on imported fresh salmon (and trout) require that the fish be heat treated — a process that reportedly impairs quality and taste. Tassal Ltd. is optimistic about its ability to meet the demand for fresh salmon in Australia through 1990.

## XVI. CONCLUSION:

World salmon aquaculture is a very dynamic business. New ventures are starting up all over the world. Research into new salmon raising techniques are producing results that will make salmon farming more predictable in the future, thus attracting more investment. It appears likely that world farmed salmon production will exceed the 200,000 mt mark in the next few years. It is also logical to expect outbreaks of disease periodically, increased competition, periods of consolidation within the industry, and increased investments in salmon farming around the world — led primarily by Norwegians — and gradual expansion of markets for salmon as consumers react to steady supplies of high quality salmon throughout the year.

1/ The National Marine Fisheries Service believes that the Subsecretaria de Pesca's projections are too high. NMFS believes that 8,000 mt by 1990 would be more realistic. A lead article in the May 1987 issue of Fish Farming International indicated that a harvest of 10,000 mt might be possible by 1990.

Table 1.—World. Farmed salmon production, by quantity, and country, 1980-1990.

| COUNTRY | YEAR | | | | | |
|---|---|---|---|---|---|---|
| | 1980 | 1982 | 1984 | 1986 | 1988 | 1990 |
| | Metric Tons, Live Weight | | | | | |
| EUROPEAN COMMUNITY: | | | | | | |
| France | 30 | 40 | 50 | 200 | 200 | 200 |
| Ireland | 21 | 100 | 385 | 1,500 | 4,520 | 10,100 |
| Spain | na | na | 100 | 150 | 300 | 600 |
| U.K. | 598 | 2,136 | 3,912 | 10,338 | 15,000 | 25,000 |
| EC, total | 649 | 2,276 | 4,447 | 12,188 | 20,020 | 35,900 |
| NON-EC EUROPE: | | | | | | |
| Faroe Islands | na | 60 | 116 | 1,370 | 4,000 | 9,000 |
| Finland | na | 30 | 94 | 100 | 100 | 100 |
| Iceland | na | 30 | 107 | 123 | 1,750 | 5,000 |
| Norway | 4,143 | 10,266 | 22,300 | 45,675 | 74,000 | 100,000 |
| Sweden | na | 10 | 20 | 300 | 800 | 1,000 |
| Non-EC, total | 4,143 | 10,396 | 22,637 | 47,568 | 81,450 | 115,100 |
| NORTH AMERICA: | | | | | | |
| Canada: | | | | | | |
| Atlantic | 6 | 140 | 200 | 400 | 1,600 | 5,000 |
| Pacific | 157 | 273 | 107 | 600 | 8,400 | 23,000 |
| United States | 392 | 691 | 1,248 | 1,399 | 3,831 | 7,720 |
| N.America total | 555 | 1,104 | 1,555 | 2,399 | 13,831 | 35,720 |
| OTHER: | | | | | | |
| Chile | na | 184 | 109 | 1,144 | 7,522 | 17,000 |
| Japan | 1,855 | 2,122 | 5,049 | 8,000 | 15,000 | 19,000 |
| New Zealand | na | 5 | 10 | 500 | 1,500 | 3,000 |
| Other, total | 1,855 | 2,311 | 5,168 | 9,644 | 24,022 | 39,000 |
| GRAND TOTAL | 7,202 | 16,087 | 33,807 | 71,799 | 139,323 | 225,720 |

Source: U.S. Embassy reports based on various official statistical tables or reports. Some 1986 figures are preliminary estimates.

Table 2.—World. Production of farmed salmon, by species, and quantity, 1980-1986, with projections to 1990.

| Year | SPECIES | | |
|---|---|---|---|
| | Atlantic | Pacific | Total |
| | Metric Tons* | | |
| 1980 | 4,798 | 2,404 | 7,202 |
| 1981 | 9,915 | 2,202 | 12,117 |
| 1982 | 12,812 | 3,275 | 16,087 |
| 1983 | 20,213 | 2,836 | 23,049 |
| 1984 | 27,207 | 6,600 | 33,807 |
| 1985 | 37,467 | 9,202 | 46,669 |
| 1986 | 60,142 | 11,657 | 71,799 |
| 1987 | 77,032 | 20,819 | 97,851 |
| 1988 | 104,542 | 34,781 | 139,323 |
| 1989 | 117,967 | 51,708 | 169,775 |
| 1990 | 160,642 | 65,078 | 225,720 |

*Live weight.
Source: U.S. Embassy reports based on various official statistical tables or reports. NMFS believes the figures for Pacific salmon for 1988-1990 are too high.

Table 3.—World. Production of farmed salmon versus catch of wild salmon with projections to 1990.

| Year | Fishery | | |
|---|---|---|---|
| | Farmed | Wild | Total |
| | Metric tons* | | |
| 1980 | 7,202 | 580,788 | 587,990 |
| 1981 | 12,117 | 661,922 | 674,039 |
| 1982 | 16,087 | 577,529 | 593,616 |
| 1983 | 23,049 | 701,718 | 724,767 |
| 1984 | 33,807 | 653,303 | 687,110 |
| 1985 | 46,669 | 838,885 | 885,554 |
| 1986 | 71,799 | 700,000** | 771,799 |
| 1987 | 97,851 | 800,000** | 897,851 |
| 1988 | 139,323 | 700,000** | 839,323 |
| 1989 | 169,808 | 800,000** | 969,808 |
| 1990 | 225,720 | 700,000** | 925,720 |

*Live weight
**NMFS estimates.
Source: U.S. Embassy reports based on various official statistical tables or reports, and FAO Yearbook of Fishery Statistics.

Table 4.—Norway. Exports of farmed salmon, fresh or frozen, to main markets, by country and quantity, 1982-1986.

| Country | 1982 | 1983 | 1984 | 1985 | 1986 |
|---|---|---|---|---|---|
| | | | Metric tons* | | |
| France | 2,710 | 4,298 | 4,374 | 3,828 | 9,904 |
| United States | 762 | 2,486 | 4,700 | 6,473 | 9,277 |
| Denmark | 1,240 | 1,957 | 2,419 | 2,494 | 5,462 |
| FRG | 1,850 | 2,466 | 2,625 | 2,819 | 4,671 |
| United Kingdom | 930 | 1,381 | 1,716 | 1,296 | 1,917 |
| Sweden | 590 | 824 | 943 | 1,023 | 1,916 |
| Spain | 453 | NA | 697 | 1,108 | 1,648 |
| Belgium | 558 | NA | 713 | 863 | 1,390 |
| Japan | - | 134 | 278 | NA | 771 |
| Switzerland | 504 | NA | 524 | NA | 725 |
| Netherlands | 182 | NA | 291 | NA | 684 |
| Other | 222 | NA | 192 | 2,330 | 1,539 |
| Total | 9,414 | 15,370 | 19,472 | 21,443 | 39,904 |

*Live weight.
Source: "Fish Facts", U.S. Embassy, Oslo (1982-1985), and Report to the Norwegian Parliament, Number 65, Norwegian Ministry of Fisheries, 1987 (for 1986).

Table 5.—U.K. Fresh or chilled salmon exports, 1980 - 1986

| Year | Quantity Metric Tons | Value US$1,000 |
|---|---|---|
| 1980 | 314 | 3,500 |
| 1981 | 495 | 4,186 |
| 1982 | 625 | 6,008 |
| 1983 | 999 | 10,089 |
| 1984 | 1,789 | 18,497 |
| 1985 | 2,942 | NA |
| 1986 | 4,277 | NA |

Sources: Sea Fish Industry Authority (1983-1985) and Eurostat (EC) trade statistics (1980-82). Note: Exchange rates were: £1 = US$1.30 (1985), US$1.33 (1984), US$1.52 (1983).

Table 6.—U.K. Production of smolts, 1980-1986 with estimates for 1988.

| Year | Quantity Million |
|---|---|
| 1980 | 1.35 |
| 1981 | 1.50 |
| 1982 | 1.70 |
| 1983 | 2.90 |
| 1984 | 3.70 |
| 1985 | 5.60 |
| 1986 | 6.50 |
| 1987 | 15.00 |
| 1988 | 21.70 |

Source: Morgan, Angus, The Status and Prospects for Aquaculture in the U.K. Chairman of the Marketing Committee of Scottish Salmon Growers Association, Scotland and Fish Farming International, May 1987 (for 1987 and 1988).

Table 7.—Canada. B.C. farmed salmon production, by species, quantity and value, 1980-1986.

| Year | Coho | | Chinook | | Total | |
|---|---|---|---|---|---|---|
| | M.T. | C$1,000 | M.T. | C$1,000 | M.T. | C$1,000 |
| 1980 | 157 | 898 | na | na | 157 | 898 |
| 1981 | 176 | 985 | na | na | 176 | 985 |
| 1982 | 230 | 908 | 43 | 228 | 273 | 1,136 |
| 1983 | 73 | 350 | 55 | 358 | 128 | 708 |
| 1984 | 64 | 306 | 43 | 396 | 107 | 702 |
| 1985 | 66 | 395 | 54 | 425 | 120 | 820 |
| 1986 | 400 | na | 60 | na | 460 | na |

*Includes an unspecified amount of pen-reared rainbow trout.
Source: Fisheries Production Statistics of British Columbia. Annual. Ministry of Environment. Province of British Columbia, 1985, and Fish Farming International, August 1987 (for 1986 data).

Table 8.—Canada. B.C. supply of salmon eggs for salmon farming, by quantity, 1980-1986.

| Year | Coho | Chinook | Chum/Pink | Total |
|---|---|---|---|---|
| | 1,000 salmon eggs | | | |
| 1980 | 6,012 | 648 | 25 | 6,658 |
| 1981 | 2,688 | 788 | 80 | 3,556 |
| 1982 | 2,516 | 345 | 151 | 3,012 |
| 1983 | 1,659 | 952 | na | 2,611 |
| 1984 | 2,187 | 950 | na | 3,137 |
| 1985 | na | na | na | na |
| 1986 | na | na | na | 30,000 |

Source: Department of Fisheries and Oceans. Ottawa, Canada.

Table 9.—Ireland.
Exports of salmon,
by quantity, 1980-86.

| Year | Quantity Metric tons |
|---|---|
| 1980 | 300 |
| 1981 | 200 |
| 1982 | 300 |
| 1983 | 700 |
| 1984 | 500 |
| 1985 | NA |
| 1986 | NA |

Source: U.S. Embassy,
Dublin

Table 10.—Faroe Islands. Number of firms and farms engaged in raising smolts and total smolt production, 1980-1986.

| Year | Firms Number | Farms | Production Million Smolts |
|---|---|---|---|
| 1980 | 1 | 3 | 30 |
| 1981 | 1 | 3 | 40 |
| 1982 | 1 | 3 | 85 |
| 1983 | 3 | 5 | 169 |
| 1984 | 3 | 5 | 345 |
| 1985 | 3 | 5 | 1,255 |
| 1986 | 6 | 6 | 1,165 |

Source: U.S. Embassy, Copenhagen

Table 11.—Faroe Islands. Exports of fresh or chilled farmed salmon, quantity and value

| Country | 1985 | 1986 | 1985 | 1986 |
|---|---|---|---|---|
| | Metric tons | | US$1,000 | |
| Denmark..... | 50 | 392 | 306 | 1,945 |
| Spain..... | - | 57 | - | 304 |
| FRG..... | 24 | 48 | 167 | 275 |
| France..... | - | 36 | - | 185 |
| Sweden..... | 21 | 24 | 138 | 166 |
| United States... | - | 9 | - | 68 |
| Great Britain... | - | 7 | - | 35 |
| Netherlands..... | - | 2 | - | 13 |
| Switzerland..... | 1 | 1 | 1 | 4 |
| Belgium/Lux..... | 1 | - | 5 | - |
| Total | 97 | 577 | 623 | 2,997 |

Source: U.S. Embassy, Copenhagen from data supplied by Faroese export statistics. Exchange rates: US$1.00 equals DKr 10.59 for 1985 and DKr 8.09 for 1986.

Table 12.—Sweden. Imports and exports of salmon smolts, by quantity, 1980-1986.

| Year | Imports | Exports |
|---|---|---|
| | Metric tons | |
| 1980 | 32 | 10 |
| 1981 | 35 | 48 |
| 1982 | 8 | 55 |
| 1983 | 13 | 104 |
| 1984 | 29 | 95 |
| 1985 | 57 | 311 |
| 1986 | 48 | 156 |

Source: U.S. Embassy, Stockholm

Table 13.—Sweden. Farmed salmon exports, by country, by quantity, and by value, 1985-1986.

| Country | 1985 | 1986 | 1985 | 1986 |
|---|---|---|---|---|
| | Metric tons | | US$1,000 | |
| Belgium | 26 | - | 121 | - |
| Denmark | 57 | 196 | 164 | 752 |
| FRG | - | 60 | - | 298 |
| Finland | 73 | - | 315 | - |
| France | 28 | 47 | 237 | 298 |
| Netherlands | - | 8 | - | 47 |
| Norway | 47 | 45 | 349 | 247 |
| Others | 42 | 53 | 154 | 129 |
| Total | 273 | 409 | 1,340 | 1,771 |

Source: U.S. Embassy, Stockholm. The exchange rate between the U.S. dollar and the Swedish Kroner was 7.11 kroner per dollar in 1986 and 8.59 kroner per dollar in 1985.

## APPENDIX II

# *SHRIMP AQUACULTURE IN LATIN AMERICA*

**I. SUMMARY:**

Latin America is a leading world producer of cultured shrimp. Shrimp farmers in the region harvested over 50,000 metric tons (t) of shrimp in 1986, a 40 percent increase over the 36,000 t of shrimp cultured in 1985. Ecuador dominates the region's shrimp culture industry—over 85 percent of the Latin American harvest was produced in that country. The industry is continuing to expand in Ecuador and is rapidly growing in several other countries as well. Prospects for the development of important shrimp culture industries are especially good in Brazil and Colombia.

Ecuador is reporting major increases in pond harvests in 1987. Several other countries are also reporting substantial, if less spectacular, 1987 harvests. Based on these increases and continuing expansion of the industry, the Branch of Foreign Fisheries Analysis believes that cultured shrimp harvests in Latin America could reach nearly 115,000 t by 1990. That projection is based primarily on one country (Ecuador) and one species (Penaeus vannamei). As more countries enter the industry and technical advances enable farmers to increase yields and perhaps use different species of shrimp, it is likely that production will continue to increase during the 1990s. Many observers are unsure, however, about the impact of rising world production on the international shrimp market. If substantially lower prices result from the increased production, profit margins could be significantly affected. If so, many farmers may have to adjust their production and expansion plans.

**II. OVERVIEW:**

**Harvests**

1960-1970s: The first successful commercial harvest in Latin America was reported in southern Ecuador during the late 1960s when farmers discovered that previously worthless coastal flats could be turned into some of the most productive land in the country. Cultured shrimp harvests in Latin America were limited

during the 1970s as growers experimented. The original Ecuadorean farms were rustic, extensive operations utilizing naturally occurring postlarvae (pl) and river/tide water exchange. They were stocked with the wild pl occuring naturally in the water. Some of the first ponds were very large, in some cases more than 100 hectares. Slowly growers developed improved techniques and pond design. A few sought foreign technicians, especially U.S. and Japanese researchers. Throughout the 1970s, the industry slowly expanded. Most of the growth was centered in Ecuador, but one of the most successful farms was built by a U.S. company in Panama. Farms were built in more than 10 other countries in the region with varying degrees of success. Latin American cultured shrimp harvests first reached 1,000 t about 1975 and probably did not exceed 5,000 t per year as recently as 1979 (appendix A).

1980-83 Boom: The shrimp culture industry began to expand rapidly in 1980. As Ecuadorean farmers began to perfect methods, their increasing success attracted the interest of investors. Pond construction accelerated. Ecuadorean farmers increased pond area over 100 percent in 1980 and 1981 and additional massive increases followed through 1983 when pond area exceeded 50,000 hectares. Latin American farmers harvested about 10,000 t in 1980 and significantly increased harvests each year through 1983 (appendix A). More than 90 percent of the region's production was reported in one country—Ecuador. Significant commercial harvests in other countries were limited to Panama and northern Peru (near the original farms in southern Ecuador). The 1982-83 El Nino resulted in an exceptionally large abundance of pl off Ecuador, helping Latin American farmers to achieve a record harvest of 39,000 tons in 1983 (appendix A).

1984-85 Postlarvae Crisis: After the 1982-83 El Nino event ended, the water off Ecuador cooled and the resulting shortage of postlarval seedstock caused production to decline in 1984 and 1985 (appendix A). Many Ecuadorean growers were unable to obtain pl to stock their ponds while others were able to stock only some of their ponds, often at less than optimal densities. Some reports suggest that at the height of the crisis in late 1985, over 50 percent of the Ecuadorean ponds were empty. The resulting losses forced many growers to scale back operations or even, in some cases, to close farms. As a result, Latin American shrimp farmers harvested only 36,000 t of shrimp in 1985. Many growers began to realize that year-round operations would require a reliable source of postlarvae. As a result, increasing numbers of growers and investors initiated plans to build hatcheries.

1986: Latin American shrimp growers recovered quickly in early 1986 as pl became more available. Growers harvested a record 52,000 t of shrimp in 1986, a 40 percent increase over 1985 and more than a 100 percent increase over 1982 when NMFS first began to compile detailed statistics on the industry's development throughout Latin America (appendix B). Most of the increase occurred in Ecuador. Warming ocean temperatures and the expanding hatchery production of pl enabled Ecuadorean growers to obtain pl in sufficient quantities to fully stock their

ponds for the first time since 1983. Regional production was also aided by harvests from the embryonic shrimp culture industries in several other countries. Until 1985, Ecuador and Panama were the only countries to report harvests over 1,000 tons. By 1986, four more countries (Brazil, Honduras, Mexico, and Peru) were reporting harvests in excess of 1,000 tons (appendix B).

1987: Current data suggest that 1987 will be another record year in Latin America with harvests estimated at nearly 80,000 tons. The abundance of pl in Ecuador has enabled farmers in that country to achieve massive production increases so that final 1987 harvests proved to be even more impressive than anticipated. Since January 1987, Ecuadorean exporters have been setting monthly records and between June and October 1987, shipments to the United states exceeded 4,000 t each month (appendix C).[1/] Ecuadorean shipments in June 1987 set an all time record, almost reached 5,000 tons. Ecuador continues to dominate the industry, but an increasing number of countries are reporting new shrimp culture projects and rapidly expanding commercial harvests of cultured shrimp.

1988: Many observers believe that 1988 will be another good year for Latin American growers, principally because of a good year anticipated for Ecuador. While Ecuadorean growers may report another good harvest in 1988, it is unlikely that they will report any major increases. Some observers believe that Ecuadorean growers may have reached a production plateau, at least given current farming methods. Ecuadorean pond harvests in late 1987 were at record monthly levels, but tending down from the record June levels. This trend may continue on into 1988. Ecuadorean growers in 1988 may not be able to match the 1987 records. The 1986-87 El Nino ended in December and water temperatures in the Eastern Pacific are returning to normal. The pl situation for 1988 can not yet be predicted with any certainty, but it is unlikely that they will be as abundant as in 1987. The ability of the new hatcheries to supply large numbers of growers may receive its first test during 1988.

1990/2000: Most experts believe that Latin American shrimp farmers are just at an initial stage of development and can significantly increase harvests. The increases for the rest of the decade, however, will probably be modest compared to the massive increases in 1986 and 1987. Ecuadorean growers may be reaching a plateau and growers in other countries are just beginning to harvest significant quantities. Based on these trends, by 1990 total Latin American harvests will probably exceed 100,000 t, perhaps reaching nearly 115,000 tons (appendix B). This projection, however, could be significantly affected by climatic conditions and, as a result, the resulting availability of postlarval seedstock. The steady development of hatchery technology in Ecuador and other countries, however, may help the industry through future natural pl shortages avoiding another massive shortage as occurred in 1984-85. The industry's full potential in the region, however, is much greater than 115,000 tons. Many observers believe that once

that growers in some of the more important countries have mastered shrimp farming methods and resolved the major technical problems, production of cultured shrimp could expand significantly beyond the 115,000 t level in the 1990s. The 115,000 t projection is based primarily on Ecuadorean production. Several other countries, especially Brazil, Colombia, and Mexico, have the potential for major shrimp culture industries. Each of these countries could be harvesting significant amounts of cultured shrimp by the mid-1990s. Other Latin American countries also have the potential of developing smaller, but profitable shrimp culture industries. Conservative projections suggest that it is likely that Latin American shrimp farmers could surpass harvests of 200,000 t by the year 2000, but other observers believe that the 200,000 t level could be reached earlier in the next decade.[2/]

**Regional Importance**

Significant quantities of shrimp are cultured in only two world regions: Asia and Latin America. Ecuador led world producers until 1985, when China reported major production increases, although data for China and some other Asian countries have not yet been fully corroborated by other sources. While precise Asian data are not available, it is clear that the industry is expanding more rapidly in Asia than in Latin America. Seven Asian countries (China, Taiwan, Indonesia, Philippines, India, Thailand, and Bangladesh) have become major producers of cultured shrimp (appendix D). Shrimp is also cultured in Africa, the Middle East, and Europe, but harvests in these areas are limited and are not likely to be statistically significant even by 1990.[3/]

The Latin American shrimp culture industry lags far behind the emerging industry in Asia. The 52,000 t of shrimp cultured by Latin Americans was only about 17 percent of the world cultured total if some of the more optimistic reports from China and the other Asian countries are to be believed (appendix E). The Latin American share of the total world harvest of cultured shrimp may increase slightly during the next few years as several important potential producers begin significant harvests. Developments in Brazil, Mexico, and Colombia will have an especially important impact on the industry's future. The Latin American share of world production, however, will probably not exceed 20 percent by 1990.

**Traditional Fisheries**

Latin American fishermen still dominate the region's shrimp production. Both Mexico and Brazil conduct massive shrimp trawl fisheries. The 210,000 t produced by the trawler fishermen in 1985 was more than 85 percent of the regions's total shrimp production (appendix F). It is likely that the 210,000 t trawler catch is at or near the maximum sustainable yield for Latin American

shrimp. As a result, the trawler catch is not increasing and the harvests of shrimp farmers are increasing rapidly. NMFS estimates that the trawler catch in 1987 had declined to less than 75 percent of the total regional shrimp harvest. Production of cultured shrimp will probably exceed Latin American landings of trawler-caught shrimp by the late 1990s or early 2000s. This means that in only a few years after beginning to farm shrimp, farmers will have doubled the total amount of shrimp produced in the region. As most of the current production comes from Ecuador, it is likely that steadily increasing amounts of shrimp will continue to flow from Latin America as the industry expands in other countries. If current trends continue, the region's shrimp fishermen may eventually supply only a small proportion of total shrimp harvests.

Trawler shrimp fishermen are concerned over the new shrimp culture industry. Their initial concern was the impact that collecting large quantities of pl would have on the the wild shrimp stocks that they harvest. Ecuadorean officials, however, have not yet detected a negative impact on wild shrimp stocks due to the extensive pl collection. The fishermen and many biologists continue to be concerned about the possible long-term impact. Trawler fishermen have, however, been affected by the competition from the shrimp farmers. Increasing farmed production has depressed prices, especially of medium-sized shrimp. If this trend continues, shrimp fishermen will find it increasingly difficult to compete with the farmers. Trawler fishermen face other problems. The trawl fishery is a fuel-intensive operation. Fishermen have been aided by relatively low fuel prices in recent years. If fuel prices rise in coming years, the fishermen will have even more difficulty competing with the farmers. Trawler fishermen will also have difficulty matching the steadily improving quality of the shrimp being delivered by the farmers. The trawler fishermen have at least one advantage which farmers can not yet match. Part of the trawler catch is high-value large (small count) shrimp. Farmers have not yet developed profitable methods for raising large shrimp.

**Quality/Size Control**

The quality and size control possible in shrimp farming, is a major advantage the industry has over trawler fishermen. Theoretically, shrimp growers should be able to produce a fresher and more uniform product than trawler fishermen. The ability to harvest and process shrimp in a matter of hours is a major advantage to shrimp farmers. The bulk of the world's farmed shrimp is harvested in developing countries, however, where growers are generally not producing nearly the quality of shrimp that is theoretically possible. Many farms are located in isolated areas,

complicating harvesting and transportation. Some farmers use inadequate quantities of ice which is probably the single most prevalent handling problem in most developing countries. For example, a harvesting operation from large ponds takes hours and ice may be delivered on the same trucks which arrive to pick up the shrimp, meaning that the shrimp first harvested may sit for hours without ice in tropical conditions. Even so, the quality of cultured shrimp is generally above that of trawler-caught shrimp and is improving rapidly. Growers are becoming more and more quality conscious as competition in the industry intensifies. An increasing number of growers harvest at night and load shrimp in iced boxes (in some cases while it is still alive) for delivery to modern packing plants. Other growers have built their own packing plants at the farm sites, giving them the capability of packing their shrimp within minutes of harvest. Few growers have yet reached this level of sophistication, but the quality of product that farmers can deliver is often a substantial improvement over the product (which can be up to 2 or 3 weeks old) delivered by the trawler fishermen . Growers are constantly improving their harvesting methods and it is likely that the quality of farmed shrimp delivered to the U.S. should steadily improve over the next few years. On the other hand, there is little likelihood that trawler fishermen will be able to improve the quality of their product.

Farmers also have another major advantage: they can, to some extent, adjust their production to market needs.[4/]. Growers using white shrimp (P. vannamei) are producing fairly uniform shrimp which they have most commonly harvest at the 26 to 40 count (shrimp tails per pound) size. Past price fluctuations have caused growers to give increased attention to price levels for shrimp of various sizes. Some growers have increased production of smaller shrimp, in the 41-50 count size. Ecuadorean growers, for example, harvested substantially more shrimp at the 41 to 50 count size during 1987 than in previous years. Other growers have begun to consider the production of larger shrimp, although this is more difficult to accomplish without major changes in methods and pond design.

**Species**

Most successful farms in Latin America have used primarily one penaeid species, a Pacific white shrimp—P. vannamei. Happily for growers, P. vannamei is a species well-accepted by U.S. consumers. As a result, the Latin American growers had a ready market. Growers have reported impressive results with P. vannamei. No other shrimp survives as well in ponds or grows as rapidly. It is not clear why P. vannamei performs so well in ponds, or why other species do not. Considerable research has been devoted to assessing the suitability of various species for pond culture. Many species indigenous to Latin America have been evaluated, including P. aztecus, brasiliensis, californiensis, duorarum, notialis, occidentalis, paulensis, schmitti, setiferus, and subtilis. Some individual growers claim varying

success with these species, but their has been no demonstrated success by large numbers of growers suggesting that any of these species will prove to be a major cultured species. Atlantic/Caribbean-coast shrimp farmers have been especially interested in culturing an indigenous species. Some farmers and researchers in Atlantic-coast countries are convinced that P. schmitti will eventually prove to be an important cultured species. Further research on culture methods and dietary requirements may eventually permit other Atlantic-coast species to be cultured, although some researchers are convinced that these species are not conducive to culture. One researcher points out, for example, that biologists and farmers have been trying to use P. schmitti for over 20 years, but that a well-documented commercial success has yet to be obtained. Brazilian and other Atlantic-coast farmers have attempted to develop methods suitable for culturing indigenous species, but recent reports suggest mixed results. Even along the Atlantic coast many growers are now adopting the methods developed in Ecuador and Panama and the use of P. vannamei is becoming increasingly common.

Latin American shrimp growers, especially those along the Atlantic coast, are also experimenting with exotic (imported) penaeid species. The two most-widely tested imported species are P. japonicus and P. monodon. Brazilian growers have used P. japonicus, which reportedly breeds well in high-salinity water, but results have been generally disappointing and the early enthusiasm for the species has declined. Some growers have also expressed an interest in P. monodon. Hatcheries in several Asian countries, especially in Taiwan and Japan, are already producing large numbers of pl of both species, often at extremely low cost.[5/] Most pond operators, however, report that P. japonicus and P. monodon yields are simply not comparable to the successes achieved with P. vannamei, but this may be primarily due to the lack of suitable feeds. Growers are also concerned about the reported tendency of P. monodon to grow at uneven rates.

Latin American growers have also experimented with freshwater shrimp (Macrobrachium rosenbergii). Except in the French territories (French Guiana, Guadeloupe, and Martinique), freshwater shrimp has not been a commercial success. Growers have reported technical success in raising the species, but meat yield are lower than with marine shrimp and the market is much smaller. Some experts are convinced, however, that freshwater shrimp may eventually prove to be a successful cultured species and contend that the species should be marketed fresh as a high-value gourmet product—the current practice on the French islands. Besides the French territories, important freshwater shrimp projects are underway in Brazil, the Dominican Republic, Mexico, Panama, Puerto Rico, and in other countries.

**Governmental Support**

Some Latin American governments have promoted shrimp culture. The industry has several attractive features that have attracted the interest of Government factors. The high price for shrimp and the demand in developed countries means that shrimp is a valuable export commodity. In Ecuador, for example, shrimp is the leading non-petroleum export commodity. Shrimp farmers often find that the land best suited for their farms is land which was formerly marginal or of limited value. The industry also creates employment, often in isolated rural areas with limited employment opportunities. As a result, the developing shrimp culture industry in Latin America has coincided with some of the major goals of many Governments in the region, especially generation of export revenue and increasing employment.

Several countries have financed research on the subject and provided credit to groups interested in investing in shrimp farms. The industry's development, however, is almost entirely due to the private sector. Successful farms invariably are operated by private investors and, with only a few small exceptions, so are almost all of the hatcheries. The industry's growth, on balance, has probably been slowed by various government policies, especially a variety of macroeconomic policies which have prevented, or discouraged, private domestic and foreign investment and the free conversion of export earnings. Exchange rate controls, discouraging investment, have been a special problem and have slowed the growth of the industry even in Ecuador. Growers in many countries complain of involved permit procedures and intractable administrative delays which have complicated their efforts to initiate new projects. Import restrictions have also often prevented or delayed the delivery of needed supplies and equipment as well as feed, vitamins, and antibiotics. A few countries have laws specifically dealing with shrimp culture. Mexican law, for example, has prevented private investment in marine shrimp culture which has seriously impaired the development of a potentially dynamic Mexican industry. In some countries (Ecuador, Panama, and others) large areas of coastal land are owned by the Government, and administrative procedures for allocating this land have often proved cumbersome.

**Postlarval Seedstock**

The growth of the shrimp culture industry in several Latin American countries faces many problems, the most serious of which has been obtaining a reliable year-round supply of pl to stock the ponds. Many countries suffer from a serious shortage of pl, which hatchery technology is just beginning to address. The most successful projects in Latin America have used P. vannamei and, to a much lesser extent, P. stylirostris. Wild stocks of these species are available only in Pacific-coast countries, and even there they are in increasingly short supply.[6/] The

problem is exacerbated by the lack of detailed information on the natural stocks (especially their spawning schedules) which is necessary to organize a sophisticated collection procedure. Atlantic-coast Latin American countries have a special problem in that they have no natural stocks of P. vannamei and, thus, have to import pl or build hatcheries to produce it.

Although difficulties continue with producing P. vannamei pl, an increasing number of hatcheries report steadily expanding production. The Granada hatchery in Panama has the longest record of success in Latin America and many Ecuadorean hatcheries have reported startling increases in pl production since 1986. Only a few hatcheries, however, have achieved their production through the full-cycle maturation process. Ecuadorean hatchery operators claim that they have developed the technology needed to produce P. vannamei pl in massive numbers. Their claims are largely untested, however, especially during the cyclical periods when pl and gravid females are scarce in the wild. Reports from Ecuador do suggest that a substantial number of farms are now being stocked with hatchery-produced postlarvae. It will almost certainly take several years for Latin American shrimp farms to become completely independent of natural reproduction cycles. Some observers believe that, as long as abundant quantities of pl can be collected in the wild, farmers will rely principally on the natural supply. It is unclear how this tendency will affect the development of a hatchery industry. Many hatcheries may find it difficult to survive economically if they can only operate a few months out of the year. Other observers express concern about the possibility of a rapid spread of diseases resulting from the widespread distribution (often across national frontiers) of hatchery produced postlarvae.

