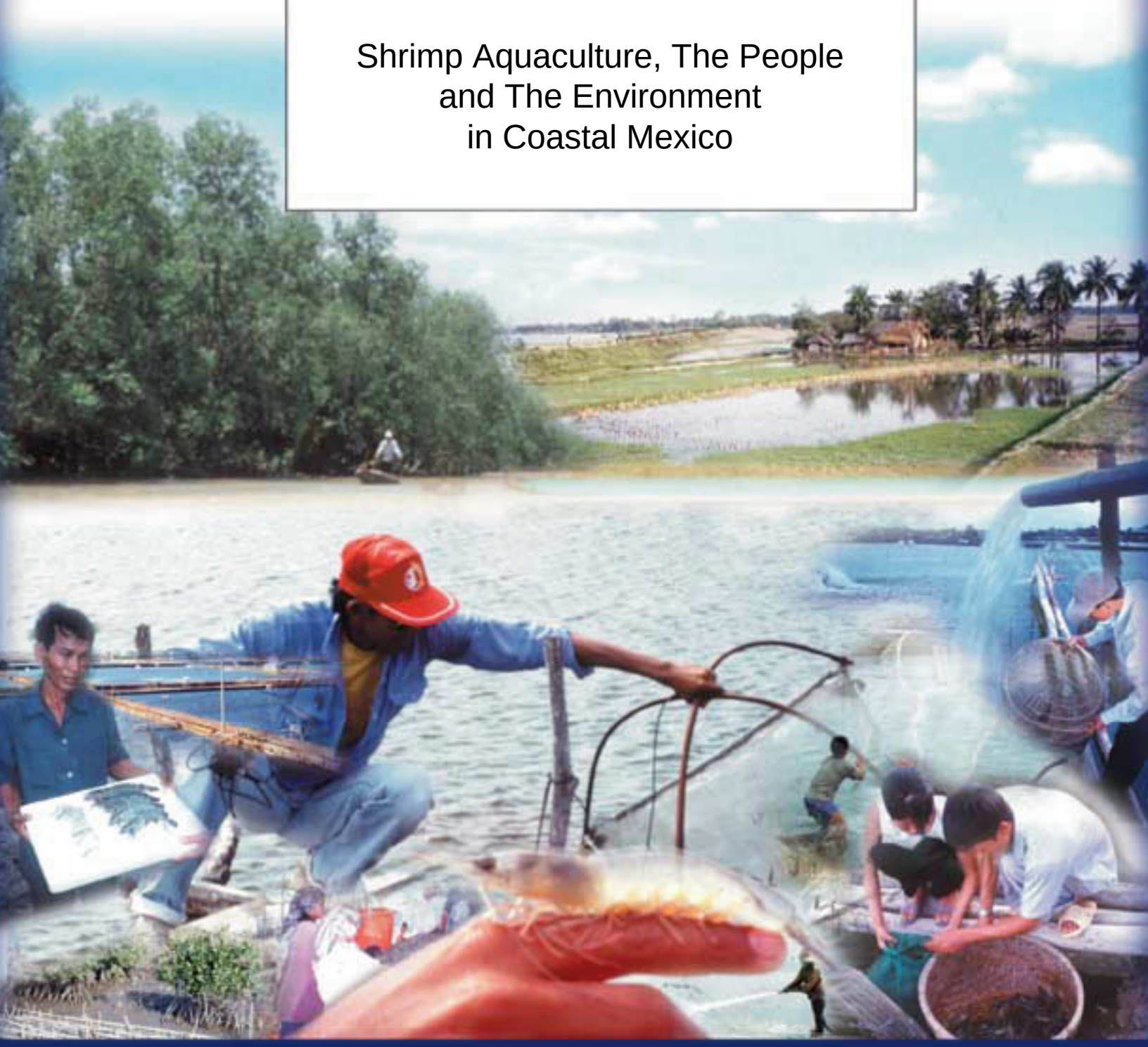
Shrimp Farming and the Environment

Shrimp Aquaculture, The People and The Environment in Coastal Mexico



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SHRIMP AQUACULTURE, THE PEOPLE AND THE ENVIRONMENT IN COASTAL MEXICO

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Preparation of this document

The research reported in this paper was prepared under the World Bank/NACA/WWF/FAO Consortium Program on Shrimp Farming and the Environment. Due to the strong interest globally in shrimp farming and issues that have arisen from its development, the consortium program was initiated to analyze and share experiences on the better management of shrimp aquaculture in coastal areas. It is based on the recommendations of the FAO Bangkok Technical Consultation on Policies for Sustainable Shrimp Culture[1], a World Bank review on Shrimp Farming and the Environment[2], and an April 1999 meeting on shrimp management practices hosted by NACA and WWF in Bangkok, Thailand. The objectives to the consortium program are: (a) Generate a better understanding of key issues involved in sustainable shrimp aquaculture; (b) Encourage a debate and discussion around these issues that leads to consensus among stakeholders regarding key issues; (c) Identify better management strategies for sustainable shrimp aquaculture; (d) Evaluate the cost for adoption of such strategies as well as other potential barriers to their adoption; (e) Create a framework to review and evaluate successes and failures in sustainable shrimp aquaculture which can inform policy debate on management strategies for sustainable shrimp aquaculture; and (f) Identify future development activities and assistance required for the implementation of better management strategies that would support the development of a more sustainable shrimp culture industry. This paper represents one of the case studies from the Consortium Program.

The program was initiated in August 1999 and comprises complementary case studies on different aspects of shrimp aquaculture. The case studies provide wide geographical coverage of major shrimp producing countries in Asia and Latin America, as well as Africa, and studies and reviews of a global nature. The subject matter is broad, from farm level management practice, poverty issues, integration of shrimp aquaculture into coastal area management, shrimp health management and policy and legal issues. The case studies together provide an unique and important insight into the global status of shrimp aquaculture and management practices. The reports from the Consortium Program are available as web versions (http://www.enaca.org/shrimp) or in a limited number of hard copies.

The funding for the Consortium Program is provided by the World Bank-Netherlands Partnership Program, World Wildlife Fund (WWF), the Network of Aquaculture Centres in Asia-Pacific (NACA) and Food and Agriculture Organization of the United Nations (FAO). The financial assistance of the Netherlands Government, MacArthur and AVINA Foundations in supporting the work is also gratefully acknowledged.

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Reference

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[1] FAO. 1998. Report of the Bangkok FAO Technical Consultation on Policies for Sustainable Shrimp Culture. Bangkok, Thailand, 8-11 December 1997. FAO Fisheries Report No. 572. Rome. 31p.

[2] World Bank. 1998. Report on Shrimp Farming and the Environment – Can Shrimp Farming be Undertaken Sustainability? A Discussion Paper designed to assist in the development of sustainable shrimp aquaculture. World Bank. Draft

Abstract

The shrimp aquaculture sector in Mexico has experienced a boom in recent years, particularly following the 1992 revisions to Article 27 of the Constitution (Agrarian reform legislation) and to the Fisheries Law. This case study documents the social and environmental effects of aquaculture, the effectiveness of government in regulating the industry, the interactions between new producers and long-term residents of coastal areas and the sources of investment in the industry. Individuals from many different stakeholder groups were consulted to esure that their concerns and viewpoints are adequately reflected in the analysis. In addition, the report identifies the most important interventions needed to make shrimp aquaculture economically and environmentally sustainable.

Approximately 90% of operating shrimp aquaculture farms are located in the three states of Sonora, Sinaloa, and Nayarít, accounting for 95% of the production of farmed shrimp in the country. Basic facts about recent shrimp farming operations include the following.