**Variables**

Accurately predicting future production of cultured shrimp is impossible because too many unquantifiable variables could affect cultured harvests. The Branch's projections must be viewed as rough approximations with wide margins of error. The projections assume a continuing high demand for shrimp in developed countries at 1987 price levels. A variety of factors, however, could sharply affect this assumption and the above projections. A host of economic, technical, environmental, and political factors could impact the industry's growth rate. Some of these factors include:

1. **Economic**
    * World shrimp prices
    * Demand in international markets
    * Supply in international markets, especially the impact on markets of increasing shrimp production as a result of developing aquaculture industries

* Production costs, especially petroleum and feed prices
* Construction costs
* Availability of investment capital
* Trade barriers
* Inflation rates
* Interest rates
* Currency exchange rates

**2. Technical**

* Success of projects to build hatcheries which can supply postlarvae (pl)
* Ability of developing countries to improve yields of existing ponds which currently use extensive methods
* Results of efforts to introduce exotic species for shrimp culture and to develop the technology for culturing indigenous species
* Progress of developing countries in training national technicians
* Availability of trained extension agents
* Future research on such subjects as genetics and selected breeding, diet, disease control, etc.

**3. Environmental**

* Impact on the natural resource of collecting large quantities of postlarvae
* Impact of building and operating large numbers of ponds in coastal areas
* Reduction of freshwater flow to natural nursery estuaries
* Possible spread of diseases and parasites as a result of introducing exotic species, either by importing broodstock or postlarvae. (Shrimp are more susceptible to disease when cultured as they are maintained at high stocking densities.)
* Danger of competition with native species if exotic species escape into the wild.
* Catastrophic events (El Nino, hurricanes, oil spills, etc.)

**4. Political**

* Government stability
* Government policies toward business in general
* Government policies specifically related to shrimp culture
* Regulatory climate
* Import regulations (on imports of live shrimp and the water that they are shipped in or essential items like Artemia, antibiotics, equipment, etc.)
* Export regulations and subsidies

Many other factors could affect the accuracy of the NMFS projections (appendix B). Statistical data from many countries are not available, or when available, are often contradictory and difficult to confirm. The sources frequently do not clearly identify data as to tail/whole weight, harvests by crop/year, etc. As a result of these and other limitations, the above estimate of 1990 production is little more than an educated guess, but it does suggest approximate production levels that can be reasonably anticipated by 1990. When differing estimates have been obtained, NMFS has generally used the more conservative figure, unless the higher figure could be corroboration with other information from the country concerned.

### 1. Economic Factors

Some of the more optimistic estimates of production increases have led market analysts to speculate about an oversupply of shrimp on international markets in the 1990s. The projections in this report are based on 1987 price levels. Substantial shifts in shrimp prices could affect these projections. Prices of 31/35 count shrimp, the size most commonly harvested by Latin American growers, have been noticeably affected by the rapidly expanding harvests of cultured shrimp around the world. Prices of most sizes of shrimp have tended downward in real dollars since the late 1970s. Prices of medium-sized shrimp most commonly harvested by growers have declined most sharply. Such real price declines, however, can not be attributed solely to increased farmed harvests. Many other factors, such as demand, also affect prices. The rising production of farmed shrimp, however, is almost certainly a key factor in current price trends and the very real possibility exists that future significant price declines are possible. If future prices do decline sharply, the projections in this report would have to be revised. The industry could be severely affected, especially the trawler fishermen and farmers with the highest production costs.

Besides prices, another key factor affecting future production will be the cost of culturing shrimp. Data on production costs are not readily available. Most farms are located in developing countries where business practices are often more informal than is common in the United States. In many cases individual growers themselves may not have compiled precise production cost data. In other cases, farms are run in a modern, businesslike manner, but data on production costs is maintained as the internal records and not released to the public. Verbal data often offered by growers must be treated with caution. Some growers may not have the data on which to base their claims. The problem is complicated by the tendency of growers to compute production costs differently. Data may vary from simple operating costs to total farm costs, including depreciation of capital investment costs. Available information can not be accepted at face value because of the quite natural tendency of growers to exaggerate their successes or to discount their failures. The available data suggests, however, that shrimp farmers in Latin America, especially in Ecuador, are producing shrimp at costs substantially below the

production costs of fishermen who trawl for shrimp. Some Ecuadorean farmers, for example, claim to be able to culture shrimp for as little as $2.50 per kilogram (kg) of whole (live weight) shrimp.[7/] Several authors have addressed the question of production costs, but reliable current data is not available.[8/] Most Ecuadorean growers have higher production costs, however, so that average costs are probably greater, perhaps averaging $3-4 per kilogram.[9/] One observer estimates that Ecuadorean production costs during 1987 probably averaged 60-65 percent of the wholesale price in the United States. Such wide profit margins would allow Ecuadorean producers to absorb even a major price reduction and still remain profitable. It is not known how many other Latin American countries will also be able to achieve such low production costs. Many observers believe that production costs in Ecuador and other important shrimp farming countries, however, are substantially less than production costs in the United States.[10/]

The cost basis of farmers and trawler fishermen is quite different. The principal costs for the farmers are feed, pl, and fuel, while fuel alone probably represents about half of the operating expenses for the fishermen. Thus while feed and pl costs will affect the relative profitability of the two groups, fuel costs will almost certainly be the key factor. Relatively low fuel prices from 1985-87 have greatly benefited fishermen. If fuel prices increase over the next few years, however, shrimp farmers, who use relatively less fuel, will be affected much less than the trawler fishermen.

The ability of shrimp farmers to lower production costs is an open question. While accurate predictions are tenuous at best, it seems unlikely that there will be any major reduction in the costs of culturing shrimp during the next few years. Significant declines in expenses for major costs (land, feed, fuel, pl, and labor) are unlikely. Major culture countries (China, India, Ecuador, etc.) are all developing countries. Reducing costs would require a much more systematic approach to shrimp farming and such an approach is not likely to occur rapidly in these countries, especially as current profit margins permit them to compete very effectively with existing methods.

Growers attempting to introduce more sophisticated methods are experiencing some difficulties. Many new entrants into the industry are often subject to higher start-up costs than the earliest companies, because their more sophisticated methods and farm designs require more expensive construction and equipment. In addition, land values in Ecuador and other countries have increased astronomically with the success of the industry. New investors hope to recover their higher initial investments, however, calculating that the increasing yields per ha will compensate for the larger initial investment. Ecuadorean growers reported

significant increases in production costs during 1987, but this was primarily due to rising feed prices[11/] and the Government's decision to increase domestic fuel prices.[12/] Attempts to adjust to these increases may at least partially explain the noticeable shift by farmers toward the harvest of smaller shrimp.

The current wide profit margins reported by some successful growers have attracted wide interest from potential investors, many of which have never before been involved in fisheries or aquaculture. Weak shrimp prices in the past few years has not yet affected investor interest as the wide profit margins have cushioned growers from future price fluctuations. Eventually, however, price movements will have a significant impact on the industry's projected growth. Except in China and Mexico, the industry is primarily financed by commercial credit markets. As a result, the continued high profitability of the industry will be necessary to secure credit in developing countries, many of which have severe credit shortages.

### 2. Technical Factors

Growers could considerably improve their yield if they applied the results of existing research on shrimp culture. Perhaps 90 percent of current and projected production comes from developing countries using extensive or primitive semi-intensive methods. Few farmers in these countries understand factors such as water exchange, fertilizer application, and feeding schedules, species composition, and a host of other factors. As a result, very few farmers maintain detailed records on the wide variety of factors and conditions (salinity, temperature, pH, feed and fertilizer applications, etc.) relevant to each growing cycle. Decisions concerning these factors are being made—if at all—intuitively and, as a result, yields are generally far below optimal levels. If a large number of existing ponds could be managed more systematically, a substantial increase in current production would result without further expansion of pond area. This is true of all of the major producing countries, except for Taiwan (which is emerging as a developed country). Given the huge increases projected in shrimp production in coming years, declining shrimp prices may force growers in developing countries to adopt more efficient pond management techniques.

Most Governments have found it difficult to provide technical assistance to shrimp growers. Few developing countries have an extension service that is effectively introducing improved methods to growers. Such a service would be difficult to introduce as any technician with the appropriate knowledge could make so much money by offering consulting services or going into business himself that he would probably not be interested in wage scales offered by government agencies.

Several countries have already carried out considerable shrimp culture research and additional research is underway. The results of the introduction of existing and future findings should gradually increase the efficiency of cultured shrimp

production. How rapidly the results of the research will be implemented is unclear. Eventually this research will, almost certainly, have a major impact on production. Gradually as production increases, competition will force the less efficient growers to modernize their operations if they are to stay in business.

One technical variable to be considered over the long run is genetics. Growers are now, in effect, farming wild animals. It is as if modern livestock growers were raising longhorn cattle or wild boars. Current yields reflect this situation. The environmental conditions in ponds are quite different from those in coastal waters where the wild shrimp are well adapted. As a result the pl currently available do not perform as well in ponds as is desirable. NMFS knows of no selective breeding programs in place. They will almost certainly be initiated, however, and will have a significant impact on future yields.

### 3. Environmental Factors

Many biologists are concerned over the possible environmental impact of converting vast areas of coastal land to shrimp farms. No one yet knows the long term impact on the environment of such large scale development. Several concerns worry officials: the collection of billions of postlarvae, development of large areas of estuaries and other coastal land, release of the pond effluent, escape of exotic species, increased chances of spreading diseases and parasites to natural stocks, and a host of other factors. While most of these activities may prove to have generally negative consequences, there is considerable debate among biologists on the possible impact. Some biologists point out that there may even be positive consequences. For example, the effluent of the ponds could actually benefit the coastal habitat. Many biologists have advised caution, but the economics of growing shrimp in the developing countries has proven too strong an inducement. In most countries the industry has developed with the same lack of concern over the possible environmental consequences that some developed countries have shown for the preservation of coastal habitat. In a few countries, however, government interest in preserving the environment has caused restrictions on the construction of ponds, and the import or export of Artemia and shrimp nauplii, pl, and broodstock, thus complicating operations for shrimp farmers and hatchery operators. Many biologists insist that such restrictions may in the long run prove beneficial and stress the importance of adopting the ICES guidelines on the importation of exotic species.

### 4. Political Factors

Political policies and decisions can also affect projections for the industry's growth. Government stability and the economic policies discussed above can significantly affect the development of a new industry like shrimp culture. Political disorders in several countries (Colombia, El Salvador, Guatemala, and others) have slowed

the industry's development. Relative political stability in the past 15 years has aided the industry's development in Ecuador. Decisions taken on the shrimp industry can have a powerful effect on the industry's development, such as Mexico's decisions to prohibit private investment in the shrimp industry. Other countries that have restricted the private sector (Cuba and Nicaragua) have made little progress in developing a commercial shrimp culture industry. Some countries (Brazil and Colombia) have benefitted from the Government's decision to promote the industry through such devices as low interest loans, export rebates, tariff free imports, and other benefits. A country's general regulatory climate also affects the industry. Investors in some countries complain of complicated permitting procedures and interminable delays in obtaining Government authorizations.

**III. Principal Countries:**

Latin America's preeminent shrimp culture country is Ecuador. Low-wage rates, relatively inexpensive coastal land[13/] ideally suited for culturing shrimp, cheap fuel, favorable climate, large vertical tidal fluctuations, extensive mangrove/estuarine systems, the nutrient-rich Guayas River, and the availability of wild pl to stock the ponds have contributed to Ecuador's success in the production of farmed shrimp. Shrimp culture is a technically sophisticated operation. The combination of ideal conditions that exist in Ecuador, however, has enabled farmers in that country to achieve success even with primitive technology. This was a key to the industry's success as most of the best locations for culturing shrimp are located in tropical or semitropical developing countries which are generally not well equipped for technically sophisticated new industries. Ecuadoreans were able to achieve success with primitive extensive systems and then slowly improve their operations as they trained local technicians and attracted investments and technology from developed countries like Japan and the United States.

Many of those conditions exist elsewhere in Latin America, but not in such an ideal combination as in Ecuador. The extensive marine shrimp culture methods developed in Ecuador and Panama, however, are spreading to other countries in the region. Farmers in many other Latin American countries are following Ecuador's and Panama's lead, beginning with rudimentary extensive farms, and gradually shifting to more sophisticated methods—in some cases approaching the semi-intensive level—to increase yields[14/]. Several countries have particular promise. Brazil is a particularly important country. Given the size of its coast and the existence of major wild shrimp fisheries, Brazil should develop an major shrimp culture industry. The industry, however, is developing slowly, probably because of the failure of indigenous species to perform well in ponds. Mexico is another country with enormous potential, but the industry's growth has been impeded by laws restricting both domestic and foreign private investment in the shrimp industry. Peru shares many of the ideal environmental conditions enjoyed by

neighboring Ecuador, but has a much smaller area of potential sites. Colombia has extensive areas on both coasts which could be devoted to shrimp culture. Several other countries have the potential for smaller, but still significant shrimp culture industries. Several new companies began production in 1985 and 1986 and many more projects are scheduled in almost every Latin American country, except the southern cone countries (Argentina, Chile, Paraguay, and Uruguay) which have temperate climates.

# CARIBBEAN AND MEXICO

## CENTRAL AMERICA AND MEXICO

Several Central American countries (Guatemala, Honduras, and Panama) have developed small but promising shrimp culture industries. Other countries in the region have a good potential, but also have a variety of problems which they have not yet resolved. These include unfavorable domestic legislation, lack of government support, poor site selection, civil disorders, and other problems which have discouraged the industry's development. Each Central American country has sites that can be developed to culture shrimp. Most successful operations to date have been along the Pacific coast, primarily because of the availability of P. vannamei pl to stock ponds. The limited number of hatcheries in Central America and Mexico keeps most countries dependent on pl seed stock collected in the wild. Even in Honduras, a country with an important Caribbean-coast shrimp fishery and only a few kilometers (km) of Pacific coast, the industry has developed primarily along the Pacific coast. Once adequate supplies of postlarval seedstock become available, however, development of Caribbean-coast sites is likely. Mexico is the leading country in the region, with a larger area suited to shrimp culture than all of Central America combined, although some Mexican sites are located in northern latitudes where the climate is less favorable than in Central America. The industry's development in Mexico, however, has been impeded by laws reserving marine shrimp culture to cooperatives. As a result, the industry in Mexico has lagged behind countries with much less potential. The successes reported in Central America have been mainly in countries which have allowed investors to enter the industry. Foreign investors have played an especially prominent role and most of the larger farms have varying degrees of foreign investment and/or technical assistance.

### I. BELIZE:

Shrimp culture in Belize is still in its infancy. Shrimp farmers began the first experimental projects in 1981, but observers differ on the country's potential for developing a viable shrimp culture industry. Some specialists note a variety of problems, including climate, temperatures, rainfall, soil and sediment types, and sites located too close to sea level. Others have disputed such a negative assessment.[1/] While Belize may not have the ideal combination of conditions which Ecuadorean growers enjoy, several investors are convinced that shrimp can be cultured there. The Government believes that good potential sites exist for 5,000-6,000 ha of ponds. Three small farms have begun preliminary test runs, but none have yet initiated full-scale commercial operations. The major projects are

Maya Mariculture, General Shrimp, and Caribbean Shrimp. Two additional farms planned to complete construction of ponds and begin operations by the end of 1987. Five other groups are studying possible investments. **Maya Mariculture** has conducted trial runs of P. stylirostris and vannemei and reported annual yields of about 0.3-0.4 t per hectare. **General Shrimp** plans to use P. vannamei. Caribbean Shrimp and hopes to conduct preliminary trials soon. Belizean growers estimate that about 220 ha of ponds should be in production by the end of 1987, but NMFS has no confirmation that they did so. If these ponds prove successful, the companies plan to construct about 800 ha of additional ponds by 1990. Growers reported harvests of 3.6 t in 1986, about the same amount harvested in 1985. Some growers have had problems such as poaching, disease control, and even sabotage. Most growers, however, are optimistic and believe that they will be able to expand production significantly and hope to harvest up to 2,700 t by 1990. Based on current results, this projection may be overly optimistic. NMFS believes that production is unlikely to exceed 500 t by 1990.

The Belizean Government and foreign financial groups have played key roles in the early development of the country's shrimp culture industry. The Government has established a Mariculture Unit within its Fisheries Department to oversee and aid shrimp farmers, who are eligible for fiscal incentives such as import duty exemptions and tax holidays. The Government has also announced plans to provide training and loans to help small operators build ponds and buy equipment. About $6.5 million has been invested in the industry so far and an additional $11.5 million investment is planned. About 95 percent of that total has come from foreign sources, primarily the United States. Swiss financiers have recently offered U.S. investors a $10-million loan secured by the Italian export-guarantee group, SACE. The loan would be for a new shrimp farm near Independence. The World Bank is also helping to finance the shrimp industry through a $9 million credit to Belize. About 15 percent of the Bank's credit will be available through Belizean banks for shrimp culture development and technical assistance programs for small farmers. Additional funds will be made available contingent upon successful production. Growers in Belize report that pond construction costs are quite low, averaging about $3,400 per ha, but some observers believe actual costs may be higher.

## II. COSTA RICA:

Several groups are convinced that the Costa Rica can develop a small shrimp culture industry for both marine and freshwater species, although the progress to date has not been promising. The negative experiences of two earlier projects which failed have made it difficult for current groups to obtain domestic credits. Even so, several new projects have been initiated. Some observers anticipate that by 1990 there might be about 200 ha of new ponds in operation, but harvests are unlikely to exceed 150 tons. Existing shrimp farms did not achieve commercial

harvests in 1986. Only small experimental harvests are expected in 1987. The development of the industry has been slower than in neighboring Panama. Local observers believe that the environmental conditions in Costa Rica, however, are as least as favorable, although one observer reports that land costs are higher. The Government estimates that 5,000-8,000 ha may be suitable for shrimp culture. This estimate may be overly optimistic as more work needs to be done on surveying potential sites. The U.S. AID mission in Costa Rica has contracted a study on Costa Rican shrimp culture, but the results are not yet available. While the country's full potential is still unknown, most observers believe that there are some excellent Pacific-coast sites that could be developed. These sites, however, are limited by the mountains running close to the Pacific Ocean, leaving only a narrow strip of coastal land.

Five marine shrimp culture projects are currently active in Costa Rica, all located along the Pacific coast. The best known project is the old Maricultura facility at Chomes near Puntarenas. **Maricultura** was jointly financed by the Costa Rican Development Corporation (CODESA), the World Bank's International Finance Corporation, private interests, and local banks. Maricultura built 130 ha of marine shrimp ponds and a hatchery to spawn wild-caught gravid females, but the company reported water quality problems, probably caused by the agricultural runoff flowing into the Gulf of Nicoya. The project lost money and closed in 1982. A Canadian company, Desourdy, bought the facilities in 1984 for about $0.5 million and plans to resume operations under the name of **Criadero Camarones de Chomes** (CCC). The company has reportedly repaired and stocked 40 ha of ponds with P. stylirostris, but has not yet initiated commercial operations. CCC is seeking additional investment capital (about $6 million), hoping to recondition about 110 ha of the existing 130 ha of ponds and build an additional 195 hectares. Some observers are critical of the design of the existing Maricultura facilities and the site selection, especially its acid sulfate soils. Four other projects are currently underway. **Camaronex**, also located at Chomes, is converting salt evaporation ponds, and plans a preliminary phase of 20 ha of ponds, 3 nursery ponds, and 6 growout ponds. **Cosechas Marinas** (CM), located near the resort town of Quepos, hopes to complete 70 ha of ponds in 1987 and achieve annual yields of 1.5 t per hectare. CM is affiliated with one of Costa Rica's principal meat packers. The CM project includes a hatchery, located near its farm on Isla Damas, that is designed to produce 70 million pl per year. **Fincas Marinas Golfiteras** (FMG) opened the southernmost project at Punto Zancudo near the southeastern end of Golfo Dulce. The farm, owned by Sea Farm Management — a Panamanian Company, began to build 200 ha of ponds in September 1986. They hoped to begin production with 25 ha of ponds and to achieve annual yields of 0.7-0.9 t per hectare. Unconfirmed reports received in mid-1987, however, indicate the company had closed its farm. One observer reports that FMG decided to build a large number of very small ponds (0.5 ha) which proved uneconomic. Construction costs reportedly exceeded

$15,000 per hectare. The company completed 13 ponds, but achieved disappointing yields from trial runs. **Acuapro** is planning an 11.5 ha project, including ponds to produce Artemia.

Several smaller Costa Rican projects are also underway. A cooperative is forming to culture shrimp, but no details are available. Other projects have begun to use old salt-producing ponds to culture shrimp. With the exception of one project owned by Arturo Alfaro, all of these projects have less than 10 ha of ponds in operation, but the total area of constructed ponds probably exceeds 100 hectares. Some of these projects include plans to produce Artemia. Costa Ricans are also trying to culture freshwater shrimp. The first freshwater shrimp project, Acuacultura, was built in Guanacaste Province and included 40 ha of ponds and a small hatchery. The project was also financed by CODESA, and while it reported some successful harvests, production costs were prohibitive, forcing the company to close. One of the principal problems was its location which required the drilling of deep wells and extensive pumping, sharply increasing production costs. Other problems included water quality at its hatchery and the increase in the price of Artemia imports when the value of the colon fell in 1982. There are also reportedly several farmers with small aquaculture projects culturing both freshwater finfish and shrimp, but no information is available on shrimp production.

Several groups are doing research work on shrimp culture. The Atlantic Coast Port Authority (JAPDEVA) has an experimental farm at Limon to assist private farmers. The Taiwan aid mission, based at nearby Finca Castro, is assisting the project. The Instituto Tecnologico de Costa Rica has an experimental freshwater shrimp project at San Carlos in northern Costa Rica which receives technical assistance from the Japanese Government. A private association (ASBANA) has been experimenting with freshwater shrimp since 1976 and currently operates experimental ponds and a hatchery.

**III. EL SALVADOR:**

Cultured shrimp production in El Salvador is just beginning, but government officials believe it to be one of the most promising medium-term investment opportunities in the fishing industry. Officials believe that the country could support a small shrimp culture industry. One estimate suggests that about 5,000 ha of land is particularly well-suited for shrimp ponds and another 15,000 ha of ponds could be built at acceptable sites. El Salvador's first shrimp farming project used salt-evaporation ponds. Farmers harvested about 100 t of shrimp in 1985 and 1986, mostly juvenile shrimp marketed locally. Three other farms are commencing operations in El Salvador and construction at two more sites was scheduled to begin in 1987. Four additional groups are studying possible investments. Known shrimp culture companies include: **Acuisal, Agromarina de El Salvador, Cultivos Agroindustriales, Crustaceos del Pacifico, Hermanos**

**Penado Alvarado, Promotora Puerto Arturo, Rey del Golfo, Sociedad Monte Verde, and Surge.** The Salvadoran farms tend to be small, but most owners plan to expand if preliminary operations prove successful. About 50 ha of ponds was operating in 1987 and the total area of ponds will probably not exceed 250 ha by 1990.[2/] Growers are using P. vannamei, P. stylirostris, and M. rosenbergii. Four small hatcheries currently operate in El Salvador, mostly for freshwater shrimp. Three are producing freshwater shrimp pl on an experimental basis: Aquisal, Surge, and the Salvadoran Fisheries Development Center, (CENDEPESCA). Crustaceos del Pacifico is the only hatchery handling marine shrimp.

Salvadoran law provides certain incentives to promote the industry's growth, such as duty exemptions on the importation of machinery, equipment, and other needed items. Shrimp farmers also qualify for benefits available under an export promotion law. The industry is being promoted by the Centro de Desarrollo Pesquero. The Foundation for Economics and Social Development (FESD) and U.S. AID are cosponsoring a $0.5 million feasibility study on a Salvadoran shrimp culture industry and its potential environmental impact.

Several factors could pose difficulties to the rapid expansion of the Salvadoran shrimp culture industry. The current overvaluation of the Salvadoran colon and governmental tax policies have caused an increase in the amount of shrimp smuggled to Honduras. It is estimated that 20 to 30 percent of total Salvadoran shrimp production is unreported because of this illicit trade. Overfishing of shrimp stocks could adversely affect the supply of postlarvae. The strong highseas shrimping lobby in El Salvador has defeated several efforts to restrict shrimp fishing. The Government would like to implement a closed season between July and September, the primary reproductive months for shrimp in El Salvador. The fishermen, however, are not convinced they would benefit from such a closure. The country's insurgency problem also continues to impede rural development projects.

## IV. GUATEMALA:

Guatemala is emerging as one of the leading Central American shrimp culture countries. The industry is currently expanding more rapidly in Guatemala than any other Central American country. Guatemalan shrimp farmers report steady progress in developing a small, but viable shrimp culture industry. Farmers harvested 530 t of shrimp in 1985, and 620 t in 1986. Future projections are unknown, but available information suggests that production will increase steadily over the next few years. Among factors which could adversely affect the industry's development are possible guerrilla activity and the widespread use of insecticides, especially by cotton farmers.

Guatemala currently has 12 shrimp farms, all located along the Pacific coast. Six of the farms have pond areas exceeding 50 hectares. Total pond area has increased from 300 ha in 1984 to over 630 ha in 1987. Most farms are near Champerico, Chiquimulilla, Escuintla, and Retalheleu. The three largest marine shrimp farms (**Agua Industrias Mar Azul, Mayasal, and Granjas Marinas**) have approximately 100 ha of ponds each. Other important farms include **Marpasa** (84 ha), **Acopolon** (93 ha), **Aguas Marinas de Guatemala** (50 ha), and **Agro-Maricultura** (35 ha). Another company, **Pesca**, one of the country's major established shrimp companies, is planning to build a shrimp farm. Some of these projects have achieved excellent results. The new Acopolon farm, for example, reported initial yields of 0.8 t per ha which it seeks to increase to 1.6 t per hectare. The company hopes to average close to three harvests annually. Most farms are planning to expand. U.S. investors participate in several companies. One U.S. investor is currently considering a $2-million shrimp culture project. One company (**Aquafana**) cultures freshwater shrimp at Escuintla using Taiwanese technology. Most marine shrimp farmers are using P. vannamei and to a lesser extent P. stylirostris. One company (Aquafana) cultures freshwater shrimp at Escuintla using Taiwan technology. No current information, however, is available on the company. Several small operators are also believed to be culturing freshwater shrimp. Guatemalan shrimp farmers report annual yields from 0.5 to 1.1 t of shrimp per year, based on the normal practice of harvesting two crops per year. There are no operational marine shrimp hatcheries in Guatemala, although **Continental Fisheries** is about to open one. Two private freshwater hatcheries operation at Retalhuleu and Santa Rosa and the Government has proposed building both freshwater and marine hatcheries at Amatitlan.

The Government recognizes the potential economic benefits of developing a shrimp culture industry and has provided free technical assistance to farmers. Japan is assisting the Guatemalan Government. No special programs exist for financing shrimp culture projects, but industries classified as new or decentralized can obtain tax benefits and import concessions.

**V. HONDURAS:**

The first shrimp culture trials in Honduras were begun in 1968. Following these trial runs, Sea Farms of Honduras opened a farm at Choluteca near the Pacific coast in 1973. Honduras now has seven commercial shrimp farms and about 20 small farms operated by campesinos. The Government has authorized the construction of approximately 2,500 ha of ponds, about 1,600 ha of which are already in operation. Almost all of these ponds are believed to be along the Pacific coast where a natural supply of P. vannamei pl and a variety of environmental conditions (large tidal exchanges, extensive, little used salt flats, and other factors) have attracted shrimp farmers. The harvest has increased from 600 t in 1985 to

1,100 t in 1986. Observers are predicting another good harvest in 1987, perhaps as much as 1,500 tons. No long-term projections are available, but at current growth rates a harvest of about 3,000 t by 1990 seems likely. There was reportedly no unused capacity in 1987, although some of the most recently constructed ponds are not yet in operation because of a shortage of working capital and expertise. Government officials believe that up to 10,000 ha of ponds could be built in Honduras. The better farms realize annual yields of over 1.4 t per ha, but many farmers report substantially lower yields. Some small farmers, using primitive 2-10 ha ponds — some of which have been built with manual labor, harvest about 0.2-0.4 t per ha in 3-4 months, but most of these small farmers are only able to harvest one crop annually because their lack of pumps limits the use of the ponds to the rainy season. Larger farms which have pumps report yields of 1.0-1.5 t of shrimp per year. One report suggests production costs of about $4.00 per kg, but it is not clear if that is the fully loaded cost, including both operating costs and underlying mortgages.

Several companies are active in Honduras, culturing primarily marine species. The largest shrimp culture company is **Granjas Marinas San Bernardo** (GMSB) which currently operates 500 ha of ponds and plans to build 500 ha more. GMSB is developing some of these ponds in a joint venture with Sea Farms. **Sea Farms**, one of the industry leaders, currently operates 250 ha of marine shrimp ponds and has begun the construction of a new 400-ha farm. The company has been forced, however, to close its freshwater shrimp farm because of high pesticide levels in the water supply. Other marine shrimp farms include: **Salinas de Honduras** (280 ha), **Cultivos Marinos** (260 ha), and **Acuicultura Fonseca** (200 ha). Marine shrimp farmers use P. vannamei and P. stylirostris, often mixing the two in various proportions.[3/] One company, **Aquafinca**, at La Lima near the Caribbean coast was also culturing freshwater shrimp. Aquafinca was started by General Mills (Red Lobster) which sold it to Honduran investors in 1983. The Hondurans, however, decided to close the farm in 1985. While technically successful, they concluded that the U.S. market for freshwater shrimp was not large enough to support a successful commercial operation.

Honduran companies have not yet established a successful hatchery and, as a result, shrimp farmers are dependent on wild shrimp stocks for postlarval seedstock. Sea Farms built a hatchery in the 1960s, but it has been closed since 1981. Pl to stock the ponds are currently collected in the wild. The lack of hatchery-produced pl is one factor restricting the development of farms along the country's more extensive Caribbean coast.

The Government provides some assistance to shrimp farmers. The export promotion program offers some benefits to exporters of non-traditional products, which include farmed shrimp. Exporters receive certificates for 15 percent of the

value of their exports which can be applied against taxes. Other benefits include exemption from import duties on heavy equipment, 5-year income-tax exemptions, and special low-interest government loans.

## VI. MEXICO:

Mexico has one of Latin American's most significant potential for shrimp aquaculture, but has lagged behind other countries in the region. Some reports suggest that the industry in Mexico may be as much as 10 years behind Ecuador and some other Latin American countries. As a result, Ecuador replaced Mexico in 1987 as the principal supplier of shrimp to the U.S. market. Mexico's failure to keep pace in the development of a shrimp culture industry has occurred despite the availability of large areas along both the Pacific and Gulf of Mexico coasts ideally suited for shrimp culture. One report estimates that up to 470,000 ha of coastal land could be devoted to marine shrimp culture, but no detailed site survey of these potential areas has been conducted to confirm this exceptionally large estimate.

Several factors explain Mexico's failure to participate fully in Latin America's shrimp culture boom. One critical factor is the northern latitude of Mexico. Temperatures fall sharply in the northern states, especially during the winter months.[4/] Even with careful control of pl it is unlikely that farms based in the northernmost states could achieve two annual harvests.[5/] While current shrimp price levels might justify building ponds where only one crop per year could be harvested, in the long run two harvests are critical if Mexico is to compete economically with the increasingly efficient shrimp culture industries developing in many tropical countries. SEPESCA believes, for example, that even as far south as Sinaloa, farmers may be able to harvest only one crop per year. SEPESCA estimates that over two thirds of the available sites are in areas where climate may restrict farms to only one annual crop.