- The number of producers nearly doubled in the period between 1993 and 1998, to nearly 400 farms.
- There are now nearly 21,000 ha of shrimp aquaculture ponds in the country.
- Average annual yields are approximately 1.34 MT per hectare.
- Shrimp aquaculture production was valued at approximately US$ 28 million in 1998.
- Shrimp farming has generated approximately 8,000 direct jobs (and perhaps twice as many indirect and part-time jobs) in regions of the country that offer few other economic options.
- Aquaculture now contributes approximately 25% of total shrimp production in Mexico, about the same as near-shore fisheries, but still lagging the high-seas fishery, which provides about 50%.
- Of Mexico's total production of 71,609 MT of shrimp in 1998, it exported about 53% of the total (38,221 MT), with 98% of exports going to the United States. There is an excellent domestic market for shrimp in Mexico, as well, and competition for product keeps prices to producers relatively high.

The historical legacy of agrarian reform has resulted in about 80% of the shrimp aquaculture farms still being held by the cooperative/ejido sector; these producers still account for about 48% of the farm-raised shrimp in the country. When individuals from ejidos decide to sell or lease their lands, they receive good prices. "Participation Associations" are being formed in some areas. In these situations, the private sector develops an aquaculture park in which a portion remains in the hands of the cooperative/ejido sector that has traditionally held the property rights to the land.

In Mexico, the issue of coastal property rights is quite complicated: federal zones, subdivided ejido lands, communal ejido lands, private property and areas in which cooperatives have been granted fishing rights can overlap or exist in close proximity. Disputes over boundary lines and associated property rights among these stakeholders are common.

All producers in both the cooperative/ejido and private sector are quite concerned about losses from disease. Mexico's use of hatchery postlarvae is extensive, with about 90% of production now using this source. This may help in preventing further disease outbreaks.

Approximately 23% of shrimp farms in Mexico were not producing in 1998, primarily because of shrimp disease, poor site choice for the farm, or lack of capital.

Shrimp aquaculture in Mexico has thus far developed largely without the major detrimental environmental effects seen in other countries of the world. Little evidence of mangrove destruction has been discovered. The most serious threat from shrimp aquaculture is probably its potential effects on water quality.

Capital to invest in shrimp farming comes from a diverse range of sources. Private capital, national banks and financial institutions have provided most of the money invested. Input suppliers (For feed and postlarvae) and marketers are also providing extended credit and/or loans to farmers. Some foreign investment is present, but most of the capital being invested originates in Mexico.

Substantial progress has been made within SEMARNAP (Ministry of the Environment, Natural Resources, and Fisheries), the main regulatory, monitoring and enforcement agency. A reasonable structure of legal regulations and standards now exists. Enforcement is still a problem, with PROFEPA (The Attorney General for Environmental Protection) suffering from a lack of funding, but the situation appears to be improving.

Overall, the state of aquaculture in Mexico appears to be evolving in a very positive direction. Because of the results stemming from its Revolution, Mexico may be the only place in Latin America in which the resource-poor sector will play a big role in production of farmed shrimp. Regulation and monitoring of the industry are still in their infancy, but SEMARNAP is putting in place a system that may be able to esure that aquaculture will be sustainable. The presence of a strong system of universities and applied research institutes should help with the development and monitoring of the industry. More effective involvement of the NGO community in the aquaculture sector may also help to monitor and ensure compliance with environmental regulations.

The major threat to developing a sustainable shrimp farming industry in Mexico is shrimp diseases. Disastrous declines in production because of disease spread, and resulting uncertainty, may make many producers unwilling to invest in the technology needed to make their operations more socially and environmentally sustainable.

Content

Acronyms and Abbreviations

ANP	Natural Protected Area
BANCOMEXT	National Bank for External Commerce
BANRURAL	National Bank of Rural Credit
CAN	National Water Commission
CANAINPES	National Chamber of the Fishing Industry
CECARENA	Center for the Conservation and Utilization of Natural Resources
CI	Conservation International
CIAD	Center for Research in Food and Development
CICTUS	Center for Scientific and Technological Research, University of Sonora
CONABIO	National Commission on the Study and Use of Biodiversity
CONACYT	National Science and Technology Foundation
CRIP	Regional Center of Research Investigations
DGA	General Directorate of Aquaculture
DICTUS	Department of Scientific and Technological Research, University of Sonora
DNA	Deoxyribonucleic acid
DUMAC	Ducks Unlimited of Mexico
EDTA	Ethylenedediamine Tetra Acetic Acid
FAO	Trust Instituted in Relation to Agriculture, Bank of Mexico
FOCIR	Capitalization Fund for Rural Development
FONAES	National Fund to Support Solidarity Enterprises
GIS	Global Information System
Ha	Hectare, 2.47 acres
HACCP	Hazard Analysis and Critical Control Point
ICM	Integrated Coastal Management
IHHNV	Infectious hypodermal and haematopoeitic necrosis virus
INE	National Institute of Ecology
ITESM	Monterrey Technological Institute of Advanced Studies
ITSON	Technological Institute of Sonora
Kg	Kilogram
Km	Kilometer
Kw	Kilowatt
LGEEPA	General Law of Ecological Equilibrium and Environmental Protection
m^2	Square meter
m^3	Cubic meter
MAP	Mexico Aquaculture Project
MT	Metric Ton
NACA	Network of Aquaculture Centres in Asia-Pacific
NGO	Non-Governmental Organization
PAIS	Integrated Agriculture Program of Sonora
Peso	Mexican currency (1 US$ = 9,53 Peso)
PL	Postlarvae
PNDEC	National Diagnostic Program for Coastal Ecosystems
PROCEDE	Program for Certification of Ejido Land Rights and Titling of Urban House Plots
PROFEPA	Attorney General for Environmental Protection
SEMARNAP	Ministry of the Environment, Natural Resource, and Fisheries[3]
SHCP	Ministry of the Treasury and Public Credit
SPF	Specific Pathogen Free

[3] In 2000 administrative changes led to the funding of a new ministry IEMA

SRA	Ministry of Agrarian Reform
TSV	Taura Syndrome Virus
UAS	Autonomous University of Sinaloa
UEASS	Union of Aquacultural Ejidos of Southern Sonora
UGOCP	General Obrero Peasant and Peoples Union
UIB	Biogeographic Information Unit
WB	The World Bank
WSSV	White Spot Syndrome Virus
WWF	World Wildlife Fund
YHV	Yellow Head Virus
ZOFEMAT	Mexican Office of the Federal Maritime Zone

Shrimp Aquaculture and Mexico

Introduction

Since 1985, shrimp aquaculture has become one of the most rapidly expanding economic activities along the coasts of Mexico. Cultivating shrimp in ponds built near the ocean's shore has created profits for many producers, generated new employment opportunities, and raised the possibility of reducing pressure on wild shrimp stocks. At the same time, the growth of this new industry has raised many questions about its impacts on the terrestrial, estuarine, and sea ecosystems of Mexico's coasts.

This report provides basic information on the shrimp aquaculture industry that has developed on the coasts of Mexico. It will explore the effectiveness of national and state governments in regulating the industry, the development of monitoring plans and organizations, the development of comprehensive management plans both for and by the shrimp industry, the interaction between new producers and long-term coastal residents, and the effects of the industry on the environment. The report will identify the most important interventions needed to make shrimp aquaculture economically and environmentally sustainable– minimizing its negative impacts or enhancing its positive effects, or both, on the ecosystems of coastal Mexico.

Historical Overview and Recent Developments in Shrimp Aquaculture

Mexico is a country with an extensive coastline, measuring approximately 9,330 km (see Figure 1). An estimated 1.6 million ha of coastal lagoons, bays, and estuaries (Rámirez and Contreras 1998) create rich repositories of biodiversity and of aquatic resources that human populations have used for thousands of years. In the distant past, pressure on these resources was relatively minimal; initially small human population densities, kept in check later by the presence of diseases that thrived in coastal regions, limited human harm to the environment.