Mexico's legal and institutional framework is major bottleneck discouraging the development of an important shrimp culture industry. Mexican law has prevented private investors, both domestic and foreign, from participating in the industry. The 1972 Fisheries Development Law reserved development of the country's shrimp resources to cooperative societies. The law has been interpreted as reserving not only marine shrimp fishing, but also shrimp aquaculture to the cooperatives. The law was revised in 1986, but marine shrimp culture continues to be reserved exclusively to the social sector — cooperatives and other communal organizations such as ejidos[6/]. The Government did address the issue of aquaculture in the revised 1986 fisheries law and several changes were made to attract private investment. It is too early, however, to determine the full impact of these changes. The most significant seems to be a provision making it possible for groups, even family groups, to form special new cooperatives to culture shrimp. Two such groups have already been formed. SEPESCA is also considering a plan

which would allow private individuals to associate with cooperatives in order to help with financing. President De la Madrid has publicly advocated a role for private investors in Mexico's shrimp culture industry. Considerable optimism has been aroused in the private sector, but it is still unclear if the changes will permit private investors to enter the industry in significant numbers.

Mexico's basic legal and institutional framework continues to prohibit private corporations from culturing shrimp. Paradoxically, those organizations that are authorized to culture shrimp (cooperatives and ejidos), do not seem to have the managerial and technical capabilities needed for a technically advanced operation such as shrimp culture. Whether the cooperatives will be able to compete with the efficiently operated industry emerging elsewhere in Latin American and in Asia is uncertain. Mexican fishery cooperatives have tended to view shrimp culture as a threat rather than an opportunity. Also, shrimp farming requires a major shift of the fishermen's life style and job skills. It is probably not realistic to expect men who have made their living for years capturing shrimp at sea to suddenly alter their mind set, work fixed schedules, change their residences, adapt to new working conditions, and invest their earnings in a technologically demanding enterprise which has yet to be fully tested in Mexico. The problem is further complicated by the economic difficulties of the social sector. It is unlikely that either cooperatives or ejidos will be able to command commercial credits, although government ownership of the banks means that the Government could decide to subsidize the cooperatives and ejidos by authorizing loans.[7/] Any purely economic assessment, however, would rank most cooperatives and ejidos as poor credit risks.[8/] The shrimp cooperatives are already deeply indebted. Ejidos and other communal groups have title to extensive coastal areas, and probably control more than 75 percent of the sites best suited for shrimp farms. Ejidos can not use their land holdings, however, as collateral to secure loans for financing shrimp culture projects. The Mexican Constitution of 1917 conferred land to the ejidos under an inalienable grant establishing their land tenure which makes it impossible to use the land as collateral to obtain credits. As a result, the groups authorized to culture shrimp have shown relatively little interest or capability to do so. The few cooperatives which have expressed an interest have had difficulty obtaining credits.

The exclusion of foreign investors has had an especially negative impact on the development of the industry in Mexico by impeding access to needed foreign technology and credits. In the past, there has been considerable foreign interest in participating in the industry's development, principally by Japan and the United States. The Japanese did some work on shrimp culture in the 1960s, but withdrew in 1972 after the Fisheries Development Law was enacted. U.S. investors have also been discouraged. In a joint project between the Coca Cola Corporation, the University of Sonora, and the University of Arizona, a promising shrimp culture project was built at Puerto Penasco, conceived as the most technologically

advanced shrimp culture project in Latin America. The joint project, initially designed to intensively culture P. stylirostris, was disbanded in 1981 over a dispute concerning the distribution of postlarvae. The project's operations were further impaired when the Secretariat of Fisheries (SEPESCA) determined that the Mexican group that continued the Puerto Penasco project could not legally culture shrimp because the species was reserved for the cooperatives. The Puerto Penasco project has continued to function on a limited scale, however, as a research facility and a hatchery producing P. stylirostris pl, but it has had little impact on the development of the country's shrimp culture industry.

Legal problems have also caused problems within the domestic social sector that have impeded the industry's development. Shrimp cooperatives and ejido societies have long been at odds concerning their respective rights to participate in the country's lucrative shrimp fishery. This long-simmering dispute has continued with shrimp farming. SEPESCA believes that the new 1986 Fisheries Law will resolve those problems, but some Mexican observers believe that it may even increase disputes because both the established shrimp fishing cooperatives and the ejidos object to the newly formed shrimp culture cooperatives. SEPESCA also hopes that the new law will attract foreign capital and technology, but that is also unclear. What is clear is that as a result of these legal impediments, the industry has not developed as rapidly in Mexico as in other countries. Without private investment and foreign technology, the industry has lagged behind its competitors in Ecuador and other countries. Whether the recent changes in Mexican regulations and SEPESCA's new national shrimp culture project will reverse that trend remains to be seen.

The Mexican Government's role in the industry, as it is now structured, is critical — given the exclusion of private investors. The industry's development will require extensive financing and support from the already financially pressed Mexican Government as long as the existing legal system is in force. SEPESCA conducts one of Latin America's largest aquaculture programs. Shrimp aquaculture was initially a minor part of that program, but since 1985 SEPESCA has given increased priority to shrimp culture. Mexican officials have reportedly become concerned about the increasing competition experienced by Mexican shrimp exports on world markets. Mexico's energetic Fisheries Secretary, Pedro Ojeda Paullada, is determined to maintain Mexico's status as the leading supplier to the U.S. market and described his plans for a massive 7-year (1987-94) Programa Nacional de Cultivo de Camaron (PNCC) at the inaugural session of a shrimp culture seminar in July 1987. SEPESCA has subsequently released details on the 650-billion peso program,[9/] designed to create a major shrimp culture industry by 1994. The PNCC calls for the construction of over 70,000 ha of ponds, producing 61,000 t of shrimp annually by 1994. The plan is the most ambitious ever conceived by a Latin American country.

The Mexican Government's financing will be a key element in the PNCC. The PNCC requires major investments by Mexican banks, development foundations, and various Government agencies.[10/] The Mexican Banco Nacional Pesquero y Portuario (BANPESCA) is the principal Mexican institution funding fishery projects. BANPESCA first began to finance shrimp culture projects in 1983, but only began to make major credits available in 1985. Other Government institutions that will play an important role in financing the program include: FICART, FIRA, and BANRURAL. Government-owned commercial banks such as BANCOMER may also play important roles. Some critics question whether the PNCC can be fully funded given Mexico's current economic difficulties. The U.S. Embassy in Mexico City reports that the Government is taking several steps to ensure that needed loan capital will be available to finance a rapid expansion of the industry. Mexico's serious economic difficulties, however, will make it difficult for the Government to fully fund the PNCC. Some Mexican experts believe that, based on previous experiences, credits to the cooperatives may prove to be loans in name only and that the Government is unlikely to recover the true cost of the loans. In past years, the Mexican Government has had to write off millions of dollars in credits to the cooperatives.

The rapid expansion of the industry is drawing the interest of many companies interested in supplying materials and services. One U.S. company, Aqua Mana Aquatic Feeds, plans to build a shrimp feed plant at Guaymas to take advantage of the market created by the new industry.

SEPESCA believes that the Pacific coast states will be the center of the country's shrimp culture industry. About 80 percent of existing Mexican shrimp ponds are located in the Pacific coast state of Sinaloa which has the greatest potential of any single state. Some farms have been built in eight other Pacific and Gulf of Mexico states as well. Pacific coast shrimp farmers are also excited about the potential in Nayarit, Oaxaxa, and Sonora States. Most of the Gulf of Mexico coast ponds are in Tamaulipas, reflecting the interest of that State Government, but some observers are concerned that Tamaulipas growers may face the same climatic problems faced by shrimp farmers in Texas. About 90 percent of Mexico's shrimp farms are being built on ejido lands.

Shrimp cooperatives began to experiment with shrimp culture in 1972 by enclosing estuarine areas in Sinaloa. The first Ecuadorean-style extensive ponds were built in 1980. Mexico has reported significant pond construction programs during the past few years. In 1985, there were only 16 shrimp farms in Mexico with about 1,000 ha of ponds. The Government's decision to promote the industry resulted in the creation of many new farms in 1986. One report suggests that construction costs total about $5,000 per hectare.[11/] SEPESCA reports that by 1987 a total of 64 shrimp farms with 5,300 ha of ponds were in operation or under construction. SEPESCA has received requests to approve another 148 projects

which 300 projects are in the formative stage. Pond harvests have increased from about 100 t in 1983 to 1,400 t in 1986, reflecting the Government's expanded role in promoting the industry. SEPESCA projects a 1987 harvest of 2,300 tons, but no harvest data exist to confirm this. SEPESCA hopes that over 20,000 t of shrimp can be harvested by 1990. Future projections are difficult to evaluate, but many observers are sceptical about Mexico's ability to achieve its 20,000 t goal by 1990 as provided in the PNCC. The experience of other Latin American countries in the early stages of the development of their shrimp culture industry, suggests that even a harvest of 4,000 t by 1990 would be an impressive achievement.

Some observers are concerned about the Government's shrimp culture program, calling it a poorly conceived, crash program. Some doubt that sufficient credits are available to adequately finance it. Other critics contend that few Mexicans have experience with shrimp culture or the necessary background to design and build such a large number of farms in such a short time. Mexico has trained a substantial number of technicians. One SEPESCA reports that a special shrimp-culture training program, initiated in 1984, has trained more than 220 individuals. Few of these individuals, however, have the experience needed to adequately support the massive expansion program planned by SEPESCA. Preliminary reports suggest that many farms are already experiencing difficulties resulting from site selection and design problems. Reports from Tamaulipas, for example, indicate that only one of the five shrimp farms in that state is functioning. Information concerning the more important state of Sinaloa, however, is not available. The results to be expected from the new farms are unclear. Based on the experience of other Latin American countries, it would be quite an impressive accomplishment if Mexico had 10,000 ha of functioning shrimp ponds by 1990. The PNCC, however, calls for building an astonishing average of 9,000 ha of ponds each year between 1987 and 1994.

The yields to be expected from Mexican growers is not yet known, Given the limited experience of Mexican shrimp farmers and the fact that SEPESCA is working primarily through cooperatives and ejidos, it is unlikely to anticipate annual yields averaging significantly above 0.4 t per year by 1990. On this basis, the Branch estimates that harvests of about 4,000 t could be conservatively expected by 1990. SEPESCA is projecting, however, much higher harvests, over 20,000 tons. Some of SEPESCA's past achievements, such as the development of a major tuna industry, would indicate that if the Mexican Government actively supports the industry, Mexico should be able to develop one of Latin America's most important shrimp culture industries. It is not clear, however, how rapidly the industry's development will occur, how profitable it will prove, or how much of an impact the existing institutional and legal structure will have. Many observers are convinced that developing the industry through existing cooperatives and ejidos will require years of direct or indirect government subsidies and other support.

A successful hatchery program will be a key element in developing a shrimp culture industry on the scale proposed by SEPESCA. If Mexico is to develop a major shrimp culture industry, it will have to supply farmers with a reliable year-round source of postlarvae. The need is especially critical along the Gulf of Mexico where native species have not proven suitable for pond culture. Several groups (**Acuacultivos del Pacifico, Acuacultora Campechana, Acualcultores de la Peninsula, Acuacultura Sud-Californiana, BIOTECMAR, Centro de Estudios Tecnologicos del Mar, Centro de Investigaciones Cientificas y Tecnologica de la Universidad de Sonora (CICTUS), Instituto Tecnologico y de Estudios Superiores de Monterrey (ITESM), SEPESCA, Tecuanillo, UAG, and the Universidad de Tamaulipas**) are operating or are building marine and/or freshwater hatcheries. The total annual capacity of these projects is only about 0.1 billion pl, only a small fraction of the 1.9 billion pl that SEPESCA estimates are needed by 1990. Even so, there is no real evidence that the above hatcheries can sustain production at even the 0.1 billion pl level. Problems have been reported at some existing hatcheries and construction of some of the hatcheries listed above has not yet been completed. In addition, several of the above hatcheries plan to produce P. californiensis pl, a species which has proven suitable for culture. SEPESCA Director General of Aquaculture, Ricardo Juarez Palacios, has announced plans to build a large number of new hatcheries. For the foreseeable future, however, the primary source of pl will be the collection in the estuaries by artisanal fishermen along the Pacific coast. Data on the natural availability of pl is incomplete, but SEPESCA reports that some preliminary work has been done. SEPESCA concludes that P. vannamei pl are available in huge quantities in Chiapas and on a smaller scale in Sinaloa during a substantial part of the year, but the situation in other potentially important shrimp culture states such as Nayarit and Sonora is not known.

While marine shrimp culture has been reserved to the cooperatives, private investors have been allowed to culture freshwater species. Several small freshwater farms have been built, but no one has yet reported great commercial success. Most farms are quite small. The new Las Acamayas farm in Veracruz, for example, has only 2.5 ha of ponds.

Various Mexican institutions are currently researching various aspects of shrimp culture, including work on hatcheries, semi-intensive and intensive methods, diet, diseases, Artemia, and natural pl availability. Some of the institutions involved include: Centro de Estudios Superiores de Sinaloa, Centro de Investigaciones Biologicas, CICTUS, CET del Mar, Centros Regionales de Investigaciones Pesqueras (Guaymas, Mazatlan, Puerto Morelos, Tampico, and Yucalpeten), Instituto Tecnologico del Mar, and the Universidad Autonoma de Guadalajara, Mexico, and Sinaloa.

## VII. NICARAGUA:

Nicaragua currently has no commercial shrimp culture projects. Research on penaeid shrimp culture began in 1975 along the Pacific coast with assistance from the Japanese Government. The Japanese research included work on both ponds and floating cages. The U.S. Domsea Company planned a $7-million project with the Instituto de Fomento Nacional (INFONAC) at Laguna de Perlas along the Caribbean coast in 1977, but decided against it. Technicians assessing Laguna de Perlas concluded that the limited tidal range and the lack of a Caribbean species suited for culture made the project infeasible. The Japanese withdrew their technical advisor in 1978 when the civil disorders made it impossible to continue the work underway at Padre Ramos. One private investor began to culture shrimp in 1978, but abandoned the farm in 1980 after experiencing little success, primarily because of inexperience in shrimp culture techniques. INFONAC studies the idea of using the fill resulting from dredging operations in the Laguna de Perlas to build enclosures within the Lagoon to culture P. schmitti. The attempt did not prove successful due to the inexperience of a foreign technician involved and the limited range of the tidal exchange. Private investors at Puerto Morazan near Estero Real in Chinandega Department during 1983 and 1984 attempted to use the system developed in Mexico of enclosing estuarine areas. The project was not successful commercially, primarily due to the inexperience of the individuals involved. The enclosures were subsequently turned the over to local residents who report only limited harvests. The Instituto Nicaraguense de la Pesca (INPESCA), which replaced INFONAC, however, still consider it to be a viable project. INPESCA believes that the "tapos" system developed in Mexico may be the best initial approach for Nicaragua. INPESCA has reported some initial success, but has been unable to pursue the project because of the level of hostilities in the frontier areas where INPESCA was conducting its studies. INPESCA believes that development of a shrimp culture industry is vital to the diversification of the country's fishing industry INPESCA is currently preparing plans to initiate a shrimp culture industry. Details are not available, but INPESCA officials report that will include a role for foreign investors. Most observers believe, however, that it will probably be several years before commercial-scale culture begins in the country, although artisanal fishermen harvest small amounts of shrimp in enclosed estuarine areas. INPESCA reported in 1985 that it signed an agreement with a Peruvian company, Empresa Langostinera Tumpis, to supply pl which were very scarce in Peru and Ecuador at the time. INPESCA hoped to earn about $1.5 million annually from the sale of pl, but problems with air transport caused considerable losses of postlarvae. It is not known if this project is currently active.

## VIII. PANAMA:

Several Panamanian companies and individuals have entered the shrimp culture industry. The first company began to culture shrimp in 1974 and approximately 20 companies are currently active.[12/] The industry is divided into three groups: large companies (Agromarina and CANASA), medium-sized farm operated by businessmen involved in other activities (Panlangosta and Mar Industria), and farmers who have built a few ponds. Most investors, with the exception of Agromarina, however, report that their shrimp farms have been, at best, only marginally profitable.[13/] Investors have reported several problems such as lack of suitable pl, higher costs for fuel and labor than competitors, and adverse government policies on allocating and taxing land, importing feed, and building hatcheries.

Additional sites are available in Panama for culturing shrimp, but estimates vary on the actual extent. Some observers estimate that the potential area available for shrimp pond construction could total as much as 19,000 ha, but this figure may be overly optimistic since it includes large mangrove areas which may not prove to be suitable sites or which the Government may choose to protect. Most observers believe that only about 9,000 ha of the available land are prime shrimp culture sites. Panama had about 2,500 ha of shrimp ponds in 1985 which growers increased to about 3,300 ha in 1987. Some observers believe that the area of ponds could expand to 5,000 ha by 1990. The majority of the land used for shrimp culture lies along the Pacific Coast in the low mangrove areas near Punta Chame and in the salt flats surrounding the Gulf of Parita. The major location of the existing ponds is at Aguadulce, but other possible Pacific-coast sites exist at Hoconcitos[14/], Felipillo, Chepo, and Darien. Some observers believe that ponds could also be built along the Caribbean coast, especially at Bocas del Toro. Land for shrimp farming is either privately owned or leased from the Government. Many groups complain about the Government's system of granting concessions, especially the complicated filing process and delays in obtaining approval from the many agencies involved.

Cultured shrimp is an important part of Panama's shrimp industry. Cultured harvests currently represent about 35 percent of the entire Panamanian white shrimp output and over 10 percent of the total shrimp production. The Directorate General of Marine Resources (DGMR) reports that the cultured shrimp harvest totaled only 1,250 t in 1986, decreasing from 1,500 t in 1985. There is considerable doubt, however, about the accuracy of these figures. Local sources suggest that the actual amount of cultured shrimp is substantially higher than indicated by the official statistics. Cultured shrimp are frequently mixed in with ocean-caught shrimp at the processing plants and are often not properly identified. The Government's statistics are based upon reports submitted by the processing

plants. One local observer stated that the Government's estimates are too low and that he doubted that farmed shrimp production declined in 1986. Panama's largest producer of cultured shrimp, Agromarina, alone reportedly harvested about 1,250 t of cultured shrimp in 1985 and about the same amount in 1986. Other companies have been less successful. Two of the three other major farms reported disappointing 1986 harvests, and one farm was reportedly shut down for a substantial period of time. Experts are optimistic that Panama's production of cultured shrimp could increase significantly by 1990. Growers plan to expand pond area and improve methods. Some observers believe that growers could produce 3,000 t of shrimp by 1990.

**Agromarina**, Panama's largest shrimp farm and a subsidiary of the U.S. Granada Corporation, is the pioneering shrimp culture company in Panama. The company operates about 640 ha of ponds at its Aguadulce farm, which produced 1,250 t of shrimp in 1986, and will have a harvest of 1,500 t in 1987. **CANASA** is Panama's second largest farm. This Mexican-owned company has over 450 ha of ponds. Unconfirmed reports indicate that CANASA experienced considerable production problems in 1986. CANASA was reportedly affected by serious viral problems. The other important farms **Panlangosta** and **Mar Industria** operate 275 and 200 ha of ponds respectively. The other companies with more than 25 ha of ponds are: **Camaronera del Pacifico, Camaronera El Nanzal, Charco de Camarones, Langostino Rub-Car, Los Guabinos, and Rachung**. One new project, **Compania Agricola Rio Bayano**, has built 40 ha of ponds and plans to culture both marine and freshwater shrimp.

Panamanian shrimp farmers report a variety of yields. The industry leader is Agromarina which in 1986 was achieving crops of about 0.8 t per hectare. The other growers report substantially lower yields, generally ranging from about 0.4 to 0.6 t per hectare, with with Palangosta and Rachung reporting the better yields. The growers also vary in how many crops per year they can harvest. Those growers with no or limited pumping capability have difficulty operating during the dry season.

The development of a reliable source of pl for farmers will be necessary if the industry is to expand. Inexpensive pl ($0.20-2.50) are available from artisanal collectors. These pls, however, have proven less satisfactory because the P. vannamei concentration tends to be low. Growers say that only about 20 percent of the pl available from collectors is P. vannamei and the percentage can be as low as 3 percent. Artisanal collectors have not developed some of the techniques acquired by Ecuadoreans for locating areas where pl with high P. vannamei concentrations can be collected[15/] and for delivering the pl to growers with few mortalities and in good condition. Panama produces a substantial part of its pl supply in hatcheries. The Agromarina hatchery is one of the most advanced in Latin America. Agromarina has been a regional leader in the development of

hatchery technology. The company produced 400 million P. vannamei pl, an average of approximately 35 million pl per month during 1986. About half of that amount is needed to stock Agromarina's ponds, while the other 200 million is exported, principally to Colombia, Ecuador, and the United States. Previously, the Government had restricted pl exports until the domestic pl demand had been met. Hatchery-produced pl tend to be more costly ($5-9 per 1,000) than pl collected in the wild. The Government at first discouraged the construction of private hatcheries, planning to build a large state-owned hatchery with French assistance, but the Government has since revised its plans and is currently encouraging private companies to build hatcheries. Panama currently has six hatcheries (Aquachame, Agromarina[16/], Agromar, CANASA, Granjas Marinas, and Palangosta) capable of producing about 1 billion pl per year which, according to some sources, is close to the existing demand.

The Panamanian Government has promoted the growth of the industry through technical assistance provided under its aquaculture program. The Government has tried to promote the entry of small-scale investors into the industry by encouraging the development of small shrimp farms. To achieve this, the Government has limited concessions on government-owned land to 200 hectares. Government officials, however, are now concerned that this policy may be seriously limiting the industry's expansion and are reevaluating it. Many small farms have problems because of the limited expertise of the small-scale growers. The Panamanian Government is also attempting to help the industry with financial assistance obtained from the the Inter-American Development Bank (IDB) in 1982. Credits are disbursed through the Banco Nacional de Panama (BNP). The BNP reports, however, that only $2.5 million of the $8.8 million available from the IDB credit has been disbursed. The BNP is now planning a second $4-million phase of its shrimp culture program which will provide funding to upgrade the Direccion Nacional de Acuacultura's (DINAAC) shrimp culture program. The IDB is financing the expansion of DINNAC's Enrique Ensenat Research Center in Aguadulce which will include additional ponds, an improved water supply system, a hatchery, nutrition research facilities, and an expanded chemical laboratory. DINAAC also hopes to expand its extension services to small scale shrimp farmers. The IDB is also financing the construction of an Artemia research and development center and is involved in a marine shrimp experimental training and developmental center, all situated in Aguadulce. DINAAC has also constructed small shrimp and fish farms and a research station with the assistance of the Taiwan Development Agency at Aguadulce which it uses primarily as a training center.

Many private investors, however, are critical of the Government's role in the industry. One of the most commonly heard charges is that the Government has assessed a "rental fee" on already issued concessions and that some municipal governments are collecting production taxes on harvests. Some growers criticize import regulations, charging that the Government's efforts to discourage imports

has forced them to purchase what they claim is inferior local feed at substantially higher prices. Panamanian shrimp farmers have also been adversely affected by the country's high fuel prices, reportedly some of the highest in Latin America. Many investors are also increasingly concerned about the growing political instability in Panama.

Several other important developments have occurred in recent years. Panamanian shrimp farmers use primarily marine species, but some work is also being done on freshwater shrimp. The Compania Agricola Rio Bayano reportedly opened one of the largest and most modern freshwater shrimp farms in Central America during 1987. A Panamanian company, Mariculture Management Services, has been established to offer consulting services to shrimp farmers. Another company, Nutricion Animal is producing shrimp feed along with other animal feeds. Various foreign companies are active in Panama. The most important has been the efforts of Ralston Purina which originally established Agromarina. Other countries, however, such as France, Germany, Italy, and Mexico are also active.

**CARIBBEAN ISLANDS**

The aquaculture industries of the Caribbean islands have lagged behind other Latin American countries. Several factors mitigate against the rapid development of aquaculture in the Caribbean. Unfavorable topography, limited available freshwater, shortages of both trained technicians and land suitable for pond construction, heavy competition for coastal land, seasonal storms (hurricanes), low tidal ranges, rapid evaporation, low nutrient content of available water, and lack of information have prevented the initiation of important shrimp and other aquaculture projects on most of the islands. Some islands, however, have promoted the industry and are reporting limited success (the Dominican Republic, Guadeloupe, Jamaica, Martinique, and Puerto Rico).

**IX. ANGUILLA:**

Anguilla, a low, flat island with extensive limestone deposits, has some salt ponds. There are no known shrimp farms on Anguilla. **Aquaculture Technologies** reportedly conducted hatchery research on marine shrimp and other species, but no current information is available on this operation.

**X. ANTIGUA:**

Antigua is a low, flat island with limestone and volcanic formations. Mangroves exist along some of the coast and about 17 percent of the island is arable. Antigua has one shrimp culture project, **Antigua Shrimpery** (ASL). The $1.1-million project is the only commercial marine shrimp project known to exist in the Lesser Antilles. ASL began trial runs in 1982 and obtained funds from AID, the Bank of

Antigua, and the Caribbean Food Corporation. The farm is located at Nonsuch Bay and has a quarantine/nursery laboratory, and six 2 ha growout ponds, supported by a 10-ha reservoir. ASL began commercial operations in 1985 using P. vannamei. The production was to be sold primarily in the local market. The owner conceived ASL as a pilot project for the Lesser Antilles, but has had difficulties and East Caribbean Flour Mills (a St. Vincent subsidiary of a Canadian company) has purchased majority ownership in ASL. The company has been tentatively renamed East Caribbean Maricultures Ltd. (ECML). The project, however, is currently inactive. ECML company is considering the use of the ASL site as a training center and a hatchery for a larger farm that it is planning on Haiti.

**XI. BAHAMAS:**

Two U.S. companies have attempted to culture marine shrimp in the Bahamas. **Morton Bahamas Ltd.** (MBL) has been conducting experimental culture operations on Great Inagua Island for 8 years. The company has used P. japonicus, stylirostris, and vannamei. Company officials report a variety of problems, especially the poor performance of pond-reared broodstock and high construction costs. Other problems included storms which destroyed ponds, cannibalism, and an infestation of predators. The farm and hatchery never began operating commercially. Company officials maintain, however, that their research demonstrated that penaeid shrimp can be successfully cultured in the Bahamas. The company cut back their activities in 1985 and temporarily suspended operations in 1987. MBL is continuing some work, however, on Artemia production. **Worldwide Protein Bahamas Ltd.** (a subsidiary of the Maritek Corporation) operates the other Bahamian project on Long Island. The 10,000-ha site with substantial infrastructure was purchased from the Diamond Crystal Salt Company in 1983 for $2 million. Diamond Crystal had 7,800 ha of salt ponds, some of which Maritek has altered and is using for its culture operations. The company is currently operating one pond with redfish broodstock, but as of September 1987, the shrimp ponds were not stocked. Maritek has constructed a seafood processing facility and cold store on the site. The company has reported considerable technical success with its experimental shrimp runs, achieving annual yields as high as 9 t per hectare, according to company spokesmen. Unlike most other Latin American growers, Maritek has adopted the intensive methods developed in Taiwan. The Bahamas, like many Caribbean islands, does not have large areas of low-cost land suitable for extensive shrimp culture, a key economic factor that made it possible to develop the industry on a vast scale in Ecuador and several Asian countries. Maritek plans to stock ponds with shrimp as part of its strategy of operating a combination redfish/shrimp farm. A freshwater shrimp project is reportedly in operation on Andros Island, but no details are available.

Some observers have projected shrimp harvests of over 1,000 t by 1990, but based on the failure of any group to initiate commercial operations and the limited amount of land available on most Bahamian islands, it is unlikely that this optimistic projection will be met. The future of cultured shrimp production in the Bahamas, as elsewhere in the Caribbean, will be significantly affected by the success of shrimp farmers in building hatcheries capable of supplying pl because the Bahamas does not have indigenous species suitable for culture. The Government has not actively promoted aquaculture, but has allowed duty-free concessions for the materials needed to set up farms and also for other items such as feed or spare needed parts.

**XII. BARBADOS:**

The island, low and flat with extensive limestone deposits and deep soils, has more freshwater resources than most other Caribbean islands and about 75 percent of the island is arable. There is no known shrimp culture project on Barbados, but the University of the West Indies is conducting some research.

**XIII. BRITISH VIRGIN ISLANDS:**

The British Virgin Islands are a small, clustered island group of low and hilly volcanic formations. Mangroves exist along some of the coast and there are salt ponds on Anegada Island. There are no known shrimp culture projects on the British Virgin Islands.

**XIV. CAYMAN ISLANDS:**

Cayman Turtle Farms has expressed an interest in shrimp culture, but there are no known farms currently culturing shrimp.

**XV. CUBA:**

Cuba has no commercial growout ponds in production. In the early 1980s, the Ministry of Fisheries (MIP) reportedly made marine shrimp culture its top aquaculture priority and 12 of 29 planned aquaculture centers were to be for shrimp culture. MIP began to research shrimp culture in 1980. Research has been conducted by both the Ministry of Fisheries (Centro de Investigaciones Pesqueros) and the University of Havana (Centro de Investigaciones Marinas). The first trial harvest was reported in 1982 at Tunas de Zaza along the southern coast of Santi Spiritus Province in central Cuba. Researchers there are conducting studies in five ponds totaling 4.8 hectares. Trial runs have yielded annual harvests of about 0.8-1.3 t per hectare. A national commission was created in 1983 to plan the development of a shrimp culture industry. Harvest data is unavailable from Cuba,

but one reports suggests that experimental operations yielded about 20 t in 1985. Officials had hoped to begin commercial production by 1987, but no such operations have yet been reported in the press. One Cuban specialist believes that the National Aquaculture Enterprise (ENACUI) will begin to make an important contribution to the island's shrimp industry by 1990. ENACUI has a special unit working on shrimp culture, the Unidad Presupuestada de Camaronicultura. Cuban technicians have been trained in France, Japan, and the Philippines. The Cubans have worked primarily with P. schmitti. Preliminary work on P. notialis proved unsuccessful. Some U.S. experts are skeptical about the suitability of P. schmitti for pond culture. U.S. researchers report that juvenile P. schmitti generally grow to about 14 grams and then stop growing. This tendency is still unexplained, but some biologists speculate that it may be a dietary problem. Resolving the P. schmitti growth problem could require a major research effort. Some South American growers have reported better results with P. schmitti, but the failure of large numbers of Caribbean-Atlantic coast growers to achieve successful commercial operations with this species, suggests that the technical problems associated with culturing the species remain unresolved. Small areas of Cuba's shrimping grounds are closed periodically so that broodstock can be collected. Cuban researcher, Melanio Borrego, believes that sufficient pl cannot be collected to adequately supply shrimp farmers. He believes that Cuba will need to develop hatcheries and reports some experimental successes with producing postlarvae. The 1986-87 drought reportedly affected some aquaculture projects, but it is not known if the shrimp aquaculture projects were among those affected.

**XVI. DOMINICA:**

Dominica has high, rugged volcanic peaks and varied soils, over 20 percent of which is arable. There are no known marine shrimp culture projects on the island, but Dominican Government officials in 1984 built small demonstration ponds to culture freshwater shrimp. The Ministry of Agriculture provided land and the farmers bought pl from hatcheries in Guadeloupe and French Guiana. The Organization of American States (OAS) provided technical assistance, training, and some equipment. Technicians were trained in Taiwan and a cooperative has been formed to operate the ponds. The international relief organization, CARE, is financing 95 percent of the cost of the project. One U.S. group is reportedly working on a project to culture Australian freshwater crayfish (Cherax tenuimanus).

**XVII. DOMINICAN REPUBLIC:**

The Dominican Government has initiated a dynamic aquaculture program and the country has emerged as the leading shrimp culture country in the Caribbean. Several groups have begun to culture shrimp, supported by government extension programs and over 30 farms are currently in operation, or under construction. A few growers had financial difficulties and were forced to close temporarily.

Dominican growers operated about 65 ha of ponds in 1985. Industry groups say that growers were operating about 200 ha of ponds by the end of 1986 and the Dominican Government reports that over 1,000 ha of pond were in operation or under construction by the end of 1987. Four farms, with a total of about 95 ha of ponds, use marine species (P. monodon, schmitti, and vannamei). Most growers are concentrating on freshwater shrimp and are using M. rosenbergii. Government officials report that indigenous freshwater species (M. acanthurus and carcinus) have not proven suitable for culture. Some growers are reportedly considering the culture of Louisiana crawfish.