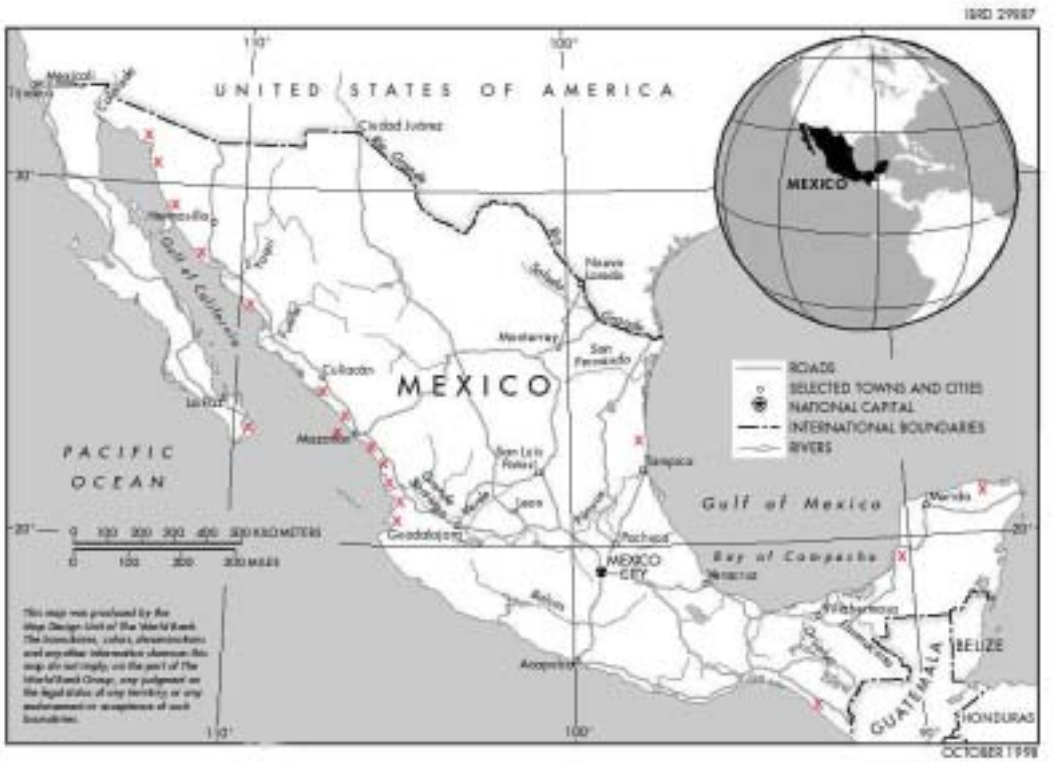

Figure 1. Geographic Features of Mexico The red markings are major shrimp farming areas (World Bank 1999; Rosenberry 2001)

Mexican fishermen have long practiced a form of rudimentary shrimp aquaculture. When high tides bring significant numbers of shrimp and fish into natural lagoons, fishermen create barriers (Tapas) to trap them. The shrimp and fish naturally feed on the resources in the lagoon and grow; when they mature, the fishermen harvest them. During the mid and late 20th century, the government sometimes assisted these efforts by dredging natural entrances or creating new canals to improve the flow of water and marine organisms into bays, lagoons, and estuaries.

The importance of marine resources for resource poor coastal people was formally recognized following the Mexican Revolution, in the early part of the 20th century. By law, the cooperative/ejido sector[4] was given the exclusive right to capture, cultivate and process the most valued seafood species, including shrimp, oysters, lobster, abalone, octopus and squid. Fisheries production cooperatives were established in the 1930s with the goals of increasing the living standards of rural fishermen, augmenting food production and generating export income (McGoodwin 1980). The net result of this policy of reserving seafood species for the cooperative/ejido sector was to inhibit the private sector from investing in aquacultural pursuits.

Unfortunately, the fisheries cooperatives did not have either secure tenure rights or the resources to invest in aquaculture. Just as the ejidos[5] in the agricultural sector were not given full property rights over their land (DeWalt and Rees 1994), the national government retained ultimate control over the exploitation of fisheries (McGoodwin 1987). Fisheries cooperatives had to work within constraints established by a paternalistic government, which directed when, where, and how resources could be exploited. The government dictated who had tenure rights to near-shore fisheries. The government was also required to provide technical assistance, credit for equipment and infrastructure, and processing and marketing facilities for the cooperatives, but substantial problems existed with this system (DeWalt 1998). In short, fisheries cooperatives had little opportunity to establish aquaculture ventures.

While these problems have existed since the 1930s, an additional problem arose in the early 1970s. As the population grew and peasants' demands for access to land increased, the government began encouraging settlement of the sparsely populated coastal regions. The government created hundreds of new ejidos on marginal coastal land that was formerly national property. The people on these ejidos thus had some land to settle on, but little of this land was suitable for agriculture. The result was that many of these people turned to fishing, competing for scarce resources with longer-term residents of the coastal areas (McGoodwin 1987).

The origins of shrimp aquaculture in Mexico date from the 1970s, when an agreement was signed between the Center for Scientific and Technological Research at the University of Sonora (CICTUS, today DICTUS) and the University of Arizona.[6] Under the agreement, an experimental farm (which continues

[4] In Mexico, the term "social sector" is generally used to refer to agrarian reform communities, communal organizations, or production cooperatives that consist primarily of resource-poor individuals. In this report, this sector will be referred to as the cooperative/ejido sector to distinguish it from private-sector farms that are generally owned and operated by wealthier investors.

[5] Ejidos were the organizations established by the Mexican state to receive and manage the land that was expropriated from large landowners and redistributed to peasants after the Revolution. Ejidos are agrarian communities composed of 20 or more individuals. Although land rights were given to these agrarian communities, in most cases arable land was subdivided within the ejido and worked by individuals. Nonarable land, including substantial areas along the coast, remained communal property, and the resources there were open to exploitation by any member of the community.

[6] During this early period, Coca-Cola® of Mexico also contributed some money to the joint venture. Apparently, its chairman thought that there was great potential to sell farm-raised shrimp to McDonald's®, but eventually Coca-Cola® withdrew from the enterprise.

functioning to this day as part of the University of Sonora) was constructed in Puerto Peñasco (Dirección General de Acuicultura 1999:78). The first experiments were done with blue shrimp (*Penaeus stylirostris*), using intensive methods. After good results were obtained, CICTUS began experiments at its Kino Experiment Station, this time using extensive and semi-intensive methods. Production rates of 0.77–0.81 kg/m^2 were obtained in rudimentary 200 m^2 tanks (Garmendia 1997).

Based on these experiments, and the success of shrimp farming in Ecuador, Panama and other countries, a few cooperatives and private producers in Sonora and Sinaloa developed shrimp aquaculture farms from the early 1980s. The reservation of prime seafood species for exploitation by the cooperative/ejido sector and the granting of land rights along the coast to these agrarian reform communities, however, meant that there was little opportunity for the private sector to invest in aquaculture, either. As we have seen, the cooperative/ejido sector did not have secure tenure or the resources to invest in aquaculture. The Ministry of Fisheries reported in the early 1990s that the land tenure situation made the development of aquaculture in Mexico a difficult proposition (1992), and it was apparent that major changes to laws and regulations would be needed if aquaculture was to become a viable, productive part of the economy.

Major Legislative Changes

The first major change that made aquaculture more viable in the country occurred in 1986, when the Fisheries Law was modified. The 1986 legislation eased the requirements for the formation of cooperatives and it created a mechanism by which private-sector investors could enter into agreements with cooperatives for activities such as shrimp aquaculture. In reality, these changes did little to stimulate private-sector investments in aquaculture. More substantial changes occurred as a result of the neoliberal reforms undertaken during the Salinas presidency. In 1992, both Article 27 of the Constitution, which deals with land tenure, and the Fisheries Laws were changed.