Shrimp farmers are clustered at two centers on the island. Marine species are being cultured in the Montecristi area, the northwest region of the country near Haiti where 7,000 ha of mangrove estuaries provide good sites. Freshwater shrimp is being cultured primarily in the Bayaguana area northeast of Santo Domingo, a poor wet area where about half the country's freshwater shrimp farms are located. The Dominican Government reports that pond harvests grew steadily from 134 t in 1984 to 216 t in 1986, when 35 t of marine shrimp and 181 t of freshwater shrimp was produced. Many investors optimistically predict shrimp exports to the United States, but for the immediate future the country will probably continue to be a net shrimp importer to supply the country's important tourist trade.

Most Dominican freshwater farms are small, recently constructed family operations, but a few companies are emerging as industry leaders. **Marien** is the largest shrimp farm; it cultures marine and freshwater shrimp on 200 ha of ponds. **Isabel Aquacultura** (IA) is another of the larger operations with a marine shrimp farm at Isabel built by a Taiwan group. IA owns 70 ha of ponds on which it cultures P. monodon, schmitti, and vannamei. The company reportedly had to rebuild some ponds because of sandy soil and had only a few ponds in production during 1987. **Camaronera Dominicana** (CD) is currently the most sophisticated freshwater project and was designed by an Israeli group. The farm has elaborate arrangements for controlling water conditions and carp are rotated with the shrimp to maintain chemical balances in the soil. CD plans to build a system of reservoirs to recycle plankton-laden pond water. The project includes a packing plant. After harvest, the shrimp will be placed in a transfer tank for cleaning. They will then be killed with ice, sorted, and frozen within 10 minutes. The OAS has been financing a freshwater shrimp project in the Dominican Republic for several years and reports that the project is one its most successful ones in the Caribbean. The project has growout ponds and a hatchery. An OAS official stated that the main problem farmers currently face is disease control. CARE Dominica and U.S. AID attempted to assist the **Federacion Dominicana de Cooperativas de Ahorro, Credito, Servicios Multipes** (FEDOCOOP) to build pilot ponds near La Vega to

demonstrate shrimp culture technology to farmers, but the project was reportedly unsuccessful. The Government claims that site selection was the main problem. The water had low (acidic) pH levels, averaging only 4-5. Most participating farmers had only a few ha of ponds.

The development of hatcheries is critical to the country's shrimp culture industry, as is the case in other Atlantic-coast countries that do not have native marine and freshwater species performing well in ponds. The Dominican Republic has 10 operating hatcheries with 5 more under construction. Three of those 15 hatcheries are for marine species; all are in operation. The remaining 12 hatcheries are for freshwater shrimp. Isabel Aquacultura at its Montecristi facility produced about 2 million P. monodon and P. schmitti pl in 1986. The company is also experimenting with P. vannamei. Cultura Mar Caribe produces P. vannamei and P. stylirostris pl, mostly for export. DANSA currently produces freshwater shrimp, crab (Mithrax) and oyster pl, but plans to begin work on marine shrimp in the near future. Freshwater shrimp pl are obtained from local hatcheries.[17/] Most Dominican freshwater hatcheries are rudimentary; some were built in a variety of already existing structures. Even so, many are successfully producing postlarvae. One hatchery, built with a $3,000 investment in a chicken coop, claims to be producing 250,000 pl in a 40-day cycle.

The Government offers special incentives to shrimp growers through tax exemptions for equipment and other costs. Incentives are also available through an agriculture and fisheries development program (Law 311). The Government also provides some land concessions. Actual farms have been developed primarily by private investors. The Government, as part of its larger aquaculture program, operates an 8-ha experimental station which began to study shrimp culture and hatchery technology in 1981. The research continued through 1985 when the Government initiated its shrimp culture extension program. The Government also operates a 20-ha demonstration freshwater shrimp center in the south at Azva. The Taiwan Agricultural Technical Mission is assisting with the project. Several farmers have applied for Government development loans through FIDE in the Banco Central.

**XVIII. GRENADA:**

Grenada has high, rugged volcanic peaks with varied soils; nearly half of the island is arable. Grenada built demonstration ponds in 1984 for freshwater shrimp (M. rosenbergii) along the Grand Bras River. The OAS is assisting Grenada with the project.

## XIX. GUADELOUPE:

A Guadeloupe cooperative began freshwater shrimp culture in 1979 when it built a few ponds. Guadeloupe has an indigenous species of freshwater shrimp, but is culturing M. rosenbergii. Growers have increased pond area to 13 ha in 1983 and 46 ha in 1986. One successful cooperative is **Sica Guadeloupeene d'Aquaculture** (SICA). About 45 t of shrimp was harvested in 1986. Farmers currently report mean yields of 1.5 t per ha[18/] and hope to improve that yield to about 2.0 t per hectare. All harvested shrimp is sold locally; the island's important tourist trade provides a ready market. A pilot hatchery built with assistance from France-Aquaculture, a subsidiary of the French Centre National pour l'Exploitation des Oceans (CNEXO), produced small quantities of pl from 1983 to 1985, before a larger hatchery was built with aid from France-Aquaculture and the Institut Francais pour la Recherche et l'Exploitation de la Mer (IFREMER).[19/] The new hatchery, called SICA Aquacul, was completed in mid-1985 and has the capacity to produce 15 million pl per year. The hatchery reportedly produced 9 million pl in 1986 and production, which has been below capacity because of insufficient demand, may reach 15 million in 1987. The hatchery began exporting to Puerto Rico in 1986. Exports are expected to increase and the hatchery may be operated at full capacity in 1988. About 3.6 million pl were exported in 1986, primarily to Puerto Rico. Two private groups have also built small hatcheries, each producing between 1.2-2.0 million pl in 1986. The small hatcheries do not export. SICA anticipates that shrimp farmers will eventually expand into marine shrimp and plans to service that market as well.

## XX. HAITI:

Haiti does not yet have a cultured shrimp industry. Several foreign groups have reportedly assessed possible marine shrimp projects along both the northern and southern coasts. Investors are currently studying a possible $0.5 million, 100-ha shrimp farm at Grande Saline in the Artibonite area. A Canadian company, based in St. Vincent, has announced plans to build a farm in Haiti. The National Bank for Development, with OAS assistance, reportedly began a demonstration freshwater shrimp project in 1984, but no details are available on the outcome. The Dominican Republic Government, as part of its aquaculture project, has reportedly provided the Haitian Government some assistance on shrimp culture.

## XXI. JAMAICA:

Jamaican shrimp farmers are culturing freshwater shrimp. The principal company is **Aquaculture Jamaica Ltd.** (AJL). The company began operations in 1983 and has invested about $1.3 million. AJL currently operates a 13-ha farm at Savana-la-Mar. The company plans to build an additional 40 ha of ponds for

polyculture by 1988. The company reports annual yields of about 3.6 t per hectare.[20/] AJL harvested 19.5 t of shrimp in 1986, a 25 percent increase over the 14.5 t harvested in 1985. AJL officials hope to increase production to 90 t by 1990. The company reports strong profits from existing operation. Production costs total about $4.95-5.75 per kg and the company sales average about $9.80 per kilogram. Much of the harvest is consumed domestically in the island's hotels and tourist restaurants. AJL has a hatchery at Barton Isle, St. Elizabeth which it purchased from an Israeli company, Aquaculture Production Technology (APT).[21/] The hatchery produces about 3.6 million pl annually, but the company claims that it has the capacity to produce 6.0 million annually. Plans call for expanding the hatchery so that by 1988 production could be increased to 12 million pl annually. AJL not only supplies its own ponds from the hatchery, but exports both pl and broodstock. Two groups have built tilapia-freshwater shrimp polyculture farms in the Elim area: **Jamaica Broilers** and **Jamaica Agro Products** (JAP). Jamaican officials are optimistic about the industry's potential. One report suggests that there could be as many as 600 ha of ponds by 1990.

There are no marine shrimp farms in Jamaica. Jamaican officials report, however, that at least one foreign investor is currently studying the possibility of culturing marine shrimp on the island. Some coastal areas, especially along the island's southern coast, appear suitable for marine shrimp culture. AGRO 21, a Government development group, has done some work in surveying potential sites.

The Jamaican Government is receptive to foreign investment and encourages investing in sectors creating employment and generating export income. Prime Minister Seaga himself has publicized aquaculture investment opportunities in Jamaica. Tax holidays ranging between 5-9 years are offered to approved investors. The Government has also made 1,200 ha of land available for fish and shrimp aquaculture.

## XXII. MARTINIQUE:

The Martinique Regional Council (MRC) began a freshwater shrimp project in 1976. Government officials believe that Martinique, because of the limited availability of freshwater, will never have a large aquaculture industry. Investors have concluded that only particularly valuable species, such as shrimp, have potential. Some sugar cane growers have expressed interest in shrimp culture as a possible side line to their business. Martinique, like Guadeloupe, has an indigenous species of freshwater shrimp, but is culturing M. rosenbergii. A small hatchery using the "green water" production technique was built in the mid-1970s to supply pl for local growers. The hatchery was adapted to the "clear water" production method in 1979-80 with assistance from the IFREMER-France Aquaculture group. The hatchery is presently operated by a cooperative and produces about 9 million pl per year. The pl cost about $30 per 1,000 and growers are

stocking ponds at about 180,000 pl per ha on an annual basis. The IFREMER-France Aquaculture Group provides assistance to the growers who have formed cooperatives. Growers launched a pond construction program and the total area stocked increased from 9 ha in 1982 to about 42 ha in 1986. About 50 t of shrimp was harvested in 1986, all of which was sold on the local market. NMFS projects harvests of about 90 t in 1987 and 120 t in 1988.

**XXIII. MONTSERRAT:**

The island has high, rugged volcanic peaks with degraded volcanic soil and is about 20 percent arable. There are no known shrimp culture projects

**XXIV. PUERTO RICO:**

Puerto Rico currently has two freshwater shrimp farms; other earlier projects have closed down. One of them, the **Caribe King Shrimp Company**, closed after serious flood damage from two hurricanes in 3 years. The most important active farm, **Sabana Grande Prawn Farms Ltd.** (SGPF), began operating in 1983 as a limited partnership when it purchased and rehabilitated the 24 ponds built by **Shrimps Unlimited**. Operations began in 1984 when 8 ha of ponds were stocked with pl from a commercial hatchery in Honduras and harvesting began in 1985. After a year of pilot-scale operations, SGPF built a hatchery and 26 ha of additional ponds. SGPF harvested about 50 t in 1986 and plans to increase that to 90 t in 1987. The company currently operates 72 ponds totaling 34 ha, and plans to add another 24 ha by 1988, some of which are already under construction. When all of the 60 ha of ponds are in place, SGPF plans to harvest about 220 t annually. The company is also planning to expand into marine shrimp culture but that project is still in the embryonic phase. SGPF reports high yields which are improving every year. SGPF reportedly achieved annual yields of 3.2 t per ha in early 1987 and the company hopes to reach 4.0 t per ha by 1988. SGPF would eventually like to expand operations to about 60 hectares. The project is financed by a group of investors with some credits from the Puerto Rican Government. The second Puerto Rican project is a small farm owned by **Jesus V. Quiles** who also began operations in 1983. Production costs average about $8.80 per kg, but growers are hopeful that they can eventually lower costs to about $6.00. The total harvest was about 50 t in 1986 which should increase to almost 100 t in 1987. Several companies are currently considering shrimp culture investments in Puerto Rico. One U.S. company evaluated possible sites for a marine shrimp farm in Puerto Rico during 1985. The company reportedly identified a 160 ha site suitable for development. The farm will be called **Camaroneros de Puerto Rico** and will include 40 ha of growout ponds to culture P. vannamei. Another company, **CPR Inc.**, is considering a 160-ha farm to culture P. vannamei and P. schmitti. A local company, **Aquaculture Consulting and Development Corporation** (AQUACORP), is planning a marine shrimp farm along the northern coast near Arecibo. Foreign

companies, especially from Japan and Taiwan, have also studied the possibility of opening farms, although no details are available. Observers in Puerto Rico estimate that 150-250 ha of ponds may be built by 1990. Projecting future harvests is difficult as most of the Puerto Rican projects are still in the developmental stage. As a result. it is unlikely that annual harvests will exceed 350 t by 1990.

There are three hatcheries on Puerto Rico; SGPF, Golden Shrimp (GSC), and The University of Puerto Rico (UPR). The SGPF hatchery is the most important, producing about 12 million pl annually, mostly for its own ponds. GSC began operations in 1987 with assistance from SGPF and may eventually open a farm of its own. The UPR (Mayaguez Campus) has an experimental hatchery on Magueyes Island for research purposes. The hatcheries sell small amounts of pl for about $30 per 1,000 postlarvae.

The Puerto Rican Government provides some assistance to shrimp farmers. UPR is experimenting with freshwater shrimp through its hatchery and a field station at Lajas and has trained technicians from Puerto Rico and other Caribbean islands. The Government also provides a 90 percent, 10-year tax exemption. Limited government funds are available to help new projects obtain start up funds. The Puerto Rican Government also offers loan guarantees. The Government recognizes limited partnerships and passes losses directly to investors who can use their investment loss as a tax shelter. Detailed information on financing and tax benefits is available from the Corporation for the Development and Administration of the Marine, Lacustrine, and Fluvial Resources of Puerto Rico (CODREMAR).

The U.S. shrimp consulting company Aquacultural Concepts (ACI) is establishing a research station in Puerto Rico which will concentrate on a genetics program for selected breeding. ACI plans to use its Puerto Rico facility for joint ventures planned in the Dominican Republic, Haiti, Jamaica, and Trinidad.

**XXV. ST. KITTS:**

The island has high elevations with volcanic formations. About 40 percent of the gentle slopping land is arable. The **Leeward Islands Shrimp Company** (LISCO) began culturing marine shrimp with 3 ha of ponds on a site leased from a former salt producer in 1983, and plans to expand to 7 hectares. LISCO reported yields of 0.4 t of shrimp per ha in 1986. The LISCO facilities include a hatchery which produces P. vannamei postlarvae. LISCO officials claim that their hatchery has been extremely successful and is producing 20 times the pl needed. As a result, LISCO is exporting limited quantities of P. vannamei postlarvae. The OAS is reportedly sponsoring a demonstration project for freshwater shrimp.

**XXVI. ST. LUCIA:**

The island has high, rugged volcanic peaks. Nearly 30 percent of the land is arable. Some mangroves are found along the coast. There are no known shrimp culture projects.

**XXVII. ST. VINCENT AND THE GRENADINES:**

St. Vincent has some high, rugged peaks with volcanic formations. The soils are varied and about 50 percent of the land is arable. The Grenadines are a low, hilly, clustered island group with limestone formations and coastal mangroves. There are no known marine shrimp projects. One St. Vincent company, Canadian-owned East Caribbean Flour Mills, has shown an interest in the industry by taking over a farm on Antigua. The company has also announced plans to build a much larger farm on Haiti. The St. Vincent Government has reportedly conducted some trials of freshwater shrimp with assistance from Taiwan.

**XXVIII. TRINIDAD:**

Trinidad and Tobago has only one shrimp culture project, a pilot project to culture P. monodon. The construction of the first phase (1.5 ha of ponds) is underway. The project is an intensive farm patterned on the Taiwan system. The U.S. company, Aquacultural Concepts, is providing technical assistance. The Government has limited the project to a small first stage to evaluate the impact of the effluent on the Gulf of Paria. Trinidad officials are concerned about pollution levels in the Gulf, primarily because of Venezuelan industrial development along the Orionoco River which flows into the Gulf. The Government is reportedly studying another experimental project, but no information is available. Other private groups are reportedly studying possible projects. The OAS has also promoted the construction of some demonstration ponds for freshwater shrimp.

**XXIX. U.S. VIRGIN ISLANDS:**

The one known company involved in shrimp culture in the U.S. Virgin Islands, Maritek Corporation, has closed its hatchery on St. Croix. Maritek had planned to provide its shrimp farm in the Bahamas with pl from the St. Croix hatchery, but expected production levels were never achieved.

# SOUTH AMERICA

The Latin American countries with the greatest potential to culture shrimp (Ecuador, Brazil, Mexico, Colombia, and Peru) are all located in South America, except Mexico. Ecuador currently dominates the region's shrimp culture industry and over 90 percent of the cultured shrimp harvested by Latin Americans comes from South America. The South American countries will continue to dominate the Latin American shrimp culture industry because of the much larger area of suitable sites in those countries. The key unanswered question in South America is Brazil, which may have the potential to produce more shrimp than all the rest of South America combined. Several companies are actively culturing shrimp in Brazil, but they have not reported the same commercial success achieved by farmers along the Pacific coast. Several South American countries should report increases in shrimp harvests by 1990, but for the most part, these increases will probably be only a fraction of the massive harvests reported by Ecuador and several Asian countries. If and when Brazilian farmers perfect methods applicable to Atlantic-coast conditions, major increases in South American shrimp harvests will be possible.

## I. ARGENTINA:

Argentina has no shrimp culture projects. The country's temperate climate probably precludes either extensive or semi-intensive culture of marine shrimp. The Instituto Biologia Marina at Mar del Plata, however, did some research on two indigenous species, Hymenopenaeus muelleri and Artemesia longinaris during the 1970s.

## II. BOLIVIA:

Bolivia has no shrimp culture projects. Some observers believe that freshwater shrimp could be cultured in the tropical conditions of the country's Amazonian Basin. One U.S. researcher believes that the environmental conditions in the Amazonian Basin are also well-suited to culture Louisiana crawfish.

## III. BRAZIL:

Brazil may have the largest potential to culture shrimp of any country in Latin America, given its 12,000 km coastline and large natural shrimp resource. Many important conditions needed for the industry, such as large expanses of low-cost and uninhabited coastal land, tropical climate, and inexpensive labor, are present.

Brazil may have more potential sites than all the other South American countries combined. The best sites are believed to be located in the northeastern states (Amapa south to Bahia). No detailed survey of potential sites, however, has yet been conducted. One study by the State of Bahia suggests that 200,000 ha of shrimp ponds could be built in that State alone. Another study estimated that there may be up to 100,000 ha of sites in Rio Grande do Norte. While these estimates may be overly optimistic, even the most conservative estimates still suggest that the Northeast has at least 70,000 ha of prime potential sites. Various studies claim Brazil could produce anywhere from 0.3-1.0 million t of cultured shrimp annually if potential sites were fully developed. Such estimates, however, can only be treated as speculation, because shrimp culture is a fairly recent development in Brazil and no one yet knows the extent to which these large areas of potential sites can be developed as commercially viable farms.

Various Government agencies have been active in the industry's development. The Brazilian Government has been researching shrimp culture for over 10 years. One of the primary Government research groups working on marine shrimp is the Rio Grande State Agriculture and Livestock Research Center (EMPARN). Scientists at the Instituto de Pesquisas Agropecuaria de Pernambuco and the UFPE have worked on freshwater shrimp. The Superintendencia de Desenvolvimiento Pesquiero (SUDEPE) and other government institutions have also played an important role in promoting commercial development. In 1981, spurred by Government credits, the first commercial shrimp farms were built. By 1984, SUDEPE had provided almost $23 million in low-interest loans to support the industry. SUDEPE has also obtained funds from foreign donors, primarily the IDB. The IDB has provided about $15 million to the Brazilian Government to finance commercial shrimp culture projects as part of a much larger fisheries development program approved in 1980. By October 1986, over 40 SUDEPE-financed shrimp farms had been built with 3,500 ha of growout ponds.[1/] SUDEPE is now helping to finance the construction of an additional 6,000 hectares of ponds in 1987 and 12,000 hectares in 1988.[2/] One author claims that the availability of credit at concessionary terms has caused many growers to enter the borrow money and then pay insufficient attention to site selection, pond design, and building costs. For this reason, some Brazilian growers have reported construction costs as high as $21,000 per hectare. This may also explain some of the difficulties reported by many Brazilian farmers in the initial stages of the industry's development.[3/]

A few major companies dominate Brazil's marine shrimp culture industry, but some of these farms are experiencing technical and economic problems. Maricultura de Bahia (MB) recently built 230 ha of ponds giving it a total of 800 hectares. The company plans to build additional ponds and projects a total of 1,000 ha by 1988 and 2,000 ha by 1990. MB is one of the few Brazilian shrimp farms using semi-intensive methods. The company reintroduced P. vannamei to Brazil in 1984-85[4/] and is currently the largest producer of P. vannamei in the country. MB

is also culturing four other species. The company operates Brazil's largest hatchery which annually produces about 30 million P. vannamei pl, 15 million P. stylirostris pl, and 12 million P. monodon postlarvae. The hatchery accounts for 30 percent of Brazil's total pl production. MB harvested about 420 t of shrimp during the 1985-86 season. Recent reports suggest, however, that MB may be experiencing problems. Its hatchery was reportedly affected by viral disease outbreaks which has reduced output by about 80 percent. The Compania Brasiliera de Aquicultura (CBA) is one of the largest shrimp farms in Latin America. CBA took over the Compania Industrial do Rio Grande do Norte (CIRNE) which had been operating a farm for over 5 years. CBA cultures P. aztecus and P. japonicus on 700 ha of flooded lands near the city of Macau. Production was only 200 t in 1985-86 when the farm was still operated by CIRNE. CBA also operates a hatchery. Unconfirmed reports indicate, however, that CBA suspended shrimp culture operations in early 1987 claiming that salt production has become more profitable. Pesquiera do Reconcaba farms about 315 ha of ponds in Bahia and harvested more than 280 t of shrimp in 1986. Mariscos de Brasil in Maranhao State currently operates 350 hectares. The company plans to build another 100 hectares of ponds by 1988. Fazenda Camaroineira de Perises (FCP), located in Maranhao, operates 350 ha of ponds using semi-intensive methods. The company uses P. schmitti and operates a hatchery. Agroplan has about 500 hectares of ponds in 1986 and produces about 120 t of shrimp. The company plans to add another 100 ha of ponds by the end of 1987. Other important farms (over 100 ha) are operated in the states of Maranhao, Bahia, Piaui, Ceara, Sergipe, and Rio Grande do Norte. Many companies report a variety of operating and/or financial problems, and two of the earliest projects, CONVESCO (100 hectares) and PESCON (340 hectares), are being leased or are for sale.

Some biologists initially believed that imported P. japonicus would be the best species to culture because of early results in maturation, spawning, and pl production. Many of the first Brazilian growers, therefore, focused on that species. P. japonicus, however, has not performed as well as expected. Growers were especially disappointed with the yields. Most growers are gradually switching to other species, both indigenous and imported, although the author has received conflicting reports concerning the species favored by Brazilian growers. Indigenous species include P. aztecus, P. brasiliensis, schmitti, and subtilis. The U.S. Embassy in Brazilia reports that P. schmitti has been the preferred indigenous species, although P. subtilis was the most commonly used species in 1985 (14 farms). The imported species being cultured include P. monodon, stylirostris, and vannamei. P. vannamei is becoming increasingly popular with Brazilian farmers, especially in the more advanced farms, although it is not yet widely used.

Several groups are also planning to culture freshwater shrimp. One such company, Capiata Aquicultura, Comercio, e Exportacao Ltd. (CACEL) operates a hatchery and is building a farm in Alagoas State which it hopes will produce over

600 t of shrimp annually by 1990. Other freshwater farms are currently operating in Bahia, Pernambuco, and other states. Some of the more important companies are: Agro-Industrial do Vale do Sao Franciso, Aquamaris Aquicultura, AGROPLAN, and INCOPESCA.

Projecting current trends in Brazil is difficult. As in Ecuador, many Brazilian farms began with rustic extensive farming methods, achieving fairly low yields. As the industry develops, more farms are replacing this method and turning to semi-intensive operations to increase yields. One farm has reported annual yields of up to 2.0 t per hectare, but this is well above the industry average. The average annual yield for Brazilian shrimp farms is currently about 0.5 t per hectare, but many farmers are convinced they can increase these yields. Farmers report they can achieve of 2.5 harvests a year. Cultured shrimp production totaled only about 1,100 t in 1985. The author believes that Brazilian shrimp farmers could produce about 4,000 t of shrimp by 1990, provided they resolve some of their current technical problems and obtain adequate postlarvae. Other observers are more optimistic and believe that the 1990 production could be as high as 6,000 tons.

Hatchery technology is also developing despite the limited number of technicians. Brazil reportedly has at least 14 operational hatcheries, but pl production is still at relatively low levels and their current annual production, according to the U.S. Embassy, is only about 200 million postlarvae. MB produces about 30 percent of Brazil's hatchery-reared postlarvae. The species in greatest demand are P. schmitti and subtilis. At least four farms are reportedly working on P. vannamei. Other species of interest to growers include P. japonicus, monodon, and penicillatus. Brazilian farmers also purchase pl collected in the wild, but this limits the farms to indigenous species. A few hatcheries are producing freshwater shrimp postlarvae, including: the Empresa Pernambucana de Pesquisa Agropecuaria and the Fazenda Santa Helena Agropecuaria. Brazil is also developing the Artemia industry needed to supply the hatcheries. Local Artemia production began in 1977 and has had considerable success. Brazil until recently imported Artemia, but has now become a net exporter.

The future of the country's shrimp culture industry is uncertain. Information from Brazil is scarce and contradictory and it is difficult to assess the progress that the industry has made. Brazilian researchers themselves indicate difficulties in obtaining reliable current data. It is clear that some of the most important growers have encountered problems. The pioneering companies had little experience with shrimp culture and many of the original farms were either poorly designed or placed on ill chosen sites. As shrimp had never been cultured in Brazil before, no one had experience with operating under local conditions with indigenous species. The IDB has stopped a projected second stage of its loan program because of problems farmers have encountered and does not foresee any future shrimp culture loan programs. Most observers nevertheless still see a bright future for the

industry. Some specialists believe that technical problems, resulting from the failure of indigenous species to perform adequately in ponds, is the primary difficulty. Technical advances such as increased hatchery production of P. vannamei pl or development of feeds meeting the dietary needs of indigenous species, could rapidly change the situation. EMPARN is currently researching the nutritional requirements of native species, especially P. schmitti, so that commercial feed can be developed. Other observers also suggest that institutional and organizational confusion is another major reason for Brazil's current difficulties. While the industry is reporting difficulties, an increasing number of Brazilians are gaining experience and expanding their knowledge of culture methods and local conditions. Once the technical problems are resolved, a rapid expansion of the industry in Brazil is possible. A small number of growers reported their first profits in 1986 and 1987. The Government reports that as many as 60 new groups have applied for Government loans. SUDEPE and FAO are currently studying the industry to help resolve these problems.

**IV. CHILE:**

There are no known commercial shrimp culture projects in Chile. The cold coastal waters probably preclude the extensive or semi-intensive culture of marine shrimp. In addition, the northern coast is extremely arid and there is little freshwater available for adjusting salinities in ponds. Various university groups, however, have conducted some research. The Universidad del Norte at Coquimbo (UNC) has been researching the culture of freshwater shrimp and plans to begin a study hatchery maturation of marine shrimp (P. vannamei). The Universidad de Antofagasta is cooperating with the UNC penaeid maturation work and is also researching freshwater shrimp culture. The Universidad Arturo Prat's Manzanar Project includes a possible shrimp culture component.

**V. COLOMBIA:**

Colombia's current shrimp industry is dominated by the trawler fishermen who harvest over 95 percent of the country's shrimp. Colombian companies, however, have aggressively entered the shrimp culture industry, aided by the Instituto Nacional de Desarrollo de Recursos Naturales Renovables (INDERENA). The Government has provided low-cost, long-term loans of up to $1 million to qualified investors through the Fund for The Promotion of Colombian Exports (PROEXPO). The Colombian Water Resources Agency has also obtained $5-6 million from the World Bank to help fund shrimp culture projects. This government support and the involvement of some important Colombian companies is resulting in an explosive increase in pond construction. Colombia's first farms were built along the country's Caribbean coast near Cartagena where eight farms with 770 ha of ponds were operating in 1987. Ponds are also being built along the Pacific coast in the Tumaco area. Five farms are currently operating there with about 400 ha

of ponds.[5/] Another 12 farms are in various stages of construction along both coasts. Heavy precipitation levels and the lack of roads and other infrastructure along the relatively sparsely settled Pacific coast have so far slowed the development of additional Pacific-coast sites. Some observers believe, however, that the Pacific sites may eventually be the most productive ones. Local sources project that about 2,000 ha of ponds will be in place by the end of 1987, but many observers believe this projection overly optimistic. Industry sources think that, by 1990, Colombia may have about 7,000 ha of ponds; 4,000 ha along the Caribbean and 3,000 ha along the Pacific. More conservative observers believe that the total area of ponds will probably not exceed 4,000 ha by 1990 (3,000 ha along the Caribbean and 1,000 ha along the Pacific). Some are convinced that Colombia has the potential to become a major producer of cultured shrimp. One report suggested that Colombia could build up to 55,000 ha of shrimp ponds, but it was not based on detailed surveys of potential sites. Other observers question this report. An estimate prepared by the growers suggests that about 23,000 ha of ponds could be built (14,000 ha along the Caribbean and 9,000 ha along the Pacific).

The industry is dominated by small, family-oriented companies. The principal companies along the Caribbean coast are: Acuacultivos del Caribe, Acuipesca, Agro Soledad, Agromarina, Camarones de Uraba, Cartagenera de Acuacultura, Colombiana de Acuacultura, CULTIMAR, Langostinos Colombianos, and Santa Ana. The main Pacific coast companies are: Acuamar, Aquamatilde, Balboa, Exportadoras Cali, Inversiones Irurita, Maragricola, Nautilius, and PEXCO. Farmers are currently reporting production costs of about $4.00-$4.50 per kg and believe that they can be reduced with more experience.[6/] Many additional groups are studying possible shrimp culture projects. The first significant pond harvest was reported in 1984 and totaled only about 50 tons. Preliminary reports suggest that about 140 t was harvested in 1986. Industry sources project a harvest of more than 800 t for 1987, but that projection may be too optimistic. Most observers expect that with the continued expansion of pond area and the increasing technical capability of pond operators, harvests could reach 3,500 t by 1990.

The principal species being cultured is P. vannamei; some farmers also use P. occidentalis, schmitti, and stylirostris. Several Caribbean coast farmers have reported encouraging results with P. schmitti, especially in high-salinity water, but their enthusiasm has not been scientifically confirmed and is not shared by all growers. Commercially successful results with P. schmitti have not yet been demonstrated. Six groups are reportedly studying the possibility of farming freshwater shrimp.

Many farmers are building hatcheries because Caribbean-coast farms do not have access to wild stocks of P. vannamei. The author knows of 10 hatchery projects currently underway. Four hatcheries have been built along the Caribbean coast and three more are under construction. Three additional hatcheries are under

construction along the Pacific coast. Pl production was negligible in 1986, but by May 1988 companies hope to be producing appreciable numbers. One industry projection of 0.5 billion pl annually seems high, but there do appear to be several technically sound hatcheries in operation.

Colombian shrimp farmers have drawn primarily on foreign companies for technical assistance, but the Colombian Government has also conducted some research. INDERENA's research centers at Cartagena and Tumaco are working on shrimp culture. Technical assistance has been obtained primarily from various U.S. companies and the French Government. Companies have contracted for foreign assistance in farm design, culture methods, and hatchery construction. France-Aquaculture, for example, surveyed the potential for shrimp farms in the Uraba area in cooperation with the French international assistance agency (SOGREAH).

**VI. ECUADOR:**

Ecuador was the first Latin American country to culture shrimp and remains the pre-eminent shrimp culture country in the region. Ecuadorean shrimp farmers harvested over 80 percent of all the shrimp farmed in Latin America during 1986. The industry began by accident in 1962 when a farmer noticed shrimp in an enclosed coastal area which was flooded by an unusually high tide and conceived the idea of farming it. Small-scale experiments began, but the first commercial pond was not built until 1969. The initial stage of development was centered in the southern-most province of El Oro. The earliest ponds were extremely rustic extensive ponds relying on natural tidal and river flows for water exchange and to provide postlarval seedstock. At first, farmers built extremely large ponds which have subsequently proven difficult to manage. From that primitive beginning, the industry has expanded to become the country's principal non-petroleum export earner, providing about 140,000 jobs and producing about $400 million worth of shrimp.

A variety of factors have combined to produce ideal conditions for shrimp farmers in Ecuador. The warm tropical climate, the nutrient-rich water supplied by the Guayas River, important estuarine systems, natural stocks of the Pacific coast species best suited for culture, extensive coastal areas that were not utilized economically, inexpensive diesel fuel, and low wage rates have all made Ecuador the regional leader. The Ecuadorean Government has authorized the construction of 110,000 ha of ponds, about 60,000 ha of which were in production during 1986.[7/] Various specialists estimated in 1986 that, between 20,000-40,000 ha of additional land could be devoted to shrimp culture. Much of that area has now been developed and there is relatively little prime shrimp culture sites remaining to be developed in Ecuador.[8/] Unconfirmed reports suggest that as many as 90,000 ha of ponds may have been in operation by 1987. The Government has attempted

to restrict pond construction, but has had difficulty in enforcing the restriction. A complete list of Ecuadorean shrimp farmers is unavailable, but probably exceeds 1,300 companies and individual operators. Some of the major companies are: Empacadora Nacional, El Rosario, Exporklore, Promariscos, Frescamar, Bajen, and Estar. Shrimp farmers are reporting annual yields averaging about 0.8 t per hectare, but some of the better farms report yields of up to 2.5 t per hectare.

Ecuadorean farmers reported startling increases in harvests during 1986 and 1987. Pond harvests totaled 43,600 t in 1986, nearly a 50 percent increase over 1985 harvests. The sharp increase was primarily due to the greater availability of pl to stock the ponds. The unusually warm water resulting from the 1986-87 El Nino led to an abundance of wild postlarvae. Many hatchery projects also reported improved results. Due to the increased availability of pl, farmers in 1986 put unused ponds back into production. The resulting record harvests in 1986 encouraged the construction of even more new ponds. Growers have achieved a new record harvest in 1987. Preliminary data suggest that the 1987 pond harvest will total about 67,000 tons, significantly above previous projections. This estimate is based on available U.S. import data. Ecuadorean growers, as predicted have replaced Mexico as the most important supplier of shrimp to the United States.

Ecuadorean farmers report some of the lowest production costs in the world. Some farmers reportedly produced shrimp for as little as $2.50 per kg in 1986, but the industry wide average is probably about $3.00-4.00 per kilogram.[9/] The higher-cost farms are mostly modern ones, built after land values had increased, and employing more sophisticated pond design and methods. Their yields are approaching those typically achieved using semi-intensive methods. The higher operating costs at these farms (typically about 30 percent more) are compensated by the larger harvests possible with the more sophisticated methods. Some growers, however, have reported major increases in their costs during 1987, narrowing profit margins. The Government increased domestic fishmeal prices which caused feed prices to rise about 25 percent.[10/] The break in the country's trans-Andean oil pipeline and resulting loss of export revenue forced the Ecuadorean Government to take some difficult fiscal decisions. Fuel prices were increased by about 40 percent. Fuel and feed are two of the largest expenses for most farms. Labor costs have also increased. The only major cost to decline in 1987 was pl prices. Farmers were assisted, however, by the declining value of the Ecuadorean currency (the sucre) which depreciated even more than the U.S. dollar during 1987. Farmers were thus able to partially cover increasing sucre costs with the increased value of their foreign exchange earnings. Reports from Ecuador on profit margins vary widely. Some observers believe that despite the production cost increases and falling U.S. prices, many Ecuadorean growers still have reasonable profit margins. Other observers believe that Ecuadorean growers, especially new entrants with high investment bases, are now operating with very narrow margins.

The extraordinarily good 1987 harvests have helped, but many growers are reportedly concerned about the consequences of any future price declines on the U.S. market.

Officials are predicting bumper crops in 1988 and 1989, but other observers are more cautious. The massive production increases in 1986 and 1987 are due primarily to the extremely favorable climatic conditions and to a lesser extent, the construction of new ponds. While 1988 harvests may continue at high levels, it is unlikely that the rate of production increases will be as large as it was in 1986 and 1987. From May to October 1987, Ecuadorean shrimp shipments to the United States exceeded 4,000 t and almost reached 5,000 t in June 1987. Shipments fell below 4,000 t in November, but it is to early to dicern a trend into 1988. The end of the 1986-87 El Nino has brought relatively normal sea surface water to Ecuador. Current sea surface temperatures suggest that the shrimp pl will not be scare, but will not be as abundant in 1988 as they were in 1987. Growers will have access to hatchery-produced pl, but probably at prices well above average 1987 prices, increasing production costs. It is not yet clear if Ecuadorean exporters, even with adequate pl, can exceed the 5,000 t monthly limit. Some observers believe that Ecuador with current production methods may have reached a production plateau, at least for the near term. Some growers, especially those with foreign investment participation, report yields well above the national average, but there appears to have been no steady, industry-wide increase in yields since 1980. It would appear that most of the bumper 1986 and 1987 harvest has come from the greater availability of pl, enabling farmers to more fully use existing ponds and, in some cases, to construct new ponds. Relatively few Ecuadorean growers have substantially increased yields as a result of improvements in methods or modifications of pond design.[11/] Some observers believe that Ecuadorean farmers may have reached a production plateau and that without widespread improvements in methods, future harvests will not increase significantly. At existing production levels, Ecuadorean farmers theoretically have the potential to harvest about 80,000 t of shrimp annually, provided all ponds constructed by 1987 (110,000 ha) were in operation. Given the likely construction of some additional ponds, a 85,000 t shrimp harvest by 1990 would seem a reasonably conservative projection, given the availability of sufficient postlarval seedstock.[12/] While some more ponds may be built, Ecuador is probably reaching its maximum harvest capacity with existing methods. Ecuadorean growers may be eventually able to reach the 100,000 t production level, but are unlikely to do so until they begin to adopt more sophisticated methods.

Almost all Ecuadorean growers prefer to use P. vannamei and, to a much lesser extent, another indigenous species, P. stylirostris. Ecuadorean growers have not experimented extensively with other species, primarily because the two available indigenous species perform so well. Frescamar and some other growers are reportedly experimented with P. monodon. Details on the results of these

experiments are unavailable. Frescamar reported some P. monodon harvests in late 1986, but other companies have been generally disappointed with that species. At least one freshwater shrimp farm (160 hectares) has been built, but was reportedly damaged by the rains associated with the 1986-87 El Nino. Several groups are studying the feasibility of growing freshwater shrimp.

Although industry and government sources now believe that past problems with penaeid pl supply are near resolution, this may be an overly optimistic evaluation. Ecuador has confronted the pl supply problem by initiating the world's most extensive shrimp hatchery program. The Government has granted more than 100 permits to groups requesting permission to build hatcheries. About 80 groups have actually done so and nearly 75 percent of the newly constructed hatcheries were operational by the end of 1987. The planned production capacity of these hatcheries is about 9 billion pl per year.[13/] The hatcheries produced about 4 billion pl in 1987, double their 1986 production. The hatcheries are scattered all along the coast from Esmeraldas in the north to El Oro in the south. The center of the hatchery industry, however, is still "Hatchery Row" near Salinas, and to a lesser extent, Manta. The hatcheries vary in size, the largest being the Aqualab hatchery which has an installed capacity of 25 million pl per month. Most other hatcheries have capacities ranging from about 5 to 15 million pl per month. Several new hatcheries are smaller than the established ones because they are designed to supply only one farm or a small group of growers. Over half of 1987 pl production came from the 10 largest hatcheries.

Hatchery operators have made great progress in recent years and insist that they will be able to supply growers through any future pl shortage. It should be emphasized, however, that they have not yet demonstrated this capability. The pl required to stock 110,000 hectares of ponds is enormous. Estimates vary, but Ecuadorean shrimp farmers probably require over 12 billion pl annually.[14/] Only about 30 percent of Ecuador's pl seedstock is currently provided by hatcheries. Even if the hatcheries could supply growers during a future pl shortage, the increased cost of hatchery produced pl would still affect pond production.

Most Ecuadorean hatcheries still depend on natural cycles. Hatchery operators rely on fishermen to bring in berried females caught in the wild. They are thus still vulnerable to the same natural phenomena that have created postlarval shortages. Pl shortages are due to the natural shortage of berried females in the wild. The technological and managerial practices necessary to produce P. vannamei nauplii through maturation, however, have reportedly been perfected by several hatcheries. Personnel hired from the more advanced hatcheries have enabled technological advances to spread quickly throughout the industry. Most observers expect that the successes of the established hatcheries will be replicated in several of the newer projects. While the ability of these hatcheries to fully supply growers when

wild pl are unavailable has not yet been proven, it seems likely that the hatcheries should be able to supply enough pl to mitigate any reoccurrence of the severe shortages that occurred in 1985.

Many hatcheries have been adversely affected by the abundant supply of wild pl during 1987[15/] and the resulting lower pl prices. During the 1985 pl shortage, hatchery-produced pl brought as much as $25 per 1,000. By mid-1987, pl prices had declined to only $2.80 per 1,000 for wild pl and $4.40 for hatchery postlarvae. Many hatchery operators had based their economic projections on much higher prices. Hatchery owners hope that prices will increase once the current El Nino subsides and water temperatures cool.[16/] During late 1987, many hatcheries reduced production and some were forced to close down. Several hatcheries are reportedly for sale. Many highly-paid foreign biologists who worked in Ecuador developing the hatcheries have left Ecuador or are about to do so. An estimated 70 foreign biologists were working in Ecuadorean hatcheries during late 1986. About one-third of them resigned or were laid off during 1987. One unknown factor is the ability of locally trained personnel to replace these biologists if and when the hatcheries resume full-scale production levels.

Ecuadorean growers also debate the relative merits of wild and hatchery-produced seedstock. Growers have mixed opinions about the relative merits of hatchery and wild postlarvae. Many growers believe that wild pl is stronger and survives better, although this may be partially due to the inexact way that the quantities of pl purchased from the artisanal fishermen are calculated. Hatchery operators maintain that their pl, if properly handled, can perform as well as wild postlarvae. Hatchery pl can be purchased in more exact counts without incidental amounts of unwanted species. This will become an increasingly important factor as shrimp culture industries develop in other countries and competition intensifies.

Artemia needed to feed the larval shrimp is currently obtained abroad. Ecuadorean hatcheries imported about 4 t of Artemia in 1985 and some experts believe that the hatcheries will need 30-50 t by 1990. Ecuador may be able to develop its own Artemia production. One company, Ecuabras, attempted to culture Artemia intensively, but was unsuccessful. Ecuasal, a salt producer, is experimenting with possible Artemia production in its salt ponds.

The Government's role in the industry's development is difficult to assess. The Ecuadorean Government recognizes the shrimp culture industry as an important source of export earnings and employment and has attempted to promote its development. The Government provides low-interest loans for both farms and hatcheries and theoretically allows the hatcheries to import some equipment duty-free. Many growers say, however, that they can rarely take advantage of this provision. Exemption from import duties requires a permit which, according to many growers, can take months, if not years, to obtain. The Government has also

attempted to assist the industry by protecting the wild shrimp stocks by seasonally closing shrimp fishing and pl collection. The effect of these closures, however, has not yet been determined. The environmental impact of the extensive collection of pl is not well understood. The Government claims that the closures proved beneficial for the shrimp stocks. Many observers point to the Government's limited enforcement capability and doubt if the new regulations had any significant impact on the stocks. Despite these efforts to promote the industry, the full impact of the Government's activities has probably been to discourage the industry's growth. After 1982, restrictions on the conversion of export earnings diverted millions of dollars from the industry. Exporters earned bonuses, but they did not make up for the lost earnings because of the difference between the official and free-market exchange rates. The Government of President Febres Cordero has eliminated that gap and, as a result, smuggling and other illegal practices have declined. Such illegal practices continue, however, at a reduced level because some exporters continue under-invoicing their shipments to avoid income taxes. The U.S. Consulate General in Guayaquil estimates that allowing the exporters to convert dollar earnings at the free market rate has enabled the packing plants to pay growers $1.75 more per kg for 31-35 count shrimp, resulting in a major new infusion of capital to the industry. Private investors have also been encouraged by the Government's decision to decontrol interest rates.

Foreign investment and technical assistance, (primarily but not exclusively from Japan, France, and the United States), have played a key role in the industry's development, even though the industry was initiated by Ecuadoreans. U.S. investment alone possibly exceeds $300 million. Companies, financed or managed by foreign owners, control the shrimp export business, shrimp food and fertilizers , many semi-intensive farms, and some of the most successful hatcheries. Ecuadorean law limits foreign ownership to 49 percent.[17/]

The Ecuadorean shrimp culture industry could be affected in the future by several different factors related to the coastal habitat. Fishery officials have been concerned for some time about the destruction of mangroves and commercial development in the coastal estuaries. Many biologists also worry about the long-term impact on the stocks of P. vannamei by removing the huge quantity of pl needed to stock the ponds. Collecting shrimp pl can also harm stocks of other species as pl collectors incidentally take a variety of other species naturally occurring along with the shrimp postlarvae. Still others are concerned about water quality. Ponds downstream of Guayaquil are reporting increasing quantities of untreated sewage being released into the Guayas River. The heavy use of agricultural chemicals in Ecuador is also affecting water quality. Rising levels of sewage and agricultural chemicals may eventually affect pond yields and the quality of the shrimp harvested. There is also a serious danger that the natural ecosystem could be affected by the pond effluent.[18/] Some specialists cite disease

control as a potentially serious problem and are concerned about the spread of exotic diseases to wild stocks. Any of these and a wide range of other habitat factors could seriously impact the pond shrimp industry in Ecuador.

**VII. FRENCH GUIANA:**

Guyana-Aquaculture (GA), the local subsidiary of CNEXO's France-Aquaculture group, began experimenting with freshwater shrimp culture in French Guiana during 1979. The first experimental pond was stocked in 1980 with pl obtained from Martinique. The results proved so successful that GA announced a 5-year development program to build 200 ha of ponds. GA began building a hatchery in 1982 capable of producing 12 million pl per year and expanded that capacity to 22 million pl in 1985. Farmers have constructed 64 ha of ponds which they hope to increase to 120 ha by 1987 or 1988.[19/] Production in 1986 was only about 9 million pl, primarily because of a lack of demand. About seven farms with pond areas ranging from 3.5 to 50.0 ha were operating in early 1987 and a much larger farm (over 100 ha) was under construction. Annual yields average 0.7 t per hectare. Only about 36 t of shrimp was harvested in 1986, but local observers expect large production increases in 1987 and 1988 because of the new pond construction and the increasing experience that farmers are gaining. The GA project is headed by Jean-Michel Griessenger, one of the CNEXO scientists who developed the "clear-water" hatchery technique.

The major difficulty is reportedly marketing as the local market is very limited. French Guiana has a population of only about 85,000 and almost no tourist trade, unlike the French Caribbean islands where freshwater shrimp is cultured. Growers on Guadeloupe and Martinique have strong local markets, but French Guiana growers will have to export most of their production, primarily to France. The first exports to France began in 1987.

INFREMER biologists at Kourou experimental station are studying shrimp culture and attempting to develop techniques to improve pond management. The research is concentrated on water control, fertilization, and aeration. No marine shrimp culture projects exist in French Guiana. The French Government helped finance studies on an indigenous species of brown shrimp (P. subtilis) in the late 1970s. The studies, conducted in estuaries near St. Laurens, were discontinued after 2 years. The French concluded that the species was unsuitable for pond culture. Private groups have assessed various sites in French Guiana, but none has yet decided to build a marine shrimp farm.

## VIII. GUYANA:

There are no shrimp culture projects in Guyana. The country does have a commercial shrimp fishery, however, which is one of the leading local industries and an important source of export earnings. Most observers believe that there are sites which could support a viable shrimp culture industry. One state corporation, the Guyana Sugar Corporation (GUYSUCO), plans to culture both Louisiana crawfish and freshwater shrimp. It has set aside about 80 ha of land for various aquaculture projects. GUYSUCO has already begun to culture crawfish. The project was initially delayed because officials were concerned that the crawfish could damage Guyana's important irrigation system. Apparently GUYSUCO determined that this concern was unfounded and imported 0.3 t of live crawfish from Louisiana in June 1987. About one-third of the June shipment died in transit and GUYSUCO subsequently arranged for an additional 0.15 t shipment. The crawfish are being cultured at the Blairmont Sugar Estate. GUYSUCO has also built several freshwater shrimp ponds and hopes to begin stocking them by 1988 with pl imported from Panama or other countries. A GUYSUCO technician will be trained in Panama. GUYSUCO plans include the construction of a freshwater shrimp hatchery in 1988.

The Guyana Government is trying to attract foreign investment. New measures announced in the 1987 budget are designed to attract potential investors. Companies which export outside the Caribbean Community (CARICOM) are allowed to keep 20 percent of their export earnings in hard currency. If approved by the National Assembly, a new law will make exporters eligible for tax deductions of up to 50 percent on earnings from export shipments. While government and foreign investors are active in Guyana's shrimp trawl fishery, no private investor has yet initiated a shrimp culture project.

## IX. PERU:

Northern Peru has many of the same favorable environmental conditions as does neighboring Ecuador, allowing Peruvian shrimp farmers to develop a smaller but profitable shrimp culture industry. Peru began to experiment with shrimp culture in 1971 and the first commercial ponds were built in 1975. The marine shrimp culture industry is dominated by about 60 small and medium sized farms, ranging from 4 to 200 ha. The area best suited for shrimp culture is situated along the estuaries and tidal areas of the northern coast, especially in the Tumbes area. The best sites are near the mouth of the Tumbes River, the only permanent source of fresh water along the northern coast, where an estimated 5,000 hectares of land is suited for shrimp culture.[20/] As of January 1987, about 4,300 ha of ponds had been built, mostly located between Tumbes and the Ecuadorean border to the north. About 60 percent of those farms are reportedly operating. One observer

estimates that another 10,000 ha of ponds could be built in the Tumbes area and 7,000 ha in the Piura area, but most of these would not have the same ideal conditions as the farms already constructed. Many of the best Peruvian sites are located in areas susceptible to flooding. The industry, for example, sustained considerable damage during the floods associated with the 1982-83 El Nino. On the other hand, the major problem with the sites south of Tumbes will be the lack of freshwater.

Many Peruvian farms are associations formed by small groups of investors. Several of these farmers have associated themselves into larger marketing-investment groups. The two most important groups have been Inversiones Nueva York (INY) and PROMARESA. INY withdrew from the industry in 1987 and sold its interests to Del Mar, an important Peruvian fishing company. PROMARESA, on the other hand, is expanding. Other important companies are Paracas, TUMPIS, San Isidro, and Maisa. The most important producers operate their own processing plants which pack both their harvest as well as the harvests of smaller neighboring farmers. Shrimp growers report annual yields averaging 0.5-0.7 t per hectare. The best farms have annual yields of about 1.25 t of shrimp per hectare. The overall performance of the industry has been below that level because many ponds were inactive in 1985 and early 1986.[21/] Yields are gradually increasing with improved methods. An increasing number of farms, for example, are applying supplementary feeds. One company, Nicolini Hermanos, produces high-quality feed for local shrimp farmers and has also begun to export it. Production costs are reportedly relatively low, probably close to Ecuadorean levels. Growers in Peru do have higher fuel costs, however, as Peruvian fuel prices are close to international levels.

The industry was severely affected by the cataclysmic 1982-83 El Nino, when floods destroyed ponds and communication lines all along the northern coast. The 1986-87 El Nino has also affected growers, but on a much smaller scale. One report from Peru suggests that nearly one-third of the growers have sustained some flood damage. About half of the growers report damage to roads which limit access to their farms, while almost all growers report problems with algae growth caused by unusually large quantities of freshwater. Many growers report recent problems from unexpectedly high stocking densities; they did not anticipate the unusually high number of pl present in the water when they stocked their ponds. As a result, the density of animals in ponds during late 1986 and early 1987 was much higher than they realized or wanted. Even so, farmers harvested about 1,015 t of shrimp in 1986, a 6 percent increase over the 955 t harvested in 1985. Local observers report a major 1987 increase in production—as much as 1,750 t of shrimp may be harvested. The industry is expected to continue expanding over the next few years and growers expect annual harvests of from 4,500-6,000 t of shrimp by 1990. Those projections may prove overly optimistic, but harvests of a least 3,500 t by 1990 are likely.

The Peruvian shrimp culture industry is primarily centered on marine shrimp, but some farmers are also working with freshwater shrimp. At least one 10-ha farm exists in San Martin Department and a group plans to build a new farm near Piura. Several additional farms are believed to exist and about 10 groups are reportedly studying the feasibility of farming freshwater shrimp, but no detailed information is currently available. Four different groups in the Lima area are reportedly producing freshwater shrimp postlarvae.

Peru has two operational marine shrimp hatcheries: Laboratorio Peru at Zorritos near Tumbes and Broodstock at La Cruz near Tumbes; each produce about 1.5-3.0 million pl monthly. Both hatcheries buy nauplii from foreign hatcheries and raise them to pl for sale to growers. Three new hatcheries with larger capacities (5.0-7.0 million pl per month) are under construction or in a testing phase: Bioltecsa and Acualarva at Zorritos; and Tecnomar at Los Organos near Piura. Government officials estimate that production could reach 0.1 billion pl by 1988. Demand for pl by that year, however, will probably exceed 1.0 billion pl which means that the industry will have to continue to rely on pl available naturally. Hatcheries in Peru have not developed as rapidly as in Ecuador because the natural abundance of pl and the limited area of ponds have kept prices low. Prices in early 1987 for wild pl were about $4 per 1,000 pl, but the artisanal fishermen collected so much pl that some growers reported paying as little as $1.50 per 1,000 pl during July 1987. The hatcheries usually operate only when wild pl are scare and generally sell their output for about $10-15 per 1,000.

The Ministry of Fisheries (MIPES) recognizes the industry's potential and has been promoting its development. MIPES has sponsored research to aid growers. One of the most successful research projects was an experimental station in Tumbes Province which provided extension services to growers during the late 1970s when the industry was in its beginning phase. MIPES conducts some shrimp culture research and has obtained aid from the European Community (EC) to provide technical assistance on shrimp culture, probably hatchery technology. MIPES has also begun an experimental program to prove the feasibility of producing Artemia for the hatcheries. The Ministry reports excellent cyst yields, 180 kg per ha per year and adds that 10 different groups have expressed an interest in commercial Artemia production. The Government obtained a low-interest loan for Cultivadores Industriales de Langostinos S.A. (CILANSA), a group formed by five companies, from a $4-million U.S. AID credit. The Peruvian Institute of Foreign Commerce has arranged for technical assistance for shrimp farmers from the EC.

**X. SURINAME:**

Two freshwater shrimp farms have been opened in Suriname: J. Surland N.V. (a quasi-government agency) and Commewijne Shrimp and Fisheries (CSF). While both only harvested experimental runs in 1987, they hope to begin small-scale

commercial production in 1988. The two farms plan to harvest about 15 t of shrimp from their experimental runs. A total of 10 ha of ponds have been built, but both companies are planning major expansion programs if the 1988 commercial trials prove successful. They report impressive, but unconfirmed annual yields of about 1.5 t per hectare. Government officials speculate that up to 3,800 ha of ponds could be built. Preinvestment assessments by private investors, however, suggest that investments would not prove profitable. One preliminary report indicated that low salinities at some of the better sites would complicate commercial development. Projections for 1990 are highly speculative, although some observers believe that harvests could reach up to 100-150 tons. Both Surinamese companies hope to produce their own postlarvae. Surland operates a hatchery capable of producing 1 million freshwater shrimp pl annually. The company hopes to expand annual production to 10 million pl by 1990. CSF is now also studying the feasibility of building a hatchery.

Surinamese Government policy currently provides no special assistance to the shrimp culture industry, although the possibility of the Government providing soft loans, tax advantages, and the use of Government land has been discussed. The unstable political situation has discouraged potential investors, but several foreign groups are helping to develop Suriname's shrimp culture industry. The Organization of American States (OAS) helped Surland build both its original demonstration ponds in 1984 and its hatchery. FAO provided $0.2 million in 1986 to assess the possibility of culturing marine shrimp in the Commewijne District. The Surinamese National Development Bank has arranged a $2.3 million loan for Surland for shrimp culture from China.

**XI. URUGUAY:**

Uruguayan biologists began working on shrimp culture in 1971, concentrating on P. paulensis. The Uruguayan Instituto Nacional de Pesca's (INAPE) research has concentrated in the Jose Ignacio, Garzon, Rocha, and Castillos lagoons. INAPE officials believe that Uruguay's coastal estuaries, especially sites near the mouth of the Maldonado River, could offer favorable environmental conditions. The Government planned to build a pilot shrimp farm, but no details on the results of that project are available. Uruguay's temperate climate probably limits the possibility of penaeid shrimp culture, but some biologists believe that freshwater shrimp may have potential. INAPE is studying the feasibility of culturing freshwater shrimp at its Laboratorio de Acuicultura Marina at Palma near La Paloma. The Government of Taiwan has provided some assistance to INAPE which has reported successful experimental harvests and planned to build a hatchery in 1985. Current information on the results of the project is not available.

## XII. VENEZUELA:

Venezuela's shrimp culture industry is at an early stage of development. No company has yet begun commercial operations, although several companies have built ponds and conducted experimental runs. About 13 different groups are building shrimp farms. Some of the most important are: Agricultura Marina, Aquacam, Asincro, Granjas Marinas Industriales, Langostinos la Sabana, Prodetec, and Protinal. Some of these companies are backed by large Venezuelan corporations — a major advantage as it provided the industry resources unavailable to shrimp farmers in most other Latin American countries. Venezuelan growers have built, or are building, about 150 ha of ponds as their first stage of development. Investors report construction costs at about $4,000-8,000 per hectare. The first commercial harvest is scheduled for late 1988. Shrimp farmers optimistically project that they will have 3,600 ha of ponds producing over 5,000 t of shrimp annually by 1990. Based on the experience of growers in other countries, however, it is not likely that yields will exceed 0.5 t per hectare during the first years of commercial development. As a result, harvests will probably not exceed 1,500 t by 1990. At least one observer, however, is much more optimistic, maintaining that some Venezuelan farmers have benefitted from the pioneering experience of shrimp farmers in other countries. Venezuelan growers will probably have fairly high production costs as environmental conditions at most of the existing sites are not ideal, although there is also disagreement among observers on this. Low domestic fuel prices will be an advantage not shared in most other countries. Farmers are generally using three different species; P. japonicus, stylirostris, and vannamei; a few are experimenting with P. monodon. The Government requires that local species also be used and growers are trying P. brasiliensis and schmitti. The La Salle Foundation (FLS) has studied freshwater shrimp, but no one has yet begun to culture the species commercially. FLS is also working on marine shrimp species and reports that it has successfully spawned P. brasiliensis and has offered to sell its pl to growers. FLS is currently working on spawning P. schmitti. Each major project plans to build their own hatchery. Most growers have concluded that it may be some time before techniques for culturing indigenous species are perfected and that they will need to import or produce pl themselves to stock their ponds. The growers charge that various government agencies have impeded their progress. Government regulations requiring, the quarantine of exotic species to be cultured and the assessment of the impact of shrimp farms built near nature preserves have delayed several projects. This seems to be more of a problem in Venezuela than in other Latin American countries because of the relatively high levels of public concern over environmental issues in Venezuela. Government officials insist that a careful examination of the environmental impact is necessary. One grower, who had trouble importing broodstock, reports that the situation has improved in 1987 and that imports of exotic species are being routinely approved after the 30-day quarantine.

The Venezuelan Government has no programs specifically designed to promote the shrimp culture industry. Shrimp farms, however, are classified as agricultural projects which are exempted from income tax. The Government offers low-interest loans (8.5 percent) for agricultural projects and some shrimp farmers have reportedly taken advantage of their availability. The IDB has provided limited financing for Prodetec. It is unclear how the industry will be affected by Venezuelan currency control rates enacted in December 1986. Importers and exporters must purchase or exchange dollars at the official rate of 14.5 bolivares to the U.S. dollar. The free market exchange rate was about 25 bolivares to the dollar in June 1987. The preinvestment studies of the growers did not consider these exchange controls and many growers are concerned. Growers hope to be eligible for an export bonus of up to 30 percent of the value of their export earnings. Technical assistance from various U.S. companies and France-Aquaculture is playing an important role in the industry's development.

Appendix A.--Latin America. Cultured shrimp production, 1975-1990

| Year | Quantity |
|---|---|
| | 1,000 Metric tons* |
| 1975 | 1.0E |
| 1976 | 2.0E |
| 1977 | 3.0E |
| 1978 | 4.0E |
| 1979 | 5.0E |
| 1980 | 9.7 |
| 1981 | 12.8 |
| 1982 | 24.2 |
| 1983 | 38.4 |
| 1984 | 37.0 |
| 1985 | 36.9 |
| 1986 | 52.1 |
| 1987 | 78.4 |
| 1988 | 95.0P |
| 1989 | 110.0P |
| 1990 | 113.0P |

E - Estimated
P - Projected
* Live weight
Sources: Various country sources.

Appendix B.--Latin America Cultured shrimp production, by country, 1982-1987, and 1990 projections.

| Country | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987E | 1990P |
| | --Metric tons(live weight)-- | | | | | | |
| Ecuador | 21,500 | 35,600 | 33,600 | 30,200 | 43,600 | 67,000E* | 85,000 |
| Brazil | 200 | N/A | N/A | 1,100 | N/A | N/A | 4,000 |
| Mexico | N/A | 100 | 300 | 500 | 1,400 | 2,300 | 4,000 |
| Peru | 600 | N/A | N/A | 955 | 1,015 | 1,750 | 3,500 |
| Colombia | - | - | 50 | 63 | 140 | 500 | 3,500 |
| Panama | 1,500E | N/A | 1,431 | 2,557 | N/A | N/A | 3,000 |
| Honduras | 250 | N/A | 465 | 600 | 1,100 | 1,500 | 3,000 |
| Guatemala | 100 | N/A | N/A | 530 | 620 | 750 | 1,500 |
| Venezuela | - | - | - | - | 5 | 10 | 1,500 |
| Dominican Rep. | - | N/A | 134 | 194 | 216 | 300 | 750 |
| French Guiana | - | N/A | N/A | N/A | 36 | 60 | 700 |
| Belize | - | - | - | 4 | 4 | 100 | 500 |
| Puerto Rico | - | - | - | 5 | 50 | 100 | 350 |
| Martinique | 50 | 50 | 50 | 50 | 50 | N/A | 300 |
| Jamaica | 25 | 25 | 25 | 30 | 35 | 90 | 300 |
| El Salvador | N/A | N/A | N/A | 100 | 100 | N/A | 250 |
| Bahamas | - | - | - | 18 | N/A | N/A | 250 |
| Costa Rica | - | - | - | 4 | 5 | 10 | 150 |
| Guadeloupe | N/A | N/A | N/A | N/A | 45 | N/A | 100 |
| Cuba | - | 5E | 10E | 21 | 25E | N/A | 100 |
| Suriname | - | - | - | - | - | 15 | 50 |
| Guyana | - | - | - | - | - | 5 | 50 |
| Haiti | - | - | - | - | - | - | 25 |
| Dominica | - | - | - | - | N/A | N/A | 25 |
| Nicaragua | - | - | - | - | - | - | 25 |
| Others | - | - | - | - | - | 5 | 75 |
| Total | 24,225 | 38,430 | 36,965 | 36,931 | 52,121 | 78,390E | 113,000P |

E - Estimated
P - Projected.
* Preliminary data based on available export data.
Note: Data for many countries is incomplete or contradictory. NMFS has generally utilized the most conservative figures unless higher estimates are verified by several sources.
N/A - Data not available. When data for a specific year is not available, the data for the previous year has been used to compute the annual regional total.
Sources: FAO and various country sources.