Article 27 of the Constitution governs the ejidos. Although the peasants had received usufruct rights from the post-Revolution laws, they did not have full rights to the land and were prevented from selling it (or even renting or leasing it except under certain circumstances). In 1992, the government declared an end to agrarian reform and began to privatize the ejido land, giving full property rights to those who had been working the land (DeWalt and Rees 1994).[7] By privatizing and allowing a land market for ejido land to develop, the government hoped to stimulate more productive investment in, and the modernization of, agriculture.

The modifications made to the Fisheries Law in 1992 had the following key provisions (this section is based on DeWalt 1998):

- Removed the restrictions that permitted only the ejido sector to cultivate and process high-value seafood species.
- Opened to private producers the natural breeding grounds of shrimp postlarvae that had previously been exclusively reserved for the cooperative/ejido sector.
- Provided greater security for investors by extending the maximum aquaculture concession authorized by the government from 20 to 50 years, and allowed these concessions to be transferred to other parties.
- Established biological (ecologically sound) and economic (likely to be financially viable) criteria as the basis for granting concessions and licenses for aquaculture.

[7] Article 27 also declares water bodies to be the property of the nation, including the territorial seas, estuaries and lagoons, lakes and marshlands that permanently or intermittently connect with the seas, and rivers and lakes (Article 27, paragraph 5).

- Encouraged private investment in aquaculture by making clear that ejido lands, which include much of the coastal land suitable for aquaculture, could be accessed through joint ventures with ejidos or directly purchased from ejidos.

The Mexican government also enacted a number of other reforms at about the same time that have affected aquaculture. The 1992 Water Law removed restrictions on the use of water for aquaculture, giving it the same priority as other productive uses of water. Modifications to the 1993 Foreign Investment Law permitted up to 100 percent foreign ownership of aquaculture production, processing and marketing facilities. Fiscal reforms also provided new incentives for aquacultural investments. Individuals, cooperatives and firms involved exclusively in aquaculture receive a 50% exemption on income tax, reimbursement of the value-added tax when the producer pays duty on imported inputs, and accelerated depreciation or tax write-offs for up to 62% of initial infrastructure investment and up to 89% of investment in machinery and equipment. Mexico's joining of the North American Free Trade Agreement resulted in zero import duty on basic inputs for aquaculture, and tariffs on feed for aquaculture were reduced.

The net effect of these changes was to provide new opportunities and incentives for the private sector to become involved in aquaculture. The dynamism of aquaculture since 1993 reflects the effects of these legislative changes and fiscal reforms.

Shrimp Aquaculture in Mexico: Current Operations

Although aquaculture began in Mexico in 1977 with technology that was largely copied from efforts in Ecuador and other Latin American countries, growth of the industry was relatively slow until the late 1980s (Figure 2). Although there were only 45 farms reported in 1987, by 1993 there were 192 producers in the country–with 12,511 ha of ponds and production of 11,486 MT. Since then, the number of farms has nearly doubled to an estimated 393 in the year 2000.[8]

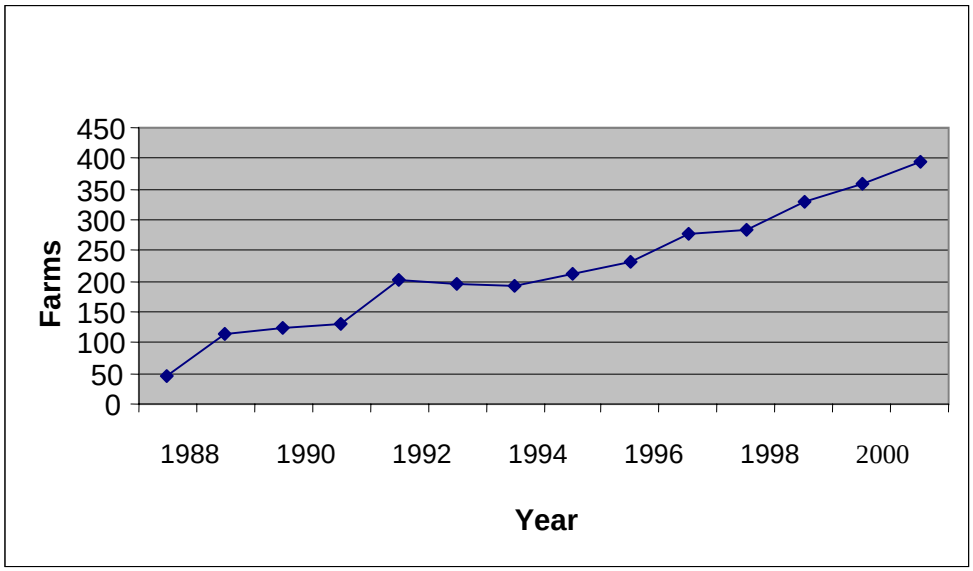

Figure 2. Number of Shrimp Farms in Mexico, 1987–2000

[8] These data should be interpreted with caution. SEMARNAP (Ministry of the Environment, Natural Resources, and Fisheries) officials reported that the data from prior to 1993 are not reliable. This is especially the case for production figures (reported, from the same source as Figure 2, as averaging more than 6 MT/ha in 1990!), but the figures for number of farms are probably more or less accurate (Those in existence, not those actually producing).

Table 1. Total area in use for shrimp aquaculture in Mexico.

	Operating		Not Operating		Total		Production
State	Farms	Area (Ha)	Farms	Area (Ha)	Farms	Area (Ha)	Tons
Pacific Coast	**239**	**17,334**	**73**	**3,110**	**312**	**20,444**	**22,828**
Baja	1	25	-	-	1	25	30
California B.C Sur	1	9	-	-	1	9	57
Sonora	33	4,411	6	230	39	4,641	6,934
Sinaloa	119	10,887	33	1,860	152	12,747	13,484
Nayarit	75	1,753	28	576	103	2,330	2,140
Colima	5	33	-	-	5	33	45
Guerrero	1	2	2	227	3	229	0
Chiapas	4	214	4	216	8	431	138
Gulf/Car. Coast	**14**	**411**	**2**	**114**	**16**	**525**	**921**
Tamaulipas	10	354	1	64	11	418	224
Veracruz	1	2	-	-	1	2	0
Tabasco	1	6	-	-	1	6	0
Campeche	1	3	-	-	1	3	8
Yucatan	1	46	-	-	1	46	689
Total	**253**	**17,746**	**75**	**3,224**	**328**	**20,969**	**23,749**

Source SEMARNAP, Anuario Estadistico de Pesca 1998

Table 1 shows that 95% of Mexico's shrimp farms are located on the Pacific Coast, concentrated in the three states of Sonora, Sinaloa and Nayarit which include almost 90% of the total. The first farms were established on the northwest coast in the early 1980s, and it is there that rapid growth has continued. In the other states of Mexico, shrimp farming has only recently begun. It is expected, however, that, barring significant disease prevalence, rapid growth will occur in new areas. Already, several farms are operating in Chiapas and Tamaulipas; many more will probably be established in the next several years. Campeche, Yucatán, Veracruz, Colima and Guerrero also have potential for the development of shrimp and other aquaculture. In Appendix A information on shrimp farming in the most important producing states in Mexico are presented.

Table 1 also shows that approximately 23% of the farms in 1998 were not producing. Every year, some farms cease production because they lack operating capital, they have had serious problems from disease, a natural disaster has affected their infrastructure (e.g. hurricanes that destroy ponds or affect road access to the production site), or have other problems.[9]

Determining the exact number of farms is difficult because changes occur frequently. Some farms do not operate in certain years because of technical or financial problems, while new farms are always coming into production. The state delegation of SEMARNAP in Sonora reported 47 projects were being evaluated in late 1999. In Sinaloa, 17 environmental impact assessments for establishing new farms or expanding existing farms were conducted during 1999. Although SEMARNAP policy indicates that they will close down any farm that begins operating without completing all of the required procedures, there are undoubtedly still farms being established without SEMARNAP's knowledge. The numbers of farms provided in Table 1 therefore, are probably underestimates. When more recent estimates from the state delegations were available, these figures were included in the state-by-state discussion (Appendix A).