Appendix C.--Ecuador. Monthly shrimp exports to the United States, by quantity, 1980-85.

| Month | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
| | Metric tons | | | | | | | |
| January | 375 | 864 | 1,122 | 1,704 | 1,951† | 1,349 | 1,015 | 1,710 |
| February | 548 | 349 | 533 | 1,210 | 1,589 | 1,882 | 886 | 2,917† |
| March | 630 | 1,115 | 1,200 | 1,505 | 1,542 | 1,619 | 1,997 | 3,098† |
| April | 664 | 855 | 1,125 | 1,865 | 2,082 | 1,803 | 1,708 | 3,557† |
| May | 851 | 926 | 1,792 | 2,527 | 1,472 | 1,742 | 2,496 | 3,893† |
| June | 1,068 | 1,237 | 2,009 | 2,382 | 1,729 | 1,792 | 2,972 | 4,995†† |
| July | 675 | 985 | 1,210 | 2,605 | 2,080 | 2,176 | 2,802 | 4,397† |
| August | 651 | 1,165 | 1,726 | 1,695 | 1,711 | 1,324 | 2,468 | 4,223† |
| September | 1,033 | 897 | 1,775 | 2,153 | 1,927 | 1,916 | 2,942 | 4,336† |
| October | 1,070 | 949 | 1,310 | 2,132 | 1,930 | 1,454 | 2,722 | 4,098† |
| November | 735 | 982 | 1,280 | 1,869 | 1,601 | 1,522 | 3,145 | 3,725 |
| December | 876 | 916 | 1,334 | 1,702 | 1,523 | 1,271 | 2,913 | 3,500P |
| Total* | 9,160 | 11,220 | 16,383 | 23,300 | 21,138 | 19,922 | 28,132 | 44,449P |

† Monthly record
†† All time record
* Totals may not agree due to rounding.
Note: The above data does not include a significant, but variable, quantity of shrimp believed to have been smuggled out of Ecuador, principally through Peru, to avoid Ecuadorean currency controls. It is believed that these illegal shipments declined in 1985 as a result of changes in Ecuadorean export regulations.
Source: U.S. Department of Commerce. Bureau of the Census.

Appendix D.-- Major world producers of cultured shrimp, 1982-1987, and 1990 projection.

| Country | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987P | 1990P |
| | --1,000 Metric tons*-- | | | | | | |
| China | 7.1 | 9.0 | 19.3 | 36.3 | 79.1 | N/A | 100.0 |
| **Ecuador** | **21.5** | **35.6** | **33.6** | **30.2** | **43.6** | **67.0** | **85.0** |
| Taiwan | 9.6 | 11.0 | 13.4 | 19.3 | 51.0 | 60.0 | 75.0 |
| Indonesia | 11.3 | 37.4 | 32.1 | 36.5 | 41.0E | 49.0 | 60.0 |
| Philippines | 4.1 | 12.1 | 28.9 | 29.0 | N/A | N/A | 40.0 |
| Thailand | 10.4 | 12.7 | 16.1 | 18.3 | N/A | N/A | 35.0 |
| India | 15.0E | 15.0 | 17.0 | 19.0 | 20.0 | N/A | 30.0 |
| Bangladesh | N/A | 4.4 | 7.6 | 14.7 | N/A | N/A | 24.0 |
| **Panama** | **1.5** | **N/A** | **1.4** | **2.6** | **N/A** | **N/A** | **3.0** |
| Japan | 2.0 | 2.0 | 2.1 | 2.2 | N/A | N/A | 2.6 |
| Subtotal | 82.5 | 140.7 | 171.5 | 208.1 | 301.5E | N/A | 454.6 |
| Others | 1.5 | 3.9 | 4.2 | 4.2 | 7.2 | N/A | 35.3 |
| World Total | 84.9 | 142.4 | 174.3 | 212.7 | 308.7 | N/A | 490.0 |

* Live weight
P - Projected
E - NMFS estimate.
N/A - Not Available.
Sources: FAO and various country sources.

Appendix E.--World. Cultured shrimp production, by region, 1982-1987, and projection for 1990.

| Region | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987P | 1990P |
| | --1,000 Metric tons*-- | | | | | | |
| Asia | 59.7 | 104.0 | 137.3 | 175.8 | 256.6 | N/A | 373.5 |
| **Latin America** | **24.2** | **38.4** | **37.0** | **36.9** | **52.1** | **78.4** | **113.0** |
| Europe | Negl | Negl | Negl | Negl | N/A | N/A | 2.1 |
| Africa | Negl | Negl | Negl | Negl | Negl | Negl | 0.9 |
| Other | Negl | Negl | Negl | Negl | Negl | Negl | 0.5 |
| Total** | 84.0 | 142.5 | 174.2 | 212.7 | 308.8 | N/A | 490.0 |

N/A - Data not available.
Negl -Negligible
* Live weight.
** Totals may not agree due to rounding.
Sources: Various country sources.

Appendix F.--Latin America. Shrimp catch and harvests, 1985

| Country | Quantity | | Total |
|---|---|---|---|
| | Caught | Cultured | |
| | 1,000 Metric tons | | |
| Mexico | 74.5 | 0.1 | 74.6 |
| Brazil | 57.5 | 1.1 | 58.6 |
| Ecuador | 6.0 | 30.2 | 36.2 |
| Argentina | 16.7 | - | 16.7 |
| Panama | 13.3 | 2.6 | 15.9 |
| El Salvador | 6.8 | 0.1 | 6.9 |
| Venezuela | 6.0 | Negl | 6.0 |
| Colombia | 5.0 | 0.1 | 5.0 |
| Cuba | 4.8 | Negl | 4.8 |
| Costa Rica | 4.3 | Negl | 4.3 |
| Honduras | 3.2 | 0.6 | 3.8 |
| Peru | 2.7 | 1.0 | 3.7 |
| Guyana | 3.4 | - | 3.4 |
| Chile | 2.9 | - | 2.9 |
| Nicaragua | 1.7 | - | 1.7 |
| Guatemala | 0.9 | 0.5 | 1.5 |
| French Guiana | 1.2 | - | 1.2 |
| Suriname | 0.6 | - | 0.6 |
| Trinidad | 0.4 | - | 0.4 |
| Dominican Rep. | N/A | 0.2 | 0.2 |
| Belize | 0.1 | Negl | 0.1 |
| Uruguay | Negl | - | Negl |
| Total | 212.0 | 36.9 | 248.9 |

Note: Above figures do not include small catch by Japan, Korea (ROK), and the United States off Latin American countries.
Sources: FAO and various country sources.

## APPENDIX III

# *SHRIMP AQUACULTURE ASIA, AFRICA, AND EUROPE*

### ASIA

**I. SUMMARY:**

Asian shrimp farmers harvested a record 257,000 metric tons (mt) in 1986, over 20 percent of Asia's shrimp production for that year (appendix A). Growth in Asian farmed production has been phenomenal in recent years—the actual 1986 harvest was nearly 1.3 times the 196,000 mt projected for the year 1990 by the National Marine Fisheries Service in 1985. Asian and Pacific Rim nations account for over 80 percent of the total world farmed shrimp production. Of these, China, Taiwan, Indonesia, the Philippines, and India were the top Asian producers of farmed shrimp in 1986. These countries, and Thailand, also have the greatest potential for expanding cultured shrimp production by 1990 (appendix B). Provided that postlarvae (pl) from already established or planned shrimp hatcheries become readily available and that better predator control, pond cleaning, aeration, and feeding techniques are used, cultured shrimp production in Asia could exceed 370,000 mt in 1990.

**II. OVERVIEW:**

Many Asian countries have a suitable climate and large areas available for both marine and freshwater shrimp culture. Several indigenous shrimp species are suitable for culturing. Three major shrimp groups are commonly cultured in Asia: marine species belonging to the genera Penaeus and Metapenaeus, and freshwater species of the genus Macrobrachium (appendix C). The more commonly cultured species are Penaeus indicus, P. japonicus, P. merguiensis, P. monodon, Metapenaeus ensis, and Macrobrachium rosenbergii. Exact data on the species composition of Asian farmed shrimp harvests are generally not available, but the Branch of Foreign Fisheries Analysis believes that the most important species is P. monodon. The shrimp culture industry is growing at a more rapid rate in Asia than in other areas because the technology for producing P. monodon pl and other important Asian shrimp species is less complicated than those for neotropical species.

The trend in Asia is to increase shrimp production by intensifying the culture methods being used and by increasing the area under culture. Shrimp farming has a centuries-long tradition in Asia and shrimp farmers currently use a myriad of variations on extensive, semi-intensive, and intensive shrimp culture techniques. Extensive shrimp farming is by far the most prevalent method utilized throughout developing countries of Southeast Asia and the Indian subcontinent because it requires relatively simple technology and low capital investments. Many extensive shrimp farms in Asia involve the polyculture of several fish species (such as milkfish and carp) in ponds, as little additional capital investment is necessary to culture shrimp in an existing pond. Rice-cum-fish culture is utilized in a few Asian countries, but the use of pesticides on rice plants has caused a decline in this practice. The application of semi-intensive farming methods to increase yields is a relatively new phenomenon. These semi-intensive methods include better predator control, feeding, and pond fertilization, aeration, and dredging. Developed and used primarily in Taiwan and Japan, intensive shrimp farming involves far greater production costs because the shrimp are carefully monocultured using sophisticated technology. In addition, most Asian countries, while producing enough pl for extensive farming, cannot yet meet the year-round pl supply requirements of intensive and semi-intensive shrimp farming.

The potential for increased foreign exchange earnings is the primary motivation for the rapid development of shrimp culture in Asia. Where Asia's natural shrimp stocks once fulfilled export demands, many now show the signs of overexploitation: the catch per unit of fishing effort and the average size of the shrimp caught are declining in most countries. Because of the lucrative nature of the shrimp industry, it is unlikely that these wild stocks can ever be effectively managed. Shrimp culture, on the other hand, represents a renewable resource which commands high prices and a high profit margin. As a result, most Asian governments have incentive programs to promote the shrimp culture industry.

Many world shrimp market observers now believe that there is a finite amount of shrimp that international markets can absorb and that these markets may begin to suffer from a shrimp glut as early as 1990. Rapid advancements in shrimp culture technology (and the resultant increase in yields) may make oversupply in the medium term a reality, as low-yield countries intensify shrimp culture efforts. (Taiwan reportedly increased its shrimp production by 4,500 percent in only 10 years.) In a 1987 report on shrimp markets, the Far Eastern Economic Review predicted a slow rate of growth in demand for shrimp for the near future. The authors expect a compounded annual growth rate of about 1 percent for Japan and the United States, 3 percent for Europe, and 5 percent for other minor markets, such as Hong Kong, Singapore, and Australia. Eventually, increases in supply may drive prices down to the level of production costs. Such costs are already quite high in Taiwan and Japan, both of which are investing in shrimp culture operations in

third countries (where labor costs are low) in anticipation of just such a development. The 1990 estimated Asian farmed shrimp production of 370,000 mt is little more than an educated guess. Current data from many countries is only a rough estimation. In addition, various economic problems continue to influence shrimp culture in Asia. Rising production costs for shrimp feed, pond construction and maintenance, processing, fuel, electricity, and shipping, as well as the vicissitudes of weather and other natural events, have affected Asian cultured shrimp production in the past and will probably continue to do so in the future. A key limiting factor will be the availability of shrimp pl for stocking growout ponds. Collection of pl from the wild does not adequately meet shrimp farmers' demands for dependable supplies of growout stock. Although the construction of hatcheries has begun at a feverish rate, it has still not caught up with demand. Large-scale farms are constructing their own hatcheries. The success of Asia's shrimp culture campaign depends on hatchery development, which will allow Asian countries to move to more intensive culture methods and higher yields.

Exporters of Asian shrimp to the United States have had to deal with several problems, two of the most important being quality control and marketing. The U.S. Food and Drug Administration (FDA) initially confronted the quality control problem in 1979 when an influx of Asian shrimp, contaminated with Salmonella and filth (or showing decomposition), arrived at U.S. ports. The FDA sampled 835 shrimp entries from six Asian countries between March and August 1979, and found 46 percent contaminated. This situation prompted the FDA to "blocklist" shrimp from these countries. Blocklisted products are barred from the U.S. market and neither the FDA, nor the Customs Bureau, do any further quality testing on the products. The owner either proves that the shipment is in compliance with U.S. standards, or rectifies the problem. If the shipment passes independent laboratory analysis, it can then be released for sale on the U.S. market. Shrimp exporters can be removed from the automatic detention list by successfully entering five successive shipments with no violations, or by getting the appropriate government agency in the exporter's country to certify that the exporter's shrimp is in compliance with U.S. standards. Automatic detention of the shrimp from the original six Asian countries was still in effect in 1987, and forced shrimp exporting countries to place more emphasis on quality control.

The second major problem arises in marketing Asian shrimp in the United States. Two of the major shrimp species cultured in Asia, P. monodon and P. japonicus, are still not widely consumed in the United States, the world's second largest shrimp market. The export growth potential for these species has been hindered because they are not extensively promoted in the United States.

Note: The detailed information on shrimp culture in various Asian countries has been obtained from diverse sources, and is extremely difficult to corroborate. Statistical data have generally been obtained from fishery officials of the various

countries (usually through the U.S. Embassy in that country), or FAO catch statistics. Anecdotal information has come from a number of international trade or industry publications, news clippings, and personal communications. It is difficult to obtain accurate information on private commercial shrimp culture farms in any country due, understandably, to the reluctance of farmers to reveal details of their operations. Nevertheless, it is hoped this report will provide the reader with a useful overview of the state of the industry in each country.

**III. AUSTRALIA:**

Cultured shrimp production in Australia is negligible (about 15 mt in 1986). There has been a recent resurgence of interest in shrimp culture associated with the introduction of new technology for the cultivation of Macrobrachium, but, according to the Department of Primary Industry, shrimp culture has a long way to go before it can be called a viable industry. A brief description of shrimp culture activities in Australia's states and territories follows.

A South Australian company has reportedly been producing western king shrimp (P. latisulcatus) on a semi-commercial scale, but the quantity and the area of ponds under culture are unknown. The company also has a small-scale hatchery.

There are a number of shrimp farming and hatchery endeavors in New South Wales. The New South Wales Government Authority maintains a pilot commercial scale operation for Metapenaeus macleayi (locally called "school shrimp") on the Clarence River in northern New South Wales. The project does not include a hatchery. Juvenile shrimp are obtained by trawling a shallow lake. A private company has also reportedly built 130 hectares (ha) of growout ponds on the Clarence River to produce commercial-size M macleayi from juveniles collected from the river. Three small hatcheries are currently in operation in New South Wales, and all have reported success with their initial batches of king and tiger prawns. Australian officials project that the total area in culture in New South Wales will expand from the current 300 ha to over 700 ha in the next few years.

In the Northern Territory, prawn farming is seen as a way of supplementing the wild shrimp industry. Three feasibility projects are now being developed near Darwin at a cost of around A$3 million. One of the projects has apparently been successful in hatching and raising P. monodon to commercial size, but reports poor growth rates.

A few new Macrobrachium aquaculture ventures are starting operations in Queensland. One project near Innisfail has been established to hatch Macrobrachium for sale to farmers and is also considering rearing marine shrimp. A Queensland-based company, Maricorp Australia, Ltd., is planning to build a 630 ha farm on ocean front property in Bowen. Maricorp is reportedly working with

Hanaqua Group of Taiwan on the hatchery design and feed formulation. The Queensland Department of Primary Industries began building an experimental prawn farm on Bribie Island in 1986. A council, the Commercial Mariculture Council of Queensland, has been established to cater to the growing number of shrimp farmers in the region. The Council will function as a forum for common problems and shrimp culture technology exchange, as well as marketing and government liaison. The Council estimates that 5,000 ha of ponds in northern Australia could employ between 3,500 and 3,700 people and produce about twice the existing trawl catch to nearly triple Australia's foreign exchange earnings on shrimp exports. Kimberly Fisheries Pty, Ltd. has established an experimental prawn farm in Western Australia near Kununurra. The farm will breed and grow Macrobrachium rosenbergii for the local tourist hotels.

Australia has a number of limitations working against its development as a major shrimp culturing nation. Among these are the country's relative isolation, high cost of labor, Government restrictions on coastal land usage, and a lack of aquaculture infrastructure (necessary equipment for hatcheries and ponds, ability to produce artificial feeds, and Government research). Like U.S. shrimp fishermen, Australian shrimpers view shrimp aquaculture in a competitive light. The deciding factor will most likely be whether the Australian Government puts its weight behind the culture industry, providing a comprehensive plan and the necessary incentives for shrimp culture development.

**IV. BANGLADESH:**

Bangladesh's total 1985 shrimp harvest exceeded 49,400 t, 30 percent (14,650 t) of which was cultured. The total harvest is expected to reach 60,000 mt by 1990, mainly by expanding cultured shrimp production to 24,000 mt (appendix D). Although Bangladesh has an ample supply of cheap labor, other factors, such as poor management, the unavailability of suitable land, good quality feeds and fertilizers, and lack of infrastructure (especially transport), continue to hold down production. In addition, the country's variable weather conditions make the attainment of consistent annual aquaculture production levels difficult.

Bangladeshi fishermen culture primarily four marine species: Penaeus monodon (giant tiger shrimp), P. semisulcatus (green tiger prawn), P. indicus (Indian white shrimp), and Metapenaeus brevicornis (brown shrimp). All four species are cultured, but P. monodon is the one most commonly used. A variety of other penaeid and metapenaeid species are cultured in smaller quantities. Macrobrachium rosenbergii (giant river prawn), is the most valuable freshwater species cultured in Bangladesh.

Bangladeshi shrimp farms primarily use extensive methods, but some farmers are beginning to utilize semi-intensive culture techniques. The species and culture methods used vary by season and rainfall, as heavy monsoon rains and flooding lower the salinity levels in culture ponds during the rainy season (May-December). The area devoted to shrimp culture has expanded rapidly in Bangladesh—from less than 20,000 ha in 1980 to over 87,500 ha in 1985. Fishery officials estimate that by 1990, approximately 120,000 ha will be under culture. There is estimated to be about 240,000 ha of estuarine area available for shrimp culture in Bangladesh. Although average annual yields of marine shrimp from Bangladeshi farms are still low (about 167 kg per ha harvested as one crop per year), this is expected to increase with improved pond management. Freshwater culture is still new in Bangladesh and therefore less important; it is practiced mainly in the Khulna District.

A number of Government and internationally funded shrimp development projects are in progress in Bangladesh. In May 1987, the Asian Development Bank (ADB) approved a $60 million aquaculture development project which includes $19.5 million for shrimp culture development. The 5-year project includes the construction of about 1,000 ha of new shrimp ponds in four districts (Sathira, Khulna, Bagerhat, and Cox's Bazaar), and the upgrading of approximately 5,000 ha of existing ponds. Ten new hatcheries, each with pl production capacity of 4 million annually, are also planned. Bangladesh currently has one private hatchery in operation and an ADB-funded hatchery project under construction. A 1986 World Bank shrimp culture project is providing financing for two Government-owned shrimp hatcheries with pl production capacity of 10 million each. The hatcheries are part of a $36 million, 9,000-ha development project, designed to help alleviate the shortages of both pl and the foreign currency needed to buy shrimp culture equipment. A French aquaculture consulting company, Aqua Service, is providing technical assistance for the project. The FAO-sponsored Bay of Bengal Programme has recently established a shrimp culture demonstration farm at Satkhira in the Khulna district. This project is designed to develop culture techniques adapted to local conditions.

The private sector is also heavily involved in shrimp culture development. Approximately nine privately-owned hatcheries, each with projected production capacities of 10 million pl, are expected to be constructed soon. Lever Brothers (Bangladesh), Ltd., a subsidiary of Unilever, U.K., and one of Bangladesh's largest shrimp culture companies, has selected sites in the Cox's Bazaar District for a marine shrimp hatchery, rearing farm, and feed mills.

To help in reaching the shrimp export target of 80,000 mt by the year 2000, the Bangladesh Government has devised an export-incentive plan for shrimp exporters. This plan includes:

1) Import duty and sales tax exemptions on commodities used for shrimp feed manufacture or shrimp pond maintenance.

2) Special financing privileges. Shrimp exporters may borrow up to 90 percent of the value of a confirmed letter of credit at a preferred interest rate of 9 percent. (Regular interest rates vary from 14-18 percent.) Companies exceeding their export targets are entitled to an even lower rate of interest—7 percent. This is referred to as "packing" credit.

The Bangladeshi Central Bank recently directed commercial banks to issue another form of financing to shrimp exporters: working capital credit established on the basis of 60 percent of a firm's production capacity. This credit is available at 9 percent interest for operational and expansion purposes on pledge terms. The Central Bank also issues export performance benefits (EPB): regularly adjusted premiums (above the official exchange rate) paid per dollar of exports . EPBs are paid to shrimp exporters at the rate of 100 percent of export value (under the EPB scheme announced in July 1986, promoted export items are entitled to EPBs at rates of 100 percent, 70 percent, or 40 percent of export value.) With the EPBs, the shrimp exporter's effective taka/dollar exchange rate in June 1987 was approximately 3 percent higher than the secondary market exchange rate.

**V. BURMA:**

Burma first produced cultured shrimp in 1984, when 7 mt of freshwater shrimp was harvested (appendix E). By 1986, over 500 mt of shrimp, primarily marine species, was harvested. The Burmese Government plans a major expansion of the industry and forecasts that harvests of cultured shrimp will reach 1,800 mt by 1990, consisting of 300 mt of freshwater shrimp and 1,500 of marine shrimp. In calculating these forecasts, the Burmese Government expects shrimp yields on freshwater farms to average 1.4 mt per ha per year, while on marine farms, where extensive methods will be used, shrimp yields are expected to average only 0.2 mt per ha per year. Current average annual freshwater shrimp production is 0.5 mt per hectare.

There are two major shrimp species being cultured in Burma: P. monodon and M. rosenbergii. The Irrawaddy River Delta area, comprised of swamps, mangroves, and other estuaries, offers the best freshwater, brackish water, and marine culture sites. Burma's other coastal regions (the Rakhine coast in the west and the Tenasserim coast, bordering on Thailand, in the east), also have substantial wild shrimp resources. Mining and the utilization of mangroves for charcoal production, however, are destroying the estuarine habitat of postlarval shrimp and polluting potential shrimp culture sites.

The state-owned People's Pearl and Fishery Corporation (PPFC), Burma's sole shrimp farming and exporting organization, originally emphasized freshwater shrimp culture. Burma's first freshwater shrimp hatchery, located at Thaketa in the Rangoon District, was completed in 1986. The Thaketa hatchery reportedly produced 1.2 million pl in 1986 and plans on producing over 4 million pl in 1987. A second freshwater hatchery, located at Kyauktan (Rangoon District) is nearing completion. Ultimately both hatcheries will have annual production capacities of 10 million pl each. Burma's Thakata Research Station also produces some freshwater pl—0.5 million in 1986.

The PPFC operates two 50 ha semi-intensive farms for M. rosenbergii production—one at Thanatpin (Pegu District) and one at Hmawbi (Rangoon District). Commercial production at the two farms is expected to begin in early 1988 and amount to 60 mt each; they have already produced 6 mt on an experimental basis.

The PPFC is also rearing marine shrimp species. Experimental farms are located at Naukme (Irrawaddy District), and Kyaukphyu and Maungdaw (Rakhine District). The farm at Maungdaw has 4,167 ha of ponds and reportedly produced 475 mt of shrimp in 1986.

Under its current Fifth 4-Year plan (1986-1989), the Burmese Government plans to construct an additional six freshwater farms and two marine farms of 50-ha, as well as one additional freshwater and two marine shrimp hatcheries. These hatcheries are supposed to supply Burmese shrimp farms with an additional 26 million pl per year. In discussing the guidelines for Burma's Fifth 4-Year plan at the Fifth Party Congress, party and state officials emphasized that their goal in promoting the shrimp culture industry is to increase export revenues and foreign currency earnings.

## VI. CHINA:

Shrimp culture in China rose rapidly from an estimated 7,000 mt in 1982 to over 19,000 mt in 1984 (appendix F). It is difficult to confirm cultured shrimp production figures for China, but the Chinese Bureau of Aquatic Products reported that 1986 cultured shrimp production exceeded 79,000 tons from 80,000 ha of ponds, making China the number one producer of cultured shrimp in the world. The main species cultured are P. orientalis, and small amounts of P. merguiensis, P. penicillatus, and P. monodon.

Shandong Province, bordering the Bohai and Yellow Seas, reportedly produced over 17,000 mt of cultured shrimp in 1986. Spawners are obtained from wild stocks in April and May by the inshore fishing fleet and brought to hatcheries, or "seeding factories" as the Chinese call them. After hatching, the young shrimp are placed in growout ponds for maturation. The shrimp are harvested at 25-30 g and

production averages 1.5 mt per ha with one crop per year. The extensive culture system continues to be the prevalent shrimp culture method used in Shandong Province.

China's southern province of Guangdong is also quite active in shrimp culture with over 40,000 ha of ponds available for shrimp production in 1986. An estimated 1,300 ha of intensive culture ponds are in already in operation and an additional 2,600 ha of intensive culture ponds are being constructed in the Shanton and Huiyang Districts of the province. The ponds are expected to be completed by 1989. In addition to wild supplies of pl, Quangdong has four hatcheries with an annual production of 1.4 billion pl to meet the stocking requirements of its farmers. Average shrimp production is estimated at over 1.1 mt per ha in Guangdong Province's intensive culture ponds, 0.6 mt per ha in semi-intensive culture ponds, and 0.5 mt per ha in extensive culture ponds.

China has several joint shrimp culture projects underway. The country is reportedly cooperating with Iran in setting up a shrimp farm in Hormuzagan Province and a shrimp culture joint venture with New Zealand is also in progress (see New Zealand). The Japanese fishing company, Taiyo, established a shrimp culture joint venture with the Zhoushan Second Fishery Corporation in Zhejiang Province in August 1986. The venture is on an experimental scale, with about 35 ha in cultivation and expected production of about 20 mt of cultured shrimp per year (most of which is destined for Japanese markets).

Because China wants to increase foreign export earnings, the production of cultured shrimp, and other high-value shellfish will probably continue to increase in the future. To accomplish this, the country will have to overcome such problems as the shortage of electric power, inadequate culture technology, and lack of high-quality formulated feeds.

**VII. FIJI:**

Fiji does culture some shrimp for its domestic market. Cultured production totaled 17 mt in 1984 and 20 mt in 1985. The Fiji Development Bank is experimenting with marine shrimp farming and expects to produce 65 mt in 1987 and 200-300 mt by 1990.

**VIII. HONG KONG:**

Some limited extensive shrimp culture, known as the "tambak" method, is practiced in Hong Kong. This method entails the opening of pond gates at high tide to allow young shrimp and other fish to enter pens where they are kept until they reach marketable size. No tambak ponds are used solely for shrimp culture. There

are currently 16 ponds in production, with a total area of 210 hectares. Penaeus, Metapenaeus, and Palaemon spp. are the main species of shrimp being raised. Hong Kong has no shrimp hatcheries. Unfortunately, statistics are not available for cultured production, but the total 1986 Hong Kong shrimp catch was 15,765 metric tons. Hong Kong fisheries officials do not expect this number to vary significantly over the next several years.

The Department of Agriculture and Fisheries successfully experimented with Macrobrachium rosenbergii culture in 1985, but found that culture of the prawn was not economically viable because of the local preference for marine shrimp.

There are no Government incentives supporting shrimp culture specifically. However, the Agriculture and Fisheries Department does provide technical assistance to aquaculturists in general. Financial assistance for thedevelopment of pond-fish culture is available from the Kadoorie Agricultural Aid Loan Fund.

**IX. INDIA:**

India's cultured shrimp production grew from an estimated 15,000 mt in 1982 to about 20,000 mt in 1986 (appendix G). Approximately 51,000 ha of ponds are reportedly in production. Under a Government program, the total hectarage under culture will increase by about 4,000 ha per year to bring the total harvest to nearly 66,000 ha producing over 30,000 mt of shrimp by 1990. In the long term, a total of 0.9 million ha could be developed for brackish water ponds. A large proportion of the existing ponds are on saline soils where dry-season aquaculture crops alternate with rice during the rainy season. The major shrimp culture areas in India are in the Karnataka (1,800 ha), Kerala (8,000 ha), and West Bengal (30,000 ha) states. P. monodon accounts for approximately 50 percent of cultured production. The remainder is comprised of P. indicus, P. merguiensis., and Metapenaeus dobsoni (Kadal shrimp).

Culture technology is predominately extensive. Indian extensive culture systems can be classified in three broad categories:

1. Paddy/Shrimp Rotation—Paddy is grown in the monsoon season (June to November) when the salinity of the ponds is low, and fish and shrimp are grown during the remainder of the year when the ponds are too saline. There is some limited stocking and feeding of shrimp. Rotation of rice and shrimp is practiced in Kerala, Karnataka, and West Bengal.

2. Paddy-Cum-Shrimp Culture—Rice and shrimp are grown together. Only shrimp which can tolerate low salinity levels can survive under this system. Paddy-cum-shrimp culture is practiced in West Bengal and in some areas of Goa.

3. Perennial Farms—Shrimp culture is carried out in deeper earthen ponds throughout the year, generally with other fish species. This type of culture is prevalent in central Kerala and Orissa. Semi-intensive culture farms are also a growing interest in India, but to date they are only in the planning stages.

According to India's Marine Products Export Development Authority (MPEDA), methods for enhancing the natural productivity of culture ponds through liming, fertilizing (with manure), and better water management have greatly increased shrimp aquaculture production. About 400-500 kg per ha per year are harvested. Inadequate feeds, lack of technical staff, and large capital requirements for development are ongoing problems. Land-use laws in many Indian states are also hindering the development of pond shrimp culture.

A major constraint India's shrimp culture industry faces is the shortage of pl for stocking ponds. In general, India's shrimp farmers depend on wild-caught pl for this purpose. It is estimated that only 10-15 percent of the potential wild supplies are currently being tapped. The Government is encouraging farmers to take advantage of this resource through the establishment of "seed banks" which regulate the trade in pl and minimize mortality during handling. To properly maintain the shrimp pl, the banks require large capital investments for tanks, aerators, pumps, and other equipment. Eight of 50 planned seed banks have already been established. The Government envisions that the banks will eventually become shrimp nurseries as the culture industry develops.

India is placing high priority on the construction of hatcheries in its future plans, so that its shrimp culture industry will not be dependent solely on wild supplies of postlarvae. The states of Kerala and Maharashtra each have one functioning hatchery. A private P. monodon hatchery, owned by Hindustan Lever, Ltd., has been in operation for over a year in the state of Tamil Nadu. The MPEDA has set up a model hatchery at Cochin, and is planning to develop two other large-scale commercial hatcheries with foreign partners in Orissa (France Aquaculture, Tahiti) and Andhra Pradesh (Aquatic Farms, Hawaii). The French venture should be on line by the end of 1987 and is expected to have a production capacity of 25 million P. monodon pl per year. The Hawaiian hatchery should be ready by 1989. The Ministry of Agriculture has plans to establish five P. monodon seed hatcheries by 1990.

The Indian Government's policies on shrimp culture development are linked with the development of the rural economy of the coastal poor. The Indian Government has endorsed shrimp farming efforts not only to increase foreign exchange earnings, but to increase both the quantity and quality of the cultured shrimp. To accomplish this, the Ministry of Agriculture provides funds to the state governments to develop the industry and improve farming methods. The Department of

Fisheries in the various states can use these funds to extend subsidies, grants, and technical assistance. Some states have also formed brackishwater fish-farming development agencies at the district level. The MPEDA also plays an important role in promoting shrimp culture by offering pond and site selection surveys, shrimp feed research, demonstrations, technical guidance, training, feasibility reports, and subsidy schemes. Banks, such as the National Bank for Agriculture and Rural Development, and other financial institutions are also offering liberal credit to shrimp farmers. The following Government subsidies are available to assist various sectors of the shrimp culture industry:

1. New Farms—15-25 percent subsidy on capital investments ranging from $600-$2,400 per hectare. To develop land for shrimp culture in India requires a capital investment of $4,000-$12,000 per hectare.

2. New Hatcheries—Subsidies vary by ownership:
   Private ownership - $12,000
   Private/State Ownership - $20,000
   State-owned - $41,000

3. Seed Banks—The MPEDA is offering a 50 percent subsidy on capital investments up to $1,675 on equipment for the establishment of seed banks.

4. Purchasing pl—For culture operations on less than 2 ha, farmers are given a 75 percent discount on the cost of pl; all others receive a 50 percent discount.