[9] Once again, these data have to be interpreted with some caution. In reality, these figures are compiled from the estimates of SEMARNAP delegations in each state. We know that some farms come into existence, as well as go out of existence, without the knowledge of ministry officials. Nevertheless, the growth curve of shrimp farms shown in Figure 2 is probably fairly accurate.

From the information in Table 1, the average production figures per hectare for the different states of Mexico can be calculated. These data are shown in Figure 3. The figures are most meaningful for the states of Sonora, Sinaloa, and Nayarít, in which the number of farms is substantial. For Chiapas, Colima and Tamaulipas, the number of operating farms was fairly small. Average yields are highest in Sonora, where the production is 1.57 MT/ha. It is somewhat surprising that the highest yields are in Sonora, because all farms in the state are limited to one harvest per year. In Sinaloa and Nayarít, the average production is closer to 1.23 MT/ha–despite the fact that farms in southern Sinaloa and all farms in Nayarít could produce two harvests per year. For Mexico as a whole, average yields were 1.34 MT/ha in 1998.

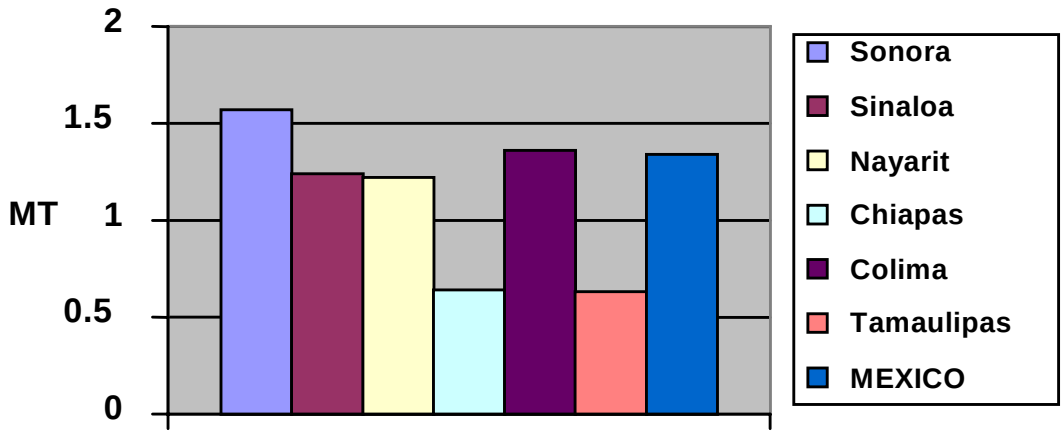

Figure 3. Average Shrimp Production (MT) per Hectare, 1998

Some caution must be used concerning the data on yields from shrimp farming. During conversations with industry stakeholders, several individuals indicated that the information reported to SEMARNAP might not be completely reliable. More than one person reported that production data was in fact being reported for farms that had not produced in years. It was intimated that reporting production data from nonexistent farms was related to laundering of drug money. One individual also reported that fishermen had offered to buy a blank invoice from him. The reason was that, during the off-season, when capturing shrimp in the estuaries or from the ocean is illegal, the only shrimp that can legally be sold are from farms. With a blank invoice, the fishermen could sell their shrimp during that time.

There is no way to estimate the magnitude of these or similar practices. The producer approached for the blank invoice, for example, reported that he would not jeopardize his operation by engaging in such an illegal practice. Other producers, particularly those with marginal operations, might be willing to participate in such schemes. Especially where cooperatives/ejidos both produce shrimp in ponds and capture them from bays and estuaries, the two sources can easily be mixed. The main message is that average figures for farmed shrimp reported here are somewhat inflated because of illegal practices.

Figure 4 shows trends in shrimp production in Mexico since 1990. Production from the high seas has increased overall; the general trend shows an increase of about 4.8% per year, on average. Production from near-shore fisheries has remained more or less stable, while production from aquaculture has grown markedly, quadrupling production since 1990. From 1990 to 1997, aquaculture production increased at an average rate of 22% per year. Disease-related losses affected production figures in 1996, but production rebounded in 1997. As Table 1 shows, production from aquaculture 23,749 MT in 1998, a notable improvement over 1997 figures. At the turn of the century, aquaculture and near-shore fisheries are each contributing about 25% of total shrimp production in Mexico, while the high-seas fishery provides about 50%. In 1998, the nearly 24,000 MT of shrimp produced by aquaculture was worth approximately

US$128 million. Mexico exported 38,211 MT of shrimp in that year, with 98% of exports headed to the United States (SEMARNAP 1998a).

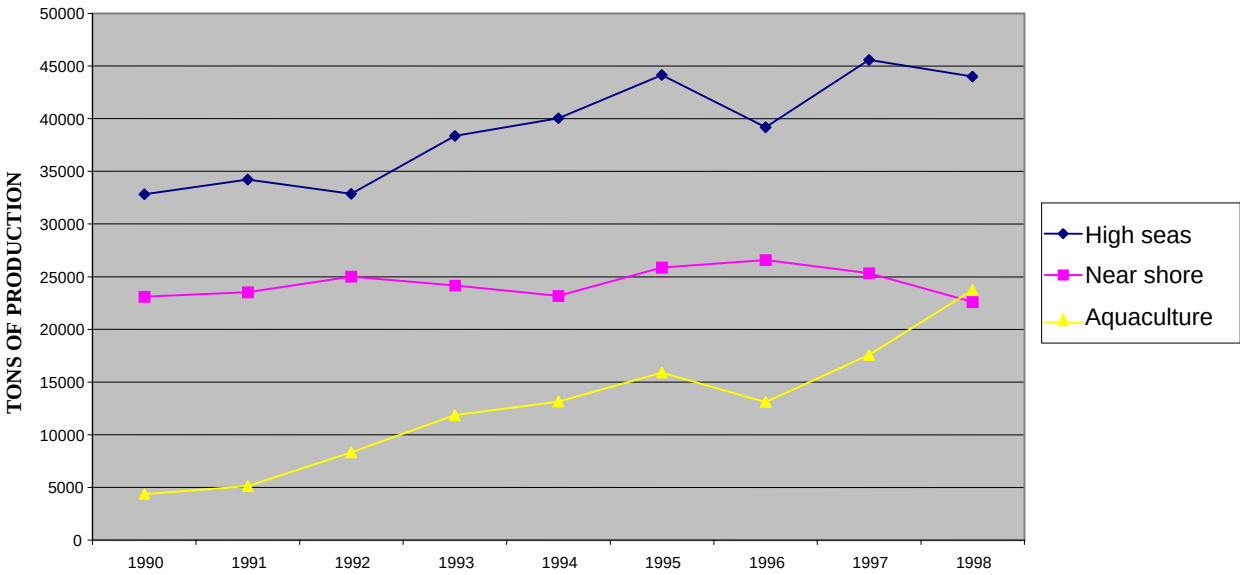

Figure 4. Sources of Shrimp Production in Mexico: 1990–1998

Production Systems

Shrimp production systems in Mexico can be compared along two basic spectra. As in other countries around the world, the systems can be grouped into categories along a continuum that runs from very extensive operations to very intensively managed systems. The other spectrum, unique to Mexico, addresses the farms' source of ownership and management–by the cooperative/ejido sector or the private sector.

The three main groupings used to describe farm management in Mexico, extensive, semi-intensive and intensive systems–are similar to those used in other Latin American countries. Intensive farms generally have small ponds of 1–2 ha, usually use aeration systems, and have high stocking densities of hatchery-raised postlarvae. These farms require high capital investment, need to employ many skilled workers, and are heavy users of feed, nutrients, chemicals and antibiotics. When everything goes well, production rates of 5 to 15 MT/ha can be reached. As Table 2 shows, only about 6% of shrimp farms in Mexico use intensive systems.

Semi-intensive systems make up the majority of farms in Latin America, including Mexico, where about two-thirds of shrimp farms are semi-intensive. Such ponds in Mexico are generally between 4 and 10 ha in size. Most have pumps to regulate water exchange, depend on skilled management and purchased feed, and have moderately high stocking densities (5–25 PL/m2). Yields are generally 1 to 3 MT/ha.

About 28% of farms in Mexico use extensive systems, which use large ponds that are often irregularly shaped. Some are constructed in a relatively primitive fashion, while others may be no more than a natural pond in which a dam is constructed to control natural tidal flows. Feed for the shrimp is naturally occurring, although some minimal additional feed may be provided. Extensive ponds are generally stocked with wild postlarvae from nearby estuaries and lagoons. Although costs associated with extensive systems are low, yields are also quite low, averaging much less than 1 MT/ha.

Table 2 shows official SEMARNAP figures for the number of each type of farm actually operating in each state. Sinaloa has the most farms and accounts for over 61% of the hectares in operation. Average size of the farms in Sinoloa is about 91 ha. Sonora has only 33 farms, but their average size is about 134 ha. All but one of the farms in this state are either semi-intensive or intensive. In contrast, in Nayarít there are 75 farms but their average size is only about 23 ha. The majority of farms in Nayarít, particularly in the cooperative/ejido sector, are extensive, and yields per hectare are quite low.

Table 2. Numbers of Operating Shrimp Farms in Mexico, by Type and State, 1998

	Total		**Extensive**		**Semi-intensive**		**Intensive**	
State	Farms	Area (Ha)	Farms	Area (Ha)	Farms	Area (Ha)	Farms	Area (Ha)
Pacific Coast	**239**	**17,334**	**70**	**2,830**	**167**	**14,210**	**16**	**705**
Baja	1	25	-	-				
B.C Sur	1	9	-	-				
Sonora	33	4,411	1	170	30	4,004	2	237
Sinaloa	119	10,887	29	2,116	87	8,537	3	234
Nayarit	75	1,753	40	545	31	1,124	4	85
Colima	5	33	-	-	4	33	1	-
Guerrero	1	2	-	-	1	2	-	-
Chiapas	4	214	-	-	2	128	2	87
Gulf/Car. Coast	**14**	**411**	**-**	**-**	**11**	**357**	**3**	**54**
Tamaulipas	10	354	-	-	10	354	-	-
Veracruz	1	2	-	-	-	-	1	2
Tabasco	1	6	-	-	-	-	1	6
Campeche	1	3	-	-	1	3	-	-
Yucatan	1	46	-	-	-	-	1	46
Total	**253**	**17,746**	**70**	**2,830**	**167**	**14,210**	**16**	**705**

Table 3 contains distribution of the types of shrimp farms in Mexico in 1998. The types and areas may have changed slightly since 1998, but the table is still probably an accurate representation. Extensive farms make up nearly 30% of farms in Mexico but the proportion of total hectares they occupy is only about 16%. Intensive farms still constitute a relatively small percentage of the total number of farms and occupy a small amount of the area dedicated to shrimp farming (roughly 5% on both counts).

Table 3. Distribution of shrimp farms in Mexico, by type and area in 1998.

	Percentage of farms	**Percentage of area**
Extensive	28	16
Semi-intensive	66	80
Intensive	6	4

Source: Anuario Estadítico de Pesca 1998. SEMARNAP

Of the shrimp farms in Mexico, about 80% are owned and operated by the cooperative/ejido sector (DeWalt 2000). The vast majority of these farms are small, many are not operated every cycle, and the production systems tend to be more primitive. Production rates on these extensive or rudimentary semi-intensive farms are usually much less than 1 MT/ha.

Included in the cooperative/ejido sector, however, are the major aquaculture parks of Sonora and Sinaloa. Sonora has the three large parks of El Tobarí, El Siarí, and Atanasia–with a total of 17 farms, 605 members/workers, and 1,052 ha in operation. An additional park has been proposed for this area. Sinaloa has El Patagüe, a park in which 130 members operate 1,150 ha of ponds.

Private sector farms are generally semi-intensive or intensive operations. These farms are among the most productive in the country, using the best technology, higher inputs, and more skilled technicians. To be

sure, there are private producers whose operating systems are as poor as many of those in the ejidos. Because of lack of knowledge, poor siting of ponds, or bad technical management, some of these farms receive minimal yields. Overall, the General Directorate of Aquaculture (1999:81) has estimated that about 52% of the shrimp produced in cultivated systems in Mexico comes from private sector farms (Which make up only 20% of the total farms), while the other 48% comes from the cooperative/ejido sector.

Conclusions

Mexico has implemented a variety of recent changes to its Constitution and regulatory frameworks that have resulted in considerable investment in shrimp aquaculture. The number of producers and production nearly doubled in the period between 1993 and 1998. By 1998, official figures indicated that there were 328 farms occupying 17,746 ha and annual production reaching 23,749 MT, with an average yield of 1.34 MT/ha. Some 95% of Mexico's shrimp farms are located on the Pacific Coast, heavily concentrated in the states of Sonora, Sinaloa and Nayarit. About 80% of the farms are still held by the cooperative/ejido sector, and these producers still account for about 48% of the farm-raised shrimp in the country. Shrimp aquaculture production was generating a value of approximately US$128 million for the Mexican economy in 1998. Aquaculture has grown to such an extent that it now contributes approximately 25% of total shrimp production in Mexico.

Shrimp Farming Inputs, Marketing, Channels and Sources of Capital

Introduction

The growth of shrimp aquaculture in Mexico has been accompanied by the growth of a variety of ancillary industries. These include hatcheries to provide postlarvae for stocking ponds, factories to produce balanced feeds for the shrimp and processing facilities for the product. This section covers the major inputs into the industry, and how the product from Mexico is processed and eventually sent to consumers.

Land

A suitable and functional site for a shrimp farm is probably the most critical element of developing a sustainable operating system. Gaining access to suitable land and wetlands in many parts of Latin America has not been costly because private producers have been able to acquire long-term concessions from the government for access to public property. This effectively converts open-access resources into private property, and conflicts with local communities who once used these areas have arisen (see DeWalt et al. 1996).

In Mexico, the situation is considerably more complicated. Theoretically, all coastal lands within 20m from the highest tide influence are part of the federal maritime zone. The agrarian reforms of the early 20th century in Mexico, however, also led to the creation of cooperatives and ejidos (also called the social sector). Prior to 1992, these cooperatives/ejidos had exclusive rights to exploit and market the most commercially valuable seafood products in the country. Cooperatives/ejidos were often given exclusive fishing rights for particular areas of bays, lagoons, and estuaries that adjoined their lands, so the cooperatives' members generally thought that they owned these areas. Since the 1992 declaration of the "end of agrarian reform" opened up the possibility of fully privatizing ejido land, there has been considerable confusion and conflict about who should have the rights to the communal coastal lands and maritime areas.

Two results have developed from such ambiguity over property rights. One is that the cooperative/ejido sector in Mexico has been able to participate in aquaculture development because it does have rights to some of the prime locations. As will be seen, in some cases this has been by their own efforts and even by using force, and in other cases, by developing associations with private producers. The second is that private producers desiring access to prime sites often have to negotiate with ejidos and cooperatives, as well as with ZOFEMAT (the government office with jurisdiction over the federal maritime zone), for property rights. The cost of accessing farmland and wetlands for aquaculture in Mexico is thus much higher than in other countries. This situation has also caused considerable conflicts over property rights (see section on Social and Environmental Impacts).