By increasing the availability of pl and improving the technology employed in the industry, observers expect India to harvest about 30,000 mt of cultured shrimp from a total pond area of approximately 66,000 ha by 1990.

**X. INDONESIA:**

Indonesia is currently a leading Asian shrimp farming country. In 1986, it produced 41,000 mt or 25.4 percent of the country's total shrimp harvest (appendix H). Many observers believe that Indonesia will emerge as the principal Asian producer of farmed shrimp by 1990, with projected production at 60,000 metric tons. Indonesian Government officials predict that shrimp may soon replace oil as the country's number one foreign exchange earner. The major species cultured are P. monodon, P. merguiensis, Metapenaeus endeavori, and Macrobrachium spp.

Shrimp growers, using primarily extensive culture methods, produce about 600 kilograms of marine shrimp per ha annually, although yields vary greatly with production region and method. Tambaks, shallow brackishwater ponds originally designed for milkfish culture, are now being used for polyculture of shrimp and

milkfish. Tambak culture is mainly practised in southern Sulawesi, Java, and Sumatra. There were reportedly 239,000 ha of tambaks in Indonesia in 1985 with shrimp species as a component of the culture operation. Existing farms are small—averaging 1.5 to 3.7 ha—and shrimp production in tambaks is modest—only about 350 kg per hectare. By developing new tambaks and increasing production in existing tambaks, Indonesia hopes to harvest nearly 44,000 mt of shrimp by the end of 1988. In addition to tambaks, Indonesia has nearly 4.3 million ha of unused mangroves, of which 20 percent, 840,000 ha, could be used for aquaculture and still be within the limit of environmental sustainability.

The major factor that has limited the expansion of the Indonesian shrimp culture industry is the availability of pl to stock the ponds. In 1983, the Asian Development Bank (ADB) estimated that Indonesia would need 1.8 billion pl annually to meet projected production goals, while another report, recently released at the JETRO International Forum on Shrimps, estimated that Indonesia would need 4.3 billion shrimp fry annually by 1988. At present, 68 private and 12 Government hatcheries produce 725 million fry, and there is the potential, at least, for 800 million fry to be supplied from the wild. The Government is concentrating on expanding hatchery capacity to meet the shortfall of postlarvae.

The Indonesian Government has promoted the development of the country's shrimp culture industry since the 1970s when the Directorate General of Fisheries established four Macrobrachium hatcheries. More recently, in its efforts to boost non-oil exports, the Government has promoted the shrimp industry to become a leading foreign exchange earner and employer. The Government provides investment incentives and credits, working capital, export credit, and technical advice. The ADB and the U.S. Agency for International Development (AID) have also provided development assistance for the culture industry. With ADB aid, the Government plans to construct another five hatcheries, each with a capacity of 40 million pl per year. ADB has also assisted the Indonesian Government in a project designed to increase production on 20,000 ha of existing tambaks by improving 280 km of primary and secondary canals in Java.

Although 54 private shrimp farming companies were licensed in 1986, only about 250 ha of the total 1,000 ha of ponds granted to them have been developed. The disbursement of credits for shrimp pond projects reached only 5 percent of the Government's target at the end of 1986. Part of the reason for this is high land prices and remote locations discouraging potential investors.

**XI. JAPAN:**

Shrimp is one of the most valuable marine commodities in Japan. Although Japan was a pioneer in shrimp culture technology, the country's production has increased only slightly over the past several years, from 2,026 mt in 1982 to 2,184

mt in 1985. The two main reasons for this are: 1) a shortage of suitable land for aquaculture, and 2) only the southern part of the country has a climate suitable for shrimp growing. Shrimp aquaculture accounted for only 4 percent of Japan's total shrimp production in 1985 (appendix I).

Penaeus japonicus, the kuruma prawn, is the most highly prized and the major farmed species of shrimp in Japan, with 1985 production of 2,151 metric tons. It is generally marketed alive and sold to the luxury restaurant and gift market. Freshwater shrimp aquaculture (primarily Macrobrachium rosenbergii) is relatively new in Japan and 1985 production was only 33 mt ns. Over 530 ha of culture ponds were in production in 1985, supplied by 31 hatcheries with production of 320 million postlarvae. Because it is difficult to obtain suitable land and/or water rights for shrimp culture in Japan and because of the country's poor shrimp-growing climate, the number of ha under cultivation will probably not change much in the future. Japanese fishery officials predict that, by 1990, marine cultured shrimp production will reach 2,600 metric tons.

Japan currently has about 150 intensive shrimp farms in operation. The sizes of company farms range from 4 to 10 ha while private farms average about 1 hectare. The largest farm covers about 30 hectares. Farmers harvest one crop per year and annual production averages about 4.1 mt per hectare.

Four methods are used in rearing shrimp in Japan: (1) Unused salt fields are converted into ponds with slide gates and mechanical aerators, (2) concrete or stone dikes fenced with fine nets are built out from shore to enclose intertidal areas (up to one ha), (3) sea pens or cages, and (4) small circular concrete tanks. The conversion of unused salt fields into culture ponds is the most prevalent method used.

To enhance the wild shrimp catch, the Japanese practice shrimp "ranching"—they release pl into the sea to increase coastal stocks available to commercial fishermen (primarily the inshore gillnet fleet); the purpose is not to raise shrimp to commercial size entirely in ponds or cages. In 1983, 1 semi-governmental and 24 prefectural shrimp hatcheries released a total of 526 million pl into the sea. In Japan, nearly every prefecture has its own shrimp ranching hatchery. The prefectures surrounding the Seto Inland Sea and those in central and southwest Japan produce the largest quantities of juvenile shrimp. The effectiveness of the project, however, has yet to be determined. The Fishery Agency of Japan (FAJ) budget for pl production and release was $16.3 million in FY 1983 and $17.4 million in FY 1984.

The FAJ provides fiscal incentives to fishery cooperatives engaged in shrimp culture. The FAJ also offers low interest loans at 6.5 percent annual interest, payable over 20 years. The Finance Corporation of the Ministry of Agriculture, Forestry, and Fisheries offers similar loans. Commercial firms are not eligible to receive either of these loans. There is no ongoing Government shrimp culture research or any new research planned.

**XII. REPUBLIC OF KOREA (ROK):**

ROK cultured shrimp production in 1986 was 133 t, about 0.3 percent of the total shrimp catch of over 45,000 tons (appendix J). Cultured shrimp production has averaged about 90 mt per year since 1976. The ROK currently has only about 430 ha of ponds in shrimp production and has no plans for further expansion. Production is expected to reach 500 mt by the year 1990.

The static state of Korean shrimp aquaculture may be attributed to two major factors:

1. Climate: The ROK does not have an ideal climate for shrimp culture. Farmers have had problems maintaining the correct salinity levels in their ponds due to frequent typhoon activity along the country's coasts. In addition, temperatures are too cool for optimum shrimp growth.

2. Availability of pond sites: There has been a scarcity of suitable pond sites for shrimp culture in the ROK. The number of shrimp ponds is dependent on coastal reclamation projects, but unfortunately, the high investment costs of these projects have kept a lid on shrimp aquacultural development.

Shrimp aquaculture in the Republic of Korea (ROK) began with the successful rearing and culture of P. orientalis, the fleshy prawn, using Japanese techniques. By 1968, approximately 50 ha of private shrimp ponds had been constructed and the Agriculture and Fisheries Development Corporation had begun construction of a 120-ha experimental farm with two 500-ha farms in the planning stage. These farms were to be created by reclamation of suitable tidal land. The ROK planned to have 4,000 to 5,000 ha of shrimp farms in operation by 1978, but this did not materialize.

Despite the introduction of P. japonicus in 1971 and Macrobrachium rosenbergii in 1978, the major cultured shrimp species remains P. orientalis. All South Korean cultured shrimp production is in brackish water ponds using semi-extensive methods. The largest commercial shrimp farm in the ROK is operated by the Doosan Industrial Company. Doosan farmed only 15 ha in 1986. The company also owns and operates four brackish water hatcheries, located at Wonbuk,

Anheung, and Anmyondo on the western coast, and Namhae on the southern coast. The hatcheries have a combined production capacity of 100 million postlarvae. There are no plans to construct any more hatcheries in the ROK. Doosan also has a refrigerated feed storage facility and a research laboratory to support its farming operations. Although the ROK Government encourages shrimp farmers to boost their production, at the present time there is no concrete policy nor any fiscal incentives at present to specifically foster shrimp culture.

## XIII. MALAYSIA:

The Malaysian shrimp culture industry is still in early stages of development. Malaysian shrimp farmers produced 269 mt of cultured shrimp (mostly P. monodon) in 1986 (appendix K). Existing marine culture ponds cover 705 hectares. Total ha under production is difficult to estimate because over 4,800 ha of freshwater farms raise shrimp together with fish. Annual shrimp yields range from 0.6 mt per ha to 6 mt per hectare.

Commercial production of shrimp in Malaysia has not been terribly successful. The obstacles to improved shrimp culture are generally lack of expertise, inadequate and inconsistent supply of spawners and pl, expensive feed, and lack of good marketing knowledge. Several farms have recently failed. Ternakan Marine, a Malaysian-Arab joint venture went under recently after 4 years of operation. The firm had cultured 600 ha of marine ponds in West Johore. East Asia Marine Farms also reportedly ran into problems in December 1986, after it began to export shrimp to Japan, but it is still in operation. East Asia Marine is an American-Malaysian joint venture. Malaysian fishery officials feel that several firms have failed because of lack of technical expertise, or, in the case of foreign projects, foreign experts failed to take local conditions into consideration in trying to carry out the projects.

Six Government hatcheries are now in operation and reportedly have a capacity of 68 million pl per year. One of the largest, the recently completed National Prawn Fry and Research Center in Pulau, Sayak, Kedah, has already begun production. The Center has the capacity to produce 55 million P. monodon pl and 5 million freshwater shrimp pl per year. In addition to the Government hatcheries, 17 private hatcheries produced 396 million pl in 1985. With this large number of hatcheries to supply Malaysian farmers, it is not inconceivable that cultured shrimp production could reach 2,000 tons by 1990. The Malaysian Government assists the shrimp culture industry through the Department of Fisheries which provides advice and technical assistance. Shrimp culture firms are also eligible to receive tax rebates and tax relief which the Malaysian Government provides to most

developing industries. A 5 percent tax investment credit is extended to all shrimp culture investors, i.e. 50 percent of the first 5 year's qualifying capital expenditures may be deducted from taxable income. These expenditures include the clearing of land, pond construction, the purchase of plant and machinery, and building construction. Investors may also borrow from the Government's new low-cost investment fund at reduced rates or benefit from a reduced interest rate export credit refinancing scheme.

Malaysian officials predict that Malaysia's shrimp production will be 2,000 mt by 1990. A resurgence of interest in shrimp culture and the country's favorable climate bodes well for the industry's expansion.

**XIV. NEW CALEDONIA**

In 1984, the South Pacific Aquaculture Company, a subsidiary of the Japanese company Tokyu Foods, began a joint shrimp culture venture with several other French concerns in a company called SODACAL. The farm reportedly produced 20 mt of shrimp in 1984 and expected to produce 40 mt in 1985. No further information is known about the company.

**XV. NEW ZEALAND:**

There is currently no commercial cultured shrimp production in New Zealand, but fishery officials predict that annual production will reach 300 mt by 1990. New Zealand should have a fully operational shrimp farming industry by 1988, if a joint venture between the Chinese National Fisheries Corporation and New Zealand succeeds. The Kiwi China Prawn Company, 60 percent New Zealand-owned, plans to culture P. orientalis at two farms north of Auckland. The first farm has started up on a 16.2-ha site, but total planned pond area of both farms is 256 hectares. The breeding stock for the operations has been imported from China and the company hopes to eventually produce 2,000 mt of shrimp annually, primarily for export live to Japan and the United States. On the Japanese market, live shrimp bring prices up to three times higher than frozen shrimp.

**XVI. PAKISTAN:**

Shrimp aquaculture in Pakistan is still in its infancy, with the production of the country's first metric ton of cultured shrimp in 1985. The Government is, however, promoting the industry's development. The Asian Development Bank is providing $14.1 million ($22.1 million total cost) for an aquaculture development project and assisting in creating a master plan for the development of Pakistan's shrimp aquaculture industry. The plan is expected to be ready in 1988.

Pakistan has two experimental shrimp farms, one run by the Government and the other by Lipton (Pakistan), Ltd. The Government has presently allocated 6,500 ha for shrimp culture, but private shrimp farms are not expected to become operative until the success of the Government demonstration farm is evident. If the two experimental farms prove to be economically viable, there should be good potential for shrimp aquaculture in Pakistan. The production estimate for 1990 is 200 tons (appendix L). The Pakistani Government encourages shrimp culture by entrepreneurs by leasing land at very low rent, exempting shrimp aquaculture income from income tax, and providing expertise to prospective shrimp farmers.

**XVII. PHILIPPINES:**

A stable wild shrimp catch, together with increased demand and prices for the tiger prawn, has given shrimp aquaculture in the Philippines increased significance as a source of foreign exchange. The Philippines produced 29,040 mt of cultured shrimp in 1985, accounting for 39 percent of the total shrimp production (73,600 t) that year (appendix M). By comparison, in 1982, aquaculture comprised only 17 percent of the total shrimp harvest. By 1990, cultured shrimp production is expected to reach 40,000 mt and account for 75 percent of the Philippines' total shrimp harvest.

The Philippines has four commercially important marine shrimp species: P. monodon (giant tiger prawn), P. merguiensis (banana prawn), P. indicus (Indian white shrimp), and Metapenaeus ensis (greasyback shrimp). P. monodon is the most important species, accounting for 90 percent of Philippine cultured shrimp.

Of the approximately 200,000 ha of brackishwater ponds available for shrimp culture in the Philippines, it is estimated that the area devoted to prawn culture (either prawn monoculture or polyculture with milkfish) increased from about 40,000 ha in 1984 to 50,000 ha in 1985. Although semi-intensive and intensive farming have increased in recent years, sources estimate that 90 percent of shrimp and prawn culture is extensive. At present, many farmers use ponds originally designed for milkfish culture, most of which are poorly adapted for higher shrimp stocking densities because of shallow depth and inadequate drainage. Currently, less than 1,000 ha of ponds are suitable for high density shrimp culture.

The extensive culture method is still the primary method used for shrimp culture in the Philippines. The survival rate for extensive shrimp culture is often less than 50 percent because of poor water control, predators, and lack of farmer expertise. Extensive culture in the Philippines still relies primarily on naturally-occuring feeds, although some fertilizers are used to stimulate natural food growth. There

has been improvement in yield, however, as numerous small- and medium-sized farms have upgraded low stocking density ponds to semi-intensive, higher stocking rate ponds. Although yields from mono- and polyculture vary widely, the average yield in 1985 was estimated at 0.6 mt per ha, compared with 0.2 mt per ha in 1981. The San Miguel Corporation claims to have obtained average annual yields of 14.4 mt per ha from its intensive culture systems on Negros Island using Taiwanese culture methods.

Eighty-nine Philippine hatcheries produced between 85-100 million shrimp fry in 1985. Two large-scale hatcheries opened in 1986 and are expected to produce an additional 180 million fry per annum. These figures represent a tremendous increase in fry production, and are the result of laws passed in 1982 and 1983 limiting the export of spawners, the successful establishment of wild broodstocks by two hatcheries in 1980, and the subsequent dissemination of this technology to other hatcheries.

The Philippine Government and various international organizations are actively promoting the development of the country's shrimp farming industry. The Philippine Government, through its Bureau of Fisheries and Aquatic Resources, has actively encouraged shrimp culture and offers assistance in the form of soft loans, training of technical staff, and extension services. The World Bank, through the International Finance Corporation, is providing loans for individual projects. The most significant source of aid is the Asian Development Bank (ADB), which extended a $22-million loan to the Philippine Government in 1983 to promote aquaculture of both finfish and shrimp. The loan will finance the construction of 15 hatcheries capable of producing 75 million postlarvae. In addition, the ADB is directly assisting two projects (one on Luzon and the other on Panay), and, in 1986, agreed to provide technical assistance to several other private aquaculture projects. Other sources of low-cost financing for shrimp farming are Government banks, such as the Development Bank of the Philippines, the Central Bank, the Philippine National Bank, and regional Government-supported agriculture banks. The Government has also lowered tariffs on imports of shrimp feeds and equipment used in aquaculture.

The probability that shrimp culture will expand in the Philippines is good. The country has nearly ideal conditions—climate, water quality, soil characteristics—for shrimp culture. The Philippines already has the infrastructure (roads, electricity, airports, and port facilities) to support a much larger shrimp culture industry and is also close to Japan, a major shrimp market. Conversely, several factors limit the potential for shrimp culture. Large areas of brackishwater ponds are available for shrimp culture, but significant investments would be required to improve the ponds, making them more suitable for shrimp culture with higher yields (e.g., dredging, and improving drainage). The estimated cost for improving brackishwater ponds is reportedly about $3,600 per ha (based on an exchange rate

of 14 Philippine pesos to the U.S. dollar). Technology is at a beginning level of development, particularly in the feed industry. The most important limiting factor for increased future production is the inadequate supply of postlarvae. Existing hatcheries are sufficient to meet current needs, but may be unable to do so in the future because of the lack of skilled technicians. Another limiting factor is the fact that many Philippine shrimp exporters often cannot meet high-quality sanitary standards demanded by the United States and Japan.

Recently, the Philippines has been faced with a new problem: shrimp farm-related pollution. In the province of Negros Occidental, arable land is being polluted by seawater seeping away from shrimp farms. The problem has become so severe in some places that the land can no longer be used for cultivation of sugar cane or other agricultural crops. Pond effluent dumped directly into the sea may also be a potentially important pollutant.

**XVIII SINGAPORE:**

Singapore's cultured shrimp production was estimated at 95 mt from approximately 300 ha of shrimp ponds in 1985. Although Singapore has a limited area for shrimp cultivation, production is expected to reach 300 mt by 1990. Singapore uses the semi-intensive pond culture method pioneered by Taiwan, as well as a locally developed floating cage culture method.

Jurong's Hitachi Zosen Robin dockyards in Singapore is investing $1.2 million in a project to construct 20 breeding ponds for P. japonicus. The shipyard will create the circular ponds on a 40,000 square meter parcel of unused land from spoiled concrete casings returned from tunnel construction sites. The shipyard hopes to get three crops per year from the ponds. Most of the harvest will be exported to Japan.

No fiscal incentives are provided for development of shrimp aquaculture, but Singapore's Primary Production Department does provide technical assistance to shrimp farmers.

**XIX. SOLOMON ISLANDS:**

There is negligible commercial cultured shrimp production in the Solomon Islands. One company, South Pacific Aquaculture Ltd., is culturing Macrobrachium rosenbergii at Aruligo, West Guadalcanal. The company is also exploring the possibility of culturing marine penaeid shrimps.

## XX. SRI LANKA:

With the aid of a $17.3 million development project from the Asian Development Bank, Sri Lanka produced its first cultured shrimp harvest of 89 mt in 1985 mt (appendix N). There are currently 280 ha under cultivation (270 marine and 10 freshwater), with unused capacity estimated at 2,400 hectares. Sri Lanka's three private hatcheries and two Government hatcheries have a total production capacity of 9.2 million fry per month. Shrimp growers have been concentrating primarily on P. monodon. The Sri Lankan Ministry of Fisheries believes that cultured shrimp production could reach 1,500 mt by 1990, nearly 17 times its current production.

There are three major companies now engaged in commercial shrimp farming in Sri Lanka. Serendib Seafoods (a U.S.-Sri Lankan joint venture) operates a 200-ha P. monodon farm on the east coast near Batticaloa and a hatchery near Negombo on the west coast. Serendib's annual production reportedly exceeds 2 mt per hectare. Lever Aquaproducts, Ltd., (a subsidiary of Unilever, a United Kingdom-based firm) operates a 30-ha shrimp pond culture complex on the west coast of the country, and a hatchery south of Colombo. The company produced about 50 mt of P. monodon in 1985. Finally, Andriesz Mariculture, Ltd., has begun to intensively culture P. monodon on the west coast of Sri Lanka, north of Chilaw. The operation has about 35 ha of ponds, supported by Andriesz's own hatchery. The hatchery is expected to produce 8 million pl per month at peak operations. Andriesz Mariculture, Ltd., is a subsidiary of Andriesz & Co., Ltd., Sri Lanka's leading frozen seafood exporter.

Several shrimp aquaculture research projects are currently underway in Sri Lanka. The Asian Development Bank began a $17.3 million project in 1986, which includes construction of a shrimp hatchery, marine culture demonstration ponds and pens, and 200 ha of growout ponds. The project will last 6 years and involve 5,000 freshwater farmers and 200 marine shrimp farmers. The Canadian Government is providing Sri Lanka with a loan for the construction of a shrimp research and development institute in the northern central part of the country. The National Aquatic Resources Agency (NARA), the research arm of the Sri Lankan Ministry of Fisheries, has funded a survey of penaeid shrimp postlarval abundance, seasonality, and recruitment in relation to environmental factors in the backwaters of the Negombo Lagoon.

The Sri Lankan Government is currently considering additional shrimp aquaculture projects, but these are as yet uncertain. The Government is actively promoting shrimp aquaculture by seeking foreign investment and expertise to supplement the dwindling catches of wild shrimp. The Government also provides various tax

incentives to promote shrimp culture, including income tax holidays and exemptions. Exporters of fishery products receive grants of 5 percent of the FOB value of their exports. About 25 percent of each grant is paid in cash, and the remainder in export development certificates, which can be reinvested in the industry or any export-oriented project or company.

Although prospects look good for Sri Lanka's infant shrimp culture industry overall, the problems of insufficient postlarval supplies, scarcity of spawners, lack of hatcheries and sufficient pond sites, and the need for trained aquaculturists must be addressed. The Sri Lankan Government is trying to overcome these problems by importing the necessary expertise and technology from abroad, and actively seeking foreign investment to inject new capital into the industry.

**XXI. TAIWAN:**

Taiwan has rapidly become one of the top Asian producers of farmed shrimp. The industry has grown from being a by-product of milkfish culture in 1968, to a multimillion dollar industry in its own right. Taiwan's farmed shrimp production was only 270 mt in 1976. Ten years later, in 1986, Taiwan produced over 51,000 mt of cultured shrimp (appendix O). Approximately 87 percent of this harvest was comprised of P. monodon (appendix P). Other important species cultured in Taiwan are M. ensis and M. rosenbergii.

Taiwan's shrimp farms are usually small, family-owned-and- operated businesses. Taiwan's shrimp culture industry is somewhat unique in its degree of specialization. Rather than farmers growing shrimp from pl to market size, they specialize in growing shrimp to only certain growth stages. Hence, shrimp may change hands as many as seven times before they reach the market.

The total area of existing freshwater and marine culture ponds is about 9,500 ha, giving Taiwan an average harvest of 5.4 mt per ha per year (appendix Q). Since the country has two shrimp crops per year, the single crop yield is 2.7 mt per hectare. Some monoculture shrimp ponds in southern Taiwan are reported to have yields up to 15 mt per ha per crop. The average size of growout ponds rarely exceeds 1 ha, allowing rapid water exchange and ease of pond aeration. To support such phenomenal production, Taiwan has approximately 2,200 small hatcheries with a total production capacity of over 3 billion pl per year.

Taiwan's shrimp hatcheries have traditionally depended on imports of spawners from Southeast Asia; however, several of their traditional suppliers (Philippines and Indonesia) have banned the export of spawners to protect their own industries. A spawner smuggled into Taiwan may bring up to $80 on Taiwan's black market. Taiwan buys some spawners from Thailand, but the country's increasing demand for spawners may have to be met by using ocean ranching, artificial insemination,

and other maturation techniques. Taiwan is now using the eye-stalk ablation method to induce shrimp maturation. The Taiwanese are also experimenting with artificial insemination techniques, to more efficiently utilize their spawners.

In addition to innovative maturation techniques, the success of Taiwan's shrimp culture industry is also partially due to the development of formulated feeds. Research began on the nutritional requirements of P. monodon in Taiwan in 1971 and the first formulated feed came on the market in 1977. In 1985, 40 Taiwanese manufacturers produced more than 50,000 mt of formulated feeds for P. monodon. The use of formulated feed is necessary to maintain the high shrimp densities used in Taiwan's culture ponds. Growers have been able to reduce feed costs by growing algae, a natural shrimp food, in their nursury and growout ponds.

Taiwan authorities have provided shrimp farmers several types of assistance. Taiwan's 10-Year Shrimp Development plan is directed toward enlarging the total area under shrimp culture by converting rice-paddy fields and milkfish culture ponds, improving water supplies and drainage systems, and introducing new shrimp farming technologies through a series of seminars held by the fishery authorities. Other assistance is available to shrimp farmers in the form of low-interest loans through cooperative banks and a new shrimp development fund of $2.5 million to promote foreign and domestic sales.

Taiwanese shrimp farmers face a number of problems. The intensive production methods used and close proximity of growout ponds, have resulted in greater incidence of shrimp diseases. Crowding and inadequate water exchange may be major reasons for this increase. Pollution, a by-product of Taiwan's rapid industrial development, is becoming a serious problem. Some shrimp hatcheries have blamed heavy metal contaminants such as mercury, cadmium, zinc, and chromium, for excessive larval shrimp mortalities. In addition, Taiwan, like the Philippines, is experiencing shrimp farm-related pollution. Saltwater is seeping from shrimp farms into adjacent farm land, ruining the soil for traditional agricultural crops. Taiwan's shrimp farmers also pump large quantities of fresh water into their ponds to maintain proper salinity levels. This has led to water shortages in some areas.

Production costs are the key to the future of Taiwan's shrimp culture industry. Growers report high yields (using semi-intensive and intensive methods) producing high-value shrimp, but production costs are also very high. The cost of land alone is reportedly as high as $100,000-$200,000 per acre for suitable shrimp-farming property. It is not clear how Taiwan will be able to compete with the relatively inexpensive shrimp produced by developing countries using extensive methods. Taiwan's leading shrimp aquaculture feed company, President Enterprises Corporation, has recently begun to market its technology in various developing Asian countries. Regardless, fishery officials predict that Taiwan's intensive culture methods can boost 1990 production to 75,000 tons (appendix O).

## XXII. THAILAND:

According to Thai fishery officials, Thailand's marine shrimp farming industry is "booming". Thais are entering into joint ventures with foreign investors in record numbers. There are reportedly 60 shrimp culture projects with a dollar investment of over $5 million under way in Thailand. The Royal Thai Government has realized the export potential of cultured shrimp and is strongly promoting shrimp farming. A marine shrimp farming development project has been incorporated into the country's current 5-Year National Economic and Social Development plan.

Thailand's cultured shrimp production in 1985 was 18,300 t, a 14 percent increase from 16,100 mt in 1984 (appendix R). A conservative estimate of Thailand's 1990 production is 35,000 metric tons. The most important species cultured are P. monodon, P. merguiensis, Metapenaeus and Macrobrachium spp. The major emphasis is currently on P. monodon because the species has a high survival rate and is popular on the Japanese market. Thailand has 40,800 ha of brackishwater ponds under culture and another 113,000 ha of suitable land available for marine shrimp production (appendix S). Over 3,000 ha of ponds are being used for freshwater shrimp culture. The area devoted to shrimp culture has increased yearly but average yields per ha have fluctuated (appendix B). In 1985, Thai marine shrimp farmers had an average yield of 388 kilograms of shrimp per hectare.

Six Government hatcheries reportedly produced 60 million P. merguiensis and 10 million P. monodon pl in 1986. There are also about 200 private, small-scale hatcheries in Thailand collectively producing approximately 150 million marine shrimp pl per year. Most Thai shrimp farmers, however, rely on wild shrimp pl to stock their ponds because the state-run and private hatcheries cannot supply the present demand.

Thailand's wild catch has been declining because of overfishing and the country has not been able to offset this decline, despite the rapid growth of shrimp culture. The main constraint on Thailand's farmers has been low pl production. The Fisheries Department has been working on rectifying the situation by raising captive spawners. Pl numbers are dependent upon the number of wild-caught spawners in Thailand. The Government also hopes that a recent measure to bring the export of P. monodon under the control of the Commerce Ministry will increase the supply. In the past, large numbers of P. monodon spawners have been shipped to hatcheries in Taiwan.

Thailand's shrimp farms are generally small. There are, however, a few larger shrimp operations worthy of mention:

1. World Aquaculture Company—A private sector pioneer in shrimp culture. World Aquaculture reported monthly pl production of 7-10 million, in 1986.

2. Thai Prawn Culture Center Company—Thai Prawn is a joint venture effort between Charoen Pokphand, Thailand's largest agro-industrial group, and Japan's Mitsubishi Company.

3. President Feed Company—This company is a Thai-Taiwanese joint venture which engages in marine shrimp culture and shrimp food production in Samut Songkram Province.

4. Mah Boon Krong Drying and Silo Company Ltd.—This is a Thai-Japanese joint venture involved in both marine and freshwater shrimp aquaculture.

Shrimp farming qualifies for Thailand's Board of Investment promotional privileges. Eligible companies receive a number of benefits including a tax "holiday" from normal Thai corporate income and business taxation and duty-free importation of capital equipment. Other assistance has come from the Asian Development Bank in the form of an $11 million loan to promote shrimp culture in the country. The loan will provide for the construction and upgrading of hatcheries, training of technicians, improving shrimp quality control, and project management. Provisions in the second phase of the project will provide credit to shrimp farmers for pond construction and improvements.

Thailand's success in shrimp culture will ultimately depend on private sector investment and the ability of Thai farmers to overcome the constraints imposed by inadequate supplies of post-larval shrimp. Those who are familiar with the potential of the industry and the energy with which the Thai private sector pursues attractive commercial possibilities, are convinced that the industry will grow rapidly.

## XXIII. VIETNAM:

Vietnam claims that its shrimp culture production increased greatly in 1984, and that approximately 90,000 ha shrimp ponds were in production. One observer estimates that the 1984 production of farmed shrimp was between 10,000-20,000 metric tons. Vietnam reportedly utilized a total of 337,000 ha for fish and shellfish aquaculture in 1984. It is unknown, however, exactly what shrimp species are being farmed, although an observer believes that it is probably P. monodon.

# AFRICA

## I. Angola:

No known experimental or commercial shrimp farms exist.

## II. Cameroon:

There are no known commercial shrimp farms or operational pilot projects in Cameroon. However, Cameroon's Fifth and Sixth Five-Year Plans (1981-1986; 1986-1991) both mention shrimp culture. The Fifth Five-Year Plan allocated a $3.2 million investment for shrimp and mollusk aquaculture, while the Sixth Plan provides $0.3 million for shrimp culture. It is not known why the Government decided to decrease these investments. It is not known how many of the allocated funds were actually spent during 1981-1986. A U.S. company began a shrimp culture feasibility study in 1986 at the request of Socarto, a Cameroonian firm. The proposed project was to include a hatchery, nursery, grow-out ponds, and processing plant. The study was to have been funded in part by a re-imbursable grant from the U.S. Trade and Development Program of the U.S. Department of State. Because of a lack of funding, the study was not done, and the project was terminated in March 1987. However, the potential for shrimp farming in Cameroon is considered good.

## III. Gabon:

No known experimental or commercial shrimp farms exist.

## IV. The Gambia:

The Government of the Gambia entered into a shrimp farming joint venture in 1986 with a Norwegian firm, Scanaqua A/S, belonging to the Bartz Group, and formed Scan Gambia Shrimp, Ltd. (SGSL). Private Gambian investors were also involved. The Government expected the project to be completed in 5 or 6 years, and comprise 1,000 hectares of ponds. SGSL has already begun Phase I of the project which includes the construction of 300 hectares of ponds, 50 hectares of which have already been completed. Two species of shrimp are to be cultured, P monodon and P notialis. The bulk of production is to be marketed in Europe. The project will

include a dam, hatchery, and processing, freezing, and packing plants. In 1987, a Gambian businessman expressed interest in finding joint venture partners for commercial farming of crayfish.

**V. Ghana:**

No known experimental or commercial shrimp farms exist.