Private investors have purchased or leased land from ejidos or cooperatives in recent years. The cost of such land was 20,000 pesos per hectare (US$2150) in Tamaulipas, for example. In Sinaloa, cooperative/ejido producers in the El Patagüe aquaculture park have been selling their rights for between 8,000 and 15,000 pesos per hectare (US$860–US$1613). Members are encouraged to offer their rights first to other cooperative/ejido sector producers, and only when such a buyer cannot be found are they permitted (by the ejido) to sell to outsiders. At a farm in Chiapas, a company obtained a 99-year lease on land in exchange for giving the owners 5% of the gross revenues. In other cases, individuals from the cooperative/ejido sector rent or lease land to private investors.

Seedstock

As in many other countries, in Mexico producers began shrimp farming by using wild postlarvae (PL). The national government attempted to control the use of wild PL by giving companies or farms permits to collect wild PL. In Sinaloa, for example, three cooperatives around the Bay of Ceuta were given permits

to gather PL–some for their own operations, but most to sell to other farms. Around San Blas in Nayarít, other cooperatives were given collecting permits. Because farms in the far northwest of Mexico are located in colder waters, they need to find a source of PL in February, when it is not available from the region. Companies were thus established to gather PL in Oaxaca and Chiapas (where it is available year-round) to transport to supply farms in northern Sinaloa and Sonora.

The other consequence of the northern location of shrimp farming in Mexico is that demand for PL from hatcheries existed early on. The hatcheries produce PL for shrimp farmers all year round, and can provide this critical input when wild PL are not available because of weather-related shortages or environmental problems.

Hatcheries have, in fact, shown the most rapid growth of any ancillary economic activities related to shrimp farming. The appearance of shrimp diseases, particularly Taura Syndrome Virus (TSV), in the mid-1990s stimulated the development of hatcheries substantially. Hatcheries are able to exert much more control over the broodstock they use, and therefore can develop lines of shrimp that can be certified to be pathogen-free (SPF) when they go into the growout ponds.

The company Super Shrimp came to dominate the market because they claimed to have postlarvae resistant to the disease.[10] Demand for their PL quickly outstripped supply, thus leading other producers to enter the business. Super Shrimp PL proved in 1999 to be susceptible to White Spot Syndrome, however, likely leading to further proliferation of hatcheries as competitors. As of December 1997, the General Directorate of Aquaculture (1999) reported that there were 33 hatcheries in the country, of which 25 were operating. As of 1999, there were 12 hatcheries operating in Sinaloa, 2 in Nayarít, and either 7 (Ministry of Economic Development and Productivity of the State of Sonora 1997) or 13 (Licón et al.2000) in Sonora, depending on the source used for the data.[11]

With the disease occurrences of recent years, the hatcheries have become much more closed-cycle operations. Most utilize their own broodstock so that they can guard against the introduction of diseases. As they develop their own supplies of broodstock, they hope to eventually produce disease-resistant lines and lines that will grow more rapidly. One hatchery owner reported (DeWalt 2000) that the next stage for his industry is genetic selection–just as occurred with poultry, swine and other livestock industries.

Another current trend is more specialized production. Some of the larger operations produce nauplii that they sell to other producers. These producers feed and raise the nauplii through several stages until they are postlarvae. Ahome Acuicola, for example, increasingly purchases nauplii. They typically keep the animals for 21–28 days, when they are ready to go to their own production ponds or sold to other farms. Some of the larger farms have taken the process further, putting the PL into densely stocked nursery ponds and later transferring them into grow-out ponds for the final maturation stage.

A major problem for hatchery producers in recent years has been raising costs. The hatcheries use *Spirulina*, brine shrimp flakes, krill from Canada, small squid, mussels, and micro-algae to feed the organisms. They also use antibiotics like oxytetracycline, fuizolidone, and EDTA. The input that is rising most rapidly in cost, however, is *Artemia*. *Artemia* cysts (brine shrimp eggs) are the most important food source for nauplii. Approximately 90% of world production comes from Great Salt Lake in Utah, but in

[10] Super Shrimp group runs an R&D and disease diagnostic lab in National City, California, along with a large shrimp farm and three huge shrimp hatcheries in Mexico, a small farm in Arizona, and hatcheries in Aruba and Venezuela (Rosenberry 1999).

[11] The large difference in number of hatcheries reported reflects the rapid change that is occurring. There are proposals for the establishment of several new hatcheries in Sonora. At the same time, some smaller hatcheries have technological or financial difficulties and cease production.

recent years it has been in very short supply. Hatcheries in Mexico report that the price has increased from US$6 or US$7 a pound three or four years ago, to US$30 a pound last year and US$70 a pound in early 2000. As a result, hatcheries are experimenting with *Artemia* from Russia and other places. There has also been some study of the possibility of using a native artemia (*Artemia franciscana*) found in the salt marshes around the Gulf of Lobos, located just south of Guaymas, Sonora (Rodríguez et al. 1990).

Most sources estimate that at least 90% of all production of shrimp in Mexico uses hatchery PL. Some producers still believe that wild PL are more hardy than hatchery PL, but in order to avoid disease-related losses, most producers use hatchery PL, perceived to have less risk. No private producer in Mexico reported using wild PL in 1999, while cooperative/ejido sector farms in Nayarít do still use wild PL. The cooperative/ejido sector that owns most of the aquaculture park El Patagüe in Sinaloa also uses wild PL when they can obtain it. Officials from that park complained that they are not given permission by SEMARNAP to collect enough wild PL. He said they need 230 million PL a year, but SEMARNAP permits them to collect about 20 million. The result is that they have to purchase most PL from hatcheries.

When wild PL is available on the market, it is considerably cheaper than PL raised in hatcheries. In Sinaloa, for example, a technician reported that wild PL cost 3,000 pesos per thousand at a time when the price for hatchery PL was double that. In Tamaulipas, producers reported that this year it would cost them US$7.50 per thousand (nearly 7,000 pesos) to buy PL from a hatchery in the United States. The aquaculture park of La Atanasia reported that it negotiated a price of US$6.25 per thousand, down from the source laboratory's regular price of US$8 per thousand. The park's managers were purchasing a total of nearly 34 million PL from the Super Shrimp company, a total expenditure of US$210,823.

Several of the larger farms have their own hatcheries, but the general trend in the industry in Mexico is for companies to specialize in either production of PL or in grow-out farms for producing adult shrimp. One hatchery owner in Mazatlán, for example, did enter into an association in 1999 with a farm near El Patagüe but reported losing money on the operation. This individual indicated that he was less likely to get involved in shrimp farming in the future. Another hatchery owner in Nayarít recently sold a farm that he operated. He is building a second hatchery and plans to concentrate his management efforts there rather than try to run both types of operations.

Feed

Companies based in Mexico did not begin producing feed for the aquaculture industry until the early 1980s. The first producers who entered the market had already been producing livestock feed. By 1997, there were eight companies that produced feed in Mexico for the aquaculture industry, and total production of feed was estimated to be about 40,000 MT–almost all of which was dedicated to shrimp aquaculture. During the same year, another 77,598 MT of shrimp feed was imported (Ramírez and Contreras 1998). The major vendors of shrimp feed in Mexico include Agribrands Purina, Productos AS, Industrias Alicon, Aquafauna Bio-Marine, Hawyang Advanced Industrial (based in Malaysia), Epicore Networks, Malta Clayton, and Cargill Aqualife. Agribrands Purina dominates the market, but the existence of a variety of other producers ensures that there is competition in the industry.