**VI. Cote d'Ivoire:**

No known commercial shrimp farms exist in Ivory Coast. A pilot shrimp farm is planned at Assinie-Mafia, about 120 km from Abidjan. The project will be carried out by France-Aquaculture and includes a hatchery, 2 hectares of ponds, and a small feed plant. The project will experiment with P duorarum and other tropical shrimp species. The rearing of freshwater shrimp will also be studied. The EC's European Development Fund, the French Cooperation Fund, and the Government of Cote d'Ivoire are financing the project. Because of infrastructure problems, the project has not yet begun. Ivoirian investors are also planning a commercial project near the city of Grand-Lahou to involve foreign partners, including a Danish consulting firm.

**VII. Kenya:**

Kenya is one of the few African countries with functioning experimental grow-out ponds. The Kenyan project was initiated in 1979 and includes an experimental shrimp hatchery at Malindi. The project has six grow-out ponds at Ngomeni. The Malindi hatchery reported a capacity of approximately 40,000-50,000 post-larvae (PLs) per month as of November 1986. This experimental project was operated under the aegis of the FAO until the beginning of 1987, at which time the Kenyan Government was to have assumed control. While the Malindi hatchery is the only one in Kenya, private firms are planning shrimp farms, and it is possible that some of these might be operational within a few years.

**VIII. Madagascar:**

At present, no experimental or commercial shrimp farms exist.
However, Peche et Froid, a French company, is constructing a large tuna cannery in the north of the country. Indications are that by-products of this cannery could be used in nearby shrimp farming if it ever develops.

**IX. Mauritania:**

No known experimental or commercial shrimp farms exist.

**X. Mozambique:**

No known experimental or commercial shrimp farms exist.

**XI. Nigeria:**

No known commercial shrimp farms exist. A Danish consultant is currently coordinating a feasibility study for a marine shrimp farm, but it appears that no such farms have yet been established. FAO has helped fund a freshwater shrimp hatchery at Port Harcourt.

**XII. Senegal:**

There are no known commercial shrimp farms in Senegal. The Senegalese Government, with the assistance of the French Government, is sponsoring the Katakalousse-Bolong pilot shrimp project in the Casamance River Valley. France-Aquaculture oversees the project. The first phase of the project was begun in 1983 with the construction of 5.3 hectares of ponds. The hatchery has the capacity to produce 5 million PLs per year. The project has experimented with P indicus, japonicus, kerathurus, monodon, notialis, stylirostris, and vannamei.

**XIII. Sierra Leone:**

No known experimental or commercial shrimp farms exist.

**XIV. South Africa:**

Little is known of shrimp aquaculture in the Republic of South Africa. In the mid-1970s, under the aegis of the Fisheries Development Corporation of South Africa, Limited (FDC), an experimental shrimp farm was established at Amatikulu in Zululand. The project included a hatchery and grow-out ponds, and focused on the cultivation of P monodon and Macrobrachium rosenbergii. In 1980, the FDC sold the farm to KwaZulu Development Corporation. Information on the present status of the project is unavailable. The South African Corporation for Economic Development (CED) announced in 1983 that it was establishing a shrimp farming program and initiated a pilot project in the Eastern Transvaal. CED later announced encouraging results, but no current information is available on this project.

**XV. Tanzania:**

No known experimental or commercial shrimp farms exist.

# WEST EUROPE

## I. SUMMARY:

Shrimp culture in Western Europe is a relatively recent development. The northerly latitude and climate probably preclude a large European shrimp aquaculture industry, but some projects exist in the Mediterranean countries. The production of farmed shrimp in Western Europe lags far behind that of Asian and Latin American countries, which, together, should produce nearly 500,000 metric tons (t) of shrimp by 1990. A variety of factors such as climate, high labor costs, and the lack of undeveloped land have made Western Europe a less desirable place for the establishment of hatcheries and farms.

Several European countries, however, especially France, have acquired considerable expertise in culturing shrimp. Most of their work has been in the developing countries, either through investments or technological assistance. Five countries, Spain, France, Italy, Turkey, and Sweden, are responsible for what little farmed shrimp production occurs on the continent. Only a small amount of this is commercially produced, and many projects are still in the experimental stage. Meanwhile, the European Community (EC) has targeted shrimp aquaculture in Spain, France, and Italy as a priority for its aquaculture funding programs. Current information on experimental and commercial operations is limited, however, some data has been reported.

## II. SPAIN:

Commercial shrimp culture in Spain is a young, but rapidly expanding industry. Several large companies have built hatcheries to supply their own farms and to sell to others. The hatcheries are reporting considerable success, but no information is available on pond areas or actual shrimp harvests. The number of post larvae (pls) produced since 1985 has increased from 5 million to more than 24 million in 1986. Estimates for 1987 indicate that production could reach 70 million pls. Most Spanish hatcheries are designed to alternate between fish (from November to March) and shrimp (April to September), making the facilities more cost-efficient. The only species currently cultured on a commercial scale in Spain is Penaeus japonicus. There are four commerical shrimp hatcheries in the country: Mariscos de Estero S.A., (MARESA) is the only hatchery in Spain dedicated exclusively to the production of shrimp larvae. The facility, located in Ayamonte, Huelva, was built in 1985, with modified French technology, and became operational soon thereafter. Production began in early 1986, reaching some 12 million

pls, half of the number produced in Spain. Most of MARESA's production was for sales to growers, however, the company has plans to build its own farm with 200 hectares (ha) of ponds and a hatchery if they receive funding from the European Community. Tinamenor S.A., located on Spain's northern coast, began as a joint venture between Spanish investors and the multinational Kraft Corporation. In addition to shrimp larvae production, this firm rears clam and oyster seed, and fish fry. Shrimp larvae are the most recent product, reaching 0.5 million pls in 1985, with a potential of 8.0 million pls by 1987. Esperanza Siglo XIX S.A., located in Cadiz, began experimental shrimp pl production in 1985. Estimated production for 1986 is between 2 and 3 million pls. All pls produced are used by the company for their grow-out ponds, where they are still experimenting with different stocking densities. Cultivos Piscicolas Marinos S.A. (CUPIMAR), also located in Cadiz, is Spain's largest aquaculture company. During 1985, the CUPIMAR hatchery produced 2 million pls. Production targets for 1986 were 6 million pls, and 6 million pls by 1987. The company is planning to build a new hatchery which will be in operation year round. Their total hatchery production is used to stock their grow-out ponds. Two other companies, Cultivos de Langostinos S.A., and Pescanova S.A., have announced plans for establishing new hatcheries. Cultivos de Langostinos (CL), backed by a credit of $1.3 million from Spain's Centro de Desarrollo Technologico Industrial, plans to open a large $2.7 million facility with a hatchery, nursery, and growout ponds in Ayamonte, Huelva. CL will also sell pls to other farmers. The CL project is claimed to be the first of its type in Spain. Pescanova, the large fishing and processing group, has financed a production center for Artemia.

**III. France:**

French shrimp aquaculture research dates from the late 1960s when the Centre National pour l'Exploitation des Oceans (CNEXO) began studies using P.japonicus. French researchers believe that shrimp can be cultured successfully along both the Atlantic and Mediterranean coasts. Although low temperature and the scarcity and cost of undeveloped coastal areas are disadvantages to culturing shrimp along the Atlantic coast, the waters are rich in nutrients. IFREMER/ CNEXO collaborates with many regional aquaculture groups in shrimp culture projects. During 1983, IFREMER furnished the Centre d'Etude et de Promotion des Activities Lagunaires et Marines en Languedoc-Roussillon (CEPRALMAR), with 1 million pls for semi-intensive and extensive culture. In 1983, after 2 years of experimentation with ponds at Mauguio, Thau, Gruissan, Bages-Sigean, and Leucate, CEPRALMAR produced 1.5 t of shrimp. Another ton of farmed shrimp was produced in 1983 at an experimental station established by another aquaculture research group, the Amenagement Service Technique Etudes Realisations Peche et Cultures Marines (ASTER). The following year a pilot farm was set up by ASTER on the salt marshes of Villeneuve les Maguelone. ASTER also contributed to an experiment in which P.japonicus were introduced to the marshes at Chateau

d'Oleron. This was the first economically successful project to breed the shrimp in Atlantic marshlands. In 1983, the 12-ha polyculture "Petite Tonille" Sea Farm was established at Ile-de-Re on the Atlantic coast. This farm produces P.japonicus, as well as clams, sea bream, rainbow trout, and sea bass, from juveniles to marketable size. During 1984, 4 new shrimp farms opened in Poitou Charente and Aquitaine. Two private experimental shrimp culture projects involving P.japonicus were reportedly conducted at Mesquer, and Beauvoir-sur-Mer during 1986. Results were encouraging, with the average weight of harvested shrimp reaching about 15 grams. A new IFREMER lab devoted to studying shrimp culture opened at Ronce-les-Bains in 1987. Several species, including P. orientalis, and P. vanemei, are currently being studied in France.

**IV. ITALY:**

The first crop of shrimp produced in Italy, 0.2 t of P.japonicus, was harvested in 1981 by the Istituto per lo Sfruttamento Biologico delle Lagune (Consiglio Nazionale delle Ricerche) in Lesina. The shrimp were cultured in the brackish waters of the Laguna di Lesina, on the south-east coast of Italy, and the Laguna di Grado, on the north east coast. By 1982, the Instituto had improved its harvest to 5 tons. Extensive breeding trials of P.japonicus up to commercial size have been successful. In 1982, 400,000 pls were stocked in the Laguna di Lesina, which yielded about 3 tons. Breeding trials of shrimp in extensive monoculture were also conducted in the brackish waters of the Laguna di Grado. A "valle da pesca" (12 ha) in this lagoon was stocked with 80,000 pls of P.japonicus, and a yield of about 75 kilograms (kg)/ha was obtained in 4 months, with a total production of about one ton of market size shrimp. Extensive monoculture in enclosure in the Laguna di Lesina has led to yields of 370 kg/ha. Intensive monoculture in an enclosure (1 ha) in the same lagoon led to yields of more than one ton. Aquaculturalists in Italy are showing interest in hatcheries to produce P.japonicus pls. Italian authorities estimate that annual shrimp production could reach 1,000 tons.

**V. TURKEY:**

Turkey's only known shrimp farm, located near Izmir on the Aegean coast, was recently established by the Turkish firm, Rafine Billur Tuz Sanayi. A U.S. company was involved in setting up the operation. Another Turkish firm, Pinar Deniz Urunleri, which currently farms sea bream and sea bass near Izmir, is looking at the possibility of raising penaeid shrimp.

## VI. SWEDEN:

Although most European shrimp farming occurs in the warmer Mediterranean countries, Swedes have been rearing Macrobrachium rosenbergii in southern Sweden for over 10 years. The only company currently involved, Simontorp Aquaculture AB (owned by Tetra Pak), produces shrimp (and crayfish) for setting out in rivers and ponds.

## VII. UNITED KINGDOM:

The United Kingdom has no commercial shrimp farms. The temperate climate precludes extensive and semi-intensive culture. Various government and private research groups, however, are working on shrimp culture. One of the most active has been the Marine Harvest company which has sponsored shrimp farms in several developing countries, including India and Bangladesh.

Appendix A.--Asia. Shrimp production, by country and fishery, with cultured shrimp as a percentage of total shrimp production, 1986.

| Country | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| China | 188,486 | 79,054 | 267,540 | 30 |
| Taiwan | 87,702 | 51,003 | 138,705 | 37 |
| Indonesia | 119,600 | 41,000 | 160,600 | 26 |
| India | 179,100 | 20,000 | 199,100 | 9 |
| Thailand* | 111,803 | 18,296 | 130,099 | 14 |
| Philippines* | 44,540 | 29,040 | 73,580 | 39 |
| Japan* | 57,151 | 2,184 | 59,335 | 4 |
| Malaysia | 57,982 | 269 | 58,251 | Negl. |
| Bangladesh* | 34,820 | 14,658 | 49,478 | 30 |
| ROK | 45,354 | 133 | 45,487 | Negl. |
| Pakistan | 27,000 | 8 | 27,008 | Negl. |
| Australia | 20,520 | 15 | 20,535 | Negl. |
| Burma | 9,744 | 506 | 10,250 | 5 |
| Sri Lanka* | 4,731 | 300 | 5,031 | 6 |
| Singapore | 1,925 | 95 | 2,020 | 5 |
| Fiji | N/A | 20 | N/A | N/A |
| New Zealand | N/A | - | N/A | N/A |
| New Caledonia* | N/A | 40 | N/A | N/A |
| Total | 990,458 | 256,621 | 1,247,019 | 21 |

* - Because 1986 data was not available for these countries, 1985 statistics were used.
Negl.- Negligible.
N/A - No data available.

Source: U.S. Embassies in listed countries, and other country sources.

Appendix B.--Asia. Cultured shrimp production, by country and quantity, 1982-1987, and projection for 1990.

| Region/Country | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1990P |
| | --Metric tons (live weight)-- | | | | | | |
| China | 7,079 | 8,975 | 19,300 | 36,279 | 79,054 | N/A | 100,000 |
| Taiwan | 9,575 | 10,973 | 13,366 | 19,315 | 51,003 | 60,000p | 75,000 |
| Indonesia | 11,313 | 37,440 | 32,093 | 36,450 | 41,000 | 49,000p | 60,000 |
| Philippines | 4,100 | 12,060 | 28,860 | 29,040 | N/A | N/A | 40,000 |
| India | 15,000 | 15,000 | 17,000 | 19,000 | 20,000 | N/A | 30,000 |
| Thailand | 10,371 | 12,701 | 16,109 | 18,296 | N/A | N/A | 35,000 |
| Bangladesh | N/A | 4,386 | 7,578 | 14,658 | N/A | N/A | 24,000 |
| Japan | 2,025 | 1,978 | 2,061 | 2,184 | N/A | N/A | 2,600 |
| Burma | - | - | 7 | 10 | 506 | N/A | 1,800 |
| Sri Lanka | - | - | 0 | 89 | 300 | N/A | 1,500 |
| Malaysia | 157 | 415 | 682 | 205 | 269 | N/A | 2,000 |
| Korea, South | 109 | 50 | 93 | 84 | 133 | N/A | 500 |
| Singapore | - | 54 | 64 | 95 | N/A | N/A | 300 |
| Fiji | - | - | 17 | 20 | N/A | 65p | 200 |
| Pakistan | - | - | - | 1 | 8 | N/A | 200 |
| Australia | - | - | - | 15 | N/A | N/A | 30 |
| New Zealand | - | - | - | - | - | - | 300 |
| New Caledonia | - | - | 20 | 40 | N/A | N/A | 60 |
| Total | 59,729 | 104,032 | 137,250 | 175,781 | 256,621* | N/A | 373,490 |

P - Projected.
N/A - Not available.
* - Where a country's shrimp culture statistics were not available for 1986, the previous year's data was used in calculating the total.

Sources: FAO and various country sources.

Appendix C.--Asia. Glossary of major cultured shrimp species.

| Scientific Name | FAO English Name | Local names |
|---|---|---|
| *Penaeus indicus* | Indian white prawn | Jaira/Jiaro (Pakistan); Jinga (India); Chapra chingri (Bangladesh); Udang putih (Indonesia); Hipon putih (Philippines); |
| *P. japonicus* | Kuruma prawn | Kuruma-ebi (Japan); Kalri (Pakistan); Flowery prawn (Hong Kong); Banded shrimp (Taiwan); Oriental brown shrimp (Korea) |
| *P. merguiensis* | Banana prawn | Jaira/Jiaro (Pakistan); Udang kaki merah (Malaysia); Udang putih (Indonesia); Kung chaebauy (Thailand); Pak ha (Hong Kong) |
| *P. monodon* | Giant tiger prawn | Jinga/Yera (India); Ushi-ebi (Japan); Kalri (Pakistan); Grass shrimp (Taiwan); Sugpo (Philippines); Udang windu (Indonesia) |
| *P. orientalis** | Fleshy prawn | Taisho-ebi/Korai-ebi (Japan) |
| *P. penicillatus* | Redtail prawn | Jaira, Jiaro (Pakistan), Pak ha, White prawn (Hong Kong); Red-tailed prawn (Taiwan) |
| *P. semisulcatus* | Green tiger prawn | Kalri (Pakistan); Kuma-ebi (Japan); Fa ha/Flower prawn/Bamboo prawn (Hong Kong); Kung kula lai (Thailand) |
| *Macrobrachium rosenbergii* | Giant river prawn | Bharo/Chooan chingri (Bangladesh); Udang satang/duri (Indonesia); Golda/Mocha chingri (India); Koong yai (Thailand) |
| *Metapenaeus ensis* | Greasyback shrimp | Udang laki (Indonesia); Yosi-ebi (Japan); Sand shrimp (Taiwan); Chung ha (Hong Kong); Kung takard (Thailand) |

* - Also referred to as *P. chinensis*.

Source: *FAO Species Catalog: Vol. 1-Shrimps and Prawns of the World*, FIR/S125 Vol. 1, 1980.

Appendix D.--Bangladesh. Total shrimp production, by fishery, with cultured shrimp as a percentage of total shrimp production, 1983-85, with 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1983 | 19,788 | 4,386 | 24,174 | 18 |
| 1984 | 25,788 | 7,578 | 33,366 | 23 |
| 1985 | 34,820 | 14,658 | 49,478 | 30 |
| 1986 | N/A | N/A | N/A | N/A |
| 1990P | 36,000 | 24,000 | 60,000 | 40 |

N/A - Not available.
P - Projected.
Source: U.S. Embassy, Dhaka, January 30, 1986, and June 24, 1987.

Appendix E.--Burma. Total shrimp production, by fishery with cultured shrimp as a percentage of total shrimp production, 1983-1985, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1983 | 4,356 | N/A | 4,356 | 0 |
| 1984 | 6,137 | 7 | 6,144 | Negl. |
| 1985 | 5,757 | 10 | 5,767 | Negl. |
| 1986 | N/A | 506 | 9,744E | 5 |
| 1990P | 12,250 | 1,800 | 14,050 | 13 |

Negl. - Negligible.
N/A - Not available.
E - Estimated.
P - Projected.

Source: American Embassy, Rangoon; January 27, 1986; May 11 and May 18, 1987.

Appendix F.--China. Total shrimp production, by fishery, with cultured shrimp as a percentage of the total, 1982-86, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1982 | 175,566 | 7,079 | 182,645 | 4 |
| 1983 | 184,190 | 8,975 | 193,165 | 5 |
| 1984 | 187,785 | 19,300 | 207,085 | 9 |
| 1985 | 188,486 | 36,279 | 224,765 | 16 |
| 1986 | N/A | 79,054 | N/A | N/A |
| 1990P | N/A | 100,000 | N/A | N/A |

N/A - Not available.
P - Projected.

Source: Bureau of Aquatic Products, People's Republic of China: FAO 1985 Yearbook of Fishery Statistics, Catches and Landings.

Appendix G.--India. Total shrimp production, by fishery, with cultured catch as a percentage of the total, 1983-1986, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1983 | 192,897 | 15,000E | 207,897 | 7 |
| 1984 | 202,967 | 17,000E | 219,967 | 8 |
| 1985 | 198,100 | 19,000E | 217,000 | 9 |
| 1986 | N/A | 20,000E | N/A | N/A |
| 1990P | N/A | 30,000E | N/A | N/A |

E - Estimated.
N/A - Not available.
P - Projected.

Source: American Consulate, Madras, India, July 9, 1987.

Appendix H.--Indonesia. Total shrimp production, by fishery, with cultured shrimp as a percentage of the total, 1982-87, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1982 | 100,490 | 11,313 | 111,803 | 10 |
| 1983 | 120,960 | 37,440 | 158,400 | 24 |
| 1984 | 108,757 | 32,093 | 140,858 | 23 |
| 1985 | 116,130 | 36,450 | 152,580 | 24 |
| 1986 | 119,600 | 41,000 | 160,600 | 25 |
| 1987P | 122,700 | 49,000 | 171,700 | 29 |
| 1990P | N/A | 60,000 | N/A | N/A |

P - Projected.
N/A - Not available.

Source: U.S. Embassy, Jakarta; January 30, 1986, and May 11, 1987.

Appendix I.--Japan. Total shrimp production, by fishery, with cultured shrimp as a percentage of the total, 1982-85, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1982 | 59,064 | 2,026 | 61,089 | 3 |
| 1983 | 68,123 | 1,978 | 70,101 | 3 |
| 1984 | 65,095 | 2,061 | 67,156 | 3 |
| 1985 | 57,151 | 2,184 | 59,335 | 4 |
| 1986 | N/A | N/A | N/A | N/A |
| 1990P | N/A | 2,600 | N/A | N/A |

N/A - Not available.
P - Projected.

Source: Regional Fisheries Attache, U.S. Embassy, Tokyo; April 28, 1986, and May 15, 1987.

Appendix J.--Republic of Korea. Total shrimp production by fishery, with cultured shrimp as a percentage of the total, 1976-1986, and 1990 projection.

| Year | Catch | | | Percentage* |
|---|---|---|---|---|
| | Cultured | Wild | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1976 | 79 | 30,399 | 30,478 | 0.3 |
| 1977 | 99 | 29,447 | 29,546 | 0.3 |
| 1978 | 85 | 26,078 | 26,163 | 0.3 |
| 1979 | 125 | 27,175 | 27,300 | 0.5 |
| 1980 | 85 | 26,970 | 27,055 | 0.3 |
| 1981 | 117 | 23,835 | 23,952 | 0.5 |
| 1982 | 109 | 33,112 | 33,221 | 0.3 |
| 1983 | 50 | 38,606 | 38,656 | 0.1 |
| 1984 | 93 | 31,717 | 31,810 | 0.3 |
| 1985 | 84 | 40,775 | 40,859 | 0.2 |
| 1986 | 133 | 45,221 | 45,354 | 0.3 |
| 1990P | 500 | 44,500 | 45,000 | 1.1 |

P - Projected.

Source: ROK National Fisheries Administration, Ministry of Agriculture and Fisheries; FAO Yearbook of Fishery Statistics, 1976-1982.

Appendix K.--Malaysia. Total shrimp production, by fishery, with cultured shrimp as a percentage of total shrimp production, 1983-1986, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | | --Metric tons-- | | --In percent-- |
| 1983 | 52,821 | 415 | 53,236 | 1 |
| 1984 | 53,650 | 682 | 54,332 | 1 |
| 1985 | 80,349 | 205 | 80,554 | Negl. |
| 1986 | 57,982 | 269 | 58,251 | Negl. |
| 1990P | N/A | 2,000 | N/A | N/A |

Negl. - Negligible.
P - Projected.
N/A - Not available.

Source: U.S Embassy, Kuala Lumpur; February 3, 1986, and May 18, 1987.

Appendix L.--Pakistan. Total shrimp production, by fishery, with cultured shrimp as a percentage of the total, 1983-1986, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1983 | 27,502 | - | 27,502 | 0 |
| 1984 | 28,570 | - | 28,570 | 0 |
| 1985 | 26,874 | 1 | 26,873 | Negl. |
| 1986 | 26,992E | 8 | 27,000 | Negl. |
| 1990P | 33,800 | 200 | 34,000 | Negl. |

Negl. - Negligible.
E - Estimated.
P - Projected.

Source: Marine Fisheries Department, Government Ministry of Food, Agriculture, and Cooperatives, Pakistan.

Appendix M.--Philippines. Total shrimp production, by fishery, with cultured shrimp as a percentage of total, 1982-85, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1982 | 20,400 | 4,100 | 24,500 | 17 |
| 1983 | 29,650 | 12,060 | 41,710 | 29 |
| 1984 | 44,440 | 28,860 | 75,300 | 38 |
| 1985 | 44,540 | 29,040 | 73,580 | 39 |
| 1986 | N/A | N/A | N/A | N/A |
| 1990P | N/A | 40,000 | 53,300 | 75 |

N/A - Not available.
P - Projected.

Source: U.S Embassy, Manila; April 30, 1986, and May 5, 1987.

Appendix N.--Sri Lanka. Total shrimp production, by fishery, with cultured shrimp as a percentage of total, 1983-1985, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1983 | 4,017 | 0 | 4,017 | 0 |
| 1984 | 4,655 | 0 | 4,655 | 0 |
| 1985E | 4,731 | 89 | 4,820 | 2 |
| 1986 | N/A | N/A | N/A | N/A |
| 1990P | 7,250 | 1,500 | 8,750 | 17 |

E - Estimated.
N/A - Not available.
P - Projected.

Source: U.S Embassy, Colombo, February 14, 1987.

Appendix O.--Taiwan. Total shrimp production, by fishery, with cultured shrimp as a percentage of total, 1983-1986, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | --Metric tons-- | | | --In percent-- |
| 1983 | 78,590 | 10,973 | 89,563 | 12 |
| 1984 | 88,864 | 13,366 | 102,212 | 13 |
| 1985 | 89,288 | 19,315 | 108,603 | 18 |
| 1986 | 87,702 | 51,003 | 138,705 | 37 |
| 1990P | N/A | 75,000 | N/A | N/A |

P - Projected.
N/A - Not available.

Source: American Institute in Taiwan, Taipei, April 29, 1987.

Appendix P.--Taiwan. Cultured shrimp production, by species and quantity, 1977-1986.

| Species | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 |
| | --Metric tons-- | | | | | | | | | |
| P. monodon | 725 | 1,156 | 4,123 | 2,533 | N/A | 6,713 | 9,178 | 10,755 | 16,715 | 44,387 |
| M. ensis | 283 | 693 | 864 | 684 | N/A | 1,576 | 840 | 902 | 1,197 | 1,214 |
| M. rosenbergii | - | - | - | - | N/A | 914 | 680 | 1,315 | 697 | 1,382 |
| P. japonicus | - | - | 81 | - | N/A | 59 | 56 | N/A | N/A | N/A |
| Other | 384 | 371 | 1,264 | 589 | N/A | 313 | 187 | 394 | 706 | 4,020 |
| Total | 1,392 | 2,220 | 6,332 | 3,806 | N/A | 9,575 | 10,941 | 13,366 | 19,315 | 51,003 |

N/A - Not available.

Source: Fisheries Yearbook of Taiwan Area, various years; American Institute in Taiwan, Taipei.

Appendix Q.--Taiwan. Total area of existing shrimp culture ponds, by type, 1983-1986.

| Type of Culture | Year | | | |
|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 |
| | --Hectares-- | | | |
| Brackish Water | 3,652 | 4,175 | 3,953 | 9,339 |
| Shallow Sea | 0 | 0 | 0 | 10 |
| Fresh Water | 401 | 313 | 337 | 171 |
| Total | 4,053 | 4,488 | 4,290 | 9,580 |

Source: American Institute in Taiwan, Taipei, April 29, 1987.

Appendix R.--Thailand. Total shrimp production, by fishery, with cultured shrimp as a percentage of total shrimp production, 1980-85, and 1990 projection.

| Year | Fishery | | | Percent |
|---|---|---|---|---|
| | Wild Catch | Cultured | Total | |
| | -Metric tons-- | | | --In percent-- |
| 1980 | 122,010 | 8,176 | 130,186 | 6 |
| 1981 | 137,035 | 10,885 | 147,920 | 7 |
| 1982 | 170,161 | 10,371 | 180,532 | 6 |
| 1983 | 148,280 | 12,701 | 160,981 | 8 |
| 1984 | 121,270 | 16,109 | 137,379 | 12 |
| 1985 | 109,347 | 18,296 | 127,643 | 14 |
| 1986 | N/A | N/A | N/A | N/A |
| 1990P | N/A | 35,000 | N/A | N/A |

N/A - Not available.
P - Projected.

Source: U.S. Embassy, Bangkok, March 31, 1986, and May 13, 1987.

Appendix S.--Thailand. Hectares under marine shrimp culture, number of shrimp farms, and yield per hectare, 1978-1985.

| Year | Ponds | Farms | Yield per hectare |
|---|---|---|---|
| | Hectares | Number | kilograms |
| 1978 | 24,169 | 3,045 | 262 |
| 1979 | 24,676 | 3,378 | 283 |
| 1980 | 26,036 | 3,572 | 308 |
| 1981 | 27,459 | 3,657 | 387 |
| 1982 | 30,792 | 3,943 | 326 |
| 1983 | 35,537 | 5,334 | 384 |
| 1984 | 36,792 | N/A | 353 |
| 1985 | 40,837 | N/A | 388 |

N/A - Not available.

Source: U.S. Embassy, Bangkok, March 31, 1986, and May 13, 1987.

## APPENDIX IV

# *FEDERAL REGULATIONS*

*(NOT ALL INCLUSIVE)*

**SITING OR PROJECTS**

Fish and Wildlife Coordination Action (16 USC 661-667) requires that action on licenses, permits, and other construction projects regulated, undertaken, or funded by the Federal Government (including Corps of Engineers below) must include consultation with resource agencies (NMFS) and equal consideration of fish and wildlife resources.

Section 10 of the River and Harbor Act requires that structures in navigable waterways and below certain tidal levels must be authorized by the U.S. Department of the Army, Corps of Engineers.

Section 404 of the Clean Water Act requires the U.S. Department of the Army, Corps of Engineers to consult with the National Marine Fisheries Service, U.S. Fish and Wildlife Service, and state agencies for advice on potential impacts of their actions, including permitting of aquaculture facilities, on marine, estuarine, and anadromous fish resources.

Aquaculture facilities sited on lands managed by the U.S. Forest Service require special use permits (38 S11.01 as amended 70 S708 (16 USC 497). Easements and power lines across USFS lands requires authorization under 90 S2776 (43 USC 1761-71).
Coastal zone management authority has been delegated to the State of Alaska under the Coastal Zone Management Act. Any aquaculture proposal would have to be consistent with the State of Alaska CZM plan or an approved local government CZM plan.

**PERMITTING OPERATION**

The National Pollution Discharge Elimination System (NPDES) program under sections 318, 402, and 405(a) of the Clean Water Act (40 CFR 122.1) requires that discharge from concentrated aquatic animal production facilities be authorized by the Environmental Protection Agency (EPA). These facilities are considered point sources of discharge.

For non-point source facilities such as net pens and floating facilities, the State of Alaska issues certification that water quality standards are met. The EPA has deferred to the State in this situation.

Food and Drug Administration rules govern the use of medications, hormones and food additives that are used in producing fish for human consumption.

The Lacey Act may come into play when aquaculture stock or products that are in conflict with state and local government rules move between states.

Unless the general permits and certificates of inclusion now issued under authority of the Marine Mammal Protection Act can be adapted to aquaculture projects, new regulations may be necessary to deal with depredations by seals, sea lions, and sea otters. Such depredations are predictable with a high level of certainty as salmon and shellfish culture develops in coastal waters of Alaska.

Conflicts with the Migratory Bird Treaty Act will probably be associated with mussel culture and pen rearing of salmon, again requiring consideration of new regulations that govern protection actions.

**FEDERAL ASSISTANCE**

The Small Business Administration is authorized (13 CFR 123) to make or guarantee loans as necessary or appropriate to victims of physical disaster or economic injury caused by such disaster, by Federal action or by certain currency fluctuations. Agricultural enterprises, including aquaculture, are eligible for these loans (13 CFR 123.17).

The Farmers Home Administration (FHA) state director is required to report the number of aquaculture operators affected by a potential natural disaster under 7 CFR 1945.19 and these operators can be considered for disaster relief. Aquaculture opeators are eligible for Economic Emergency Loans Administered by the FHA under 7 CFR 1980.512.

**OTHER**

Criteria for the issuance of permits to Aquaculture projects are outlined in 40 CFR 122.11. The EPA is charged with encouraging aquaculture projects while at the same time protecting other beneficial uses of the waters (40 CFR 122.10). This includes discharge variances into aquaculture projects for the purpose of determining the feasibility of using pollutants to grow aquatic organisms.

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Figure i-1. Yearbook of Fishery Statistics, Food and Agricultural Organization of the United Nations (FAO), various years.

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Figure II-3. Fisheries Analysis Branch, National Marine Fisheries Service.

Figure II-4. FAO, various years.

Figure II-5. Fisheries of the United States, NMFS.

Figures II-6 to II-10. Economics Staff, NMFS.

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Figure II-14. Import Statistics of Japan, various years.

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**APPENDIX IV**

NMFS Alaska Regional Office



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