For the production of shrimp feed, ingredients used include fishmeal, grains, soybeans, fish oil, synthetic amino acids, vitamins, minerals and sometimes krill. The feed industry acquires the raw materials from both domestic and imported sources. These ingredients are used to produce pellets, generally about 3/32" in size, that are fed to the shrimp in ponds. When it is difficult to secure some of the raw materials (because they are out of season or otherwise not available), the feed producers will substitute poorer quality ingredients. Because of this potential for substituting non-nutritious filler, the government began to develop regulatory standards for the feed industry in 1995.

One of the primary in the literature is that shrimp aquaculture operations routinely engage in overfeeding and use more protein from wild fish than is produced (Naylor et al. 2000). Overfeeding not only increases costs of production, but also leads to water quality problems both within the ponds and in the effluents (Clay 1997). The percentage of protein in feeds in Mexico is probably much higher than it needs to be. As Table 4 shows, fishmeal ranges in protein percentage from 25 to 40%.

Table 4. Analysis of Fishmeal Products from Agribrands Purina (percentages)

Product	Protein (max.)	Fat (min.)	Fiber (max.)	Ashes (max.)	Moisture (max.)
Camaronina 40	40	9.5	4	10.0	12
Camaronina 40 H.P.	40	8.0	4	10.0	12
Camaronina 35 H.P.	35	8.5	4	10.0	12
Camaronina 35	35	8.5	5	10.0	12
Camaronina 35 AT	35	8.0	5	10.0	12
Camaronina 30	30	7.0	5	10.0	12
Camaronina 25	25	6.5	5	10.5	12
Camaronina 25 L.D.	25	6.0	5	11.0	12

The cost of feed is already one of the major expenses for shrimp farmers. As production systems become more intensive, the amount of feed needed increases substantially. Producers are quite concerned about the conversion rate of feed to weight gain in harvested shrimp. One technique that has become widespread to try to reduce the amount of feed used and to reduce pollution problems is the use of feeding trays. Producers reported to us conversion rates that ranged from about 1:1 to 2.5:1.

Large producers that buy in volume are able to negotiate lower prices from feed producers. For example, the Union of Aquacultural Ejidos of Southern Sonora (operating 704 ha) used 6,500 MT of feed in 1999. They paid US$ 626.50/MT for the feed, or a total of US$ 4,072,250. Based on the amount of feed purchased, Agribrands Purina refunded 4% of the gross amount billed (US$ 162,500).

Because feed is such a large part of the cost of shrimp farm operations, aquaculture parks are especially interested in constructing their own feed plants. In early 2000, the park of El Patagüe in Sinaloa was in the process of constructing a feed factory. The aquaculture parks of Sonora were also engaged in exploring whether constructing their own factory was economically feasible.

Processing and Marketing

Extensive operations or those in colder water areas like Sonora and northern Sinaloa, only produce one harvest per year. Where waters are warmer, or the farms are semi-intensive, two harvests per year are common. Intensive operations that have very little down time between harvests can get up to 2.3 harvests per year.

There is an extensive network of processing plants that operate in the shrimp industry in Mexico. Most of these processing facilities were established for the seafood products, especially shrimp and tuna, caught by the fishing fleet or by the near-shore fishing communities. With the development of shrimp aquaculture, the processors simply have another source of supply for their operations. In practice, no distinction is made among the shrimp that comes from the high-seas fishery, the near-shore fishery, and aquaculture. The main determinant is the size of the product. Most larger-size marine products are exported while smaller ones stay primarily in the domestic market. Processing can include some combination of heading, peeling, deveining, sorting, weighing, packing and freezing (Tobey et al. 1998).

Just as Super Shrimp has dominated the market for providing PL, Ocean Garden Products has dominated the shrimp processing and marketing channels for export.[12] Ocean Garden Products was established by the Mexican government in 1957 to handle the processing and marketing of seafood products and now has 13 regional offices throughout the country. It has only two packing plants of its own, one located in Tampico on the Gulf Coast and the other near Mazatlán, Sinaloa. The company, however, has contracts with 90 packing plants throughout Mexico. Twenty-one of the 26 plants in Sonora, for example, have contracts with Ocean Garden. The company is still state-owned (now by BANCOMEXT), although there have been several attempts to privatize it.[13]

One important role that Ocean Garden Products has played was assisting packing plants throughout Mexico to implement health standards. The first three people in Mexico trained in HACCP standards were Ocean Garden employees. They worked with all of the other packing plants with which they have contracts to implement these standards.

There are, however, many other buyers of shrimp for export. These include Meridian, Crest, Pacífico, Ocean Creel and Ahome Village (a Spanish company). Producers generally report satisfaction with the prices they receive. A single buyer of shrimp dominates the domestic market, an individual from Guadalajara employing an extensive network of buyers who often arrange to purchase shrimp directly from the pond.

It is difficult to say with precision how many processors handle shrimp in Mexico. As mentioned earlier, Ocean Garden Products has contracts with 90 packing plants. Sonora has 26 packing plants, generally quite large operations that are reportedly the best run in the country. A SEMARNAP official reported that there are 52 packing plants in Sinaloa, half located in Mazatlán (DeWalt 2000). Many of the packing plants in Sinaloa are smaller operations; several of the plants there have been shut down in recent years as health standards in the industry are more adequately enforced. In other states, there tend to be only a handful of packing plants. Nayarit, for example, has just two, and shrimp farmers report that they have a choice of only two packers in Tampico. In total, there are approximately 100 seafood packing plants in Mexico.

Processing and packing can be quite expensive, and there are times during the year when supply of product outstrips the capacity of the existing plants to process it. Aquaculture producers in Sonora, for example, have reported that they sometimes have to send their shrimp to Sinaloa or to Nayarit for processing. For these reasons, some producers have attempted to establish their own facilities to cut costs. The cooperative/ejido sector aquaculture parks in Sonora, for example, reported that they spend approximately one million dollars a year for processing and packaging. They currently use six processing plants in Ciudad Obregon and Guaymas but have investigated the possibility of constructing their own processing plant.

The cooperative/ejido sector aquaculture park El Patagüe has developed its own brand of shrimp. The managers of the cooperative provide these shrimp to several packing plants, which process and package the shrimp in containers that are labeled to mark the El Patagüe brand. The park produces about 2,000 MT of shrimp a year for export; their smaller shrimp is marketed through the main domestic buyer located in

[12] On January 27, 1999, Ocean Garden Products, Inc., was purchased by Bancomext, Mexico's export development bank. Headquartered in San Diego, California, Ocean Garden Products is the largest shrimp importing company in the U.S. (Rosenberry 1999).

[13] On February 25, 2000, El Financiero published an article based on an interview with Carlos Vidali, executive president of Ocean Garden Products, Inc. Vidali said that it would be up to the next presidential administration to decide whether to privatize the company. Ocean Garden Products currently sells between US$330 and US$360 million of seafood products annually (Rudiño 2000).

Guadalajara. The cooperative is also in the process of purchasing its own trucks to carry the product to the packagers.

Sources of Investment for Aquaculture

The earliest formal investment in shrimp aquaculture in Mexico dates from the 1970s, CICTUS (today DICTUS), the University of Arizona and Coca-Cola® of Mexico began an experimental farm in Puerto Peñasco. The real growth in the industry, however, has been stimulated by the 1992 changes to the fisheries and land tenure laws. Since then, a variety of investment sources have assisted in the expansion of the industry.

Private Capital

Probably the largest amount of investment in shrimp aquaculture has come from private sources. Individuals with capital to invest have seen shrimp farming as a potentially profitable industry. In Sonora, Tamaulipas and Sinaloa, many people talked about sons (no reports of daughters involved in this business were documented) of wealthy families who owned some of the largest private-sector farms and hatcheries. Often, their families had accumulated wealth in farming or livestock, and it was this capital that they were investing in shrimp aquaculture.

Small companies that pool the investments of several shareholders also own many of the private-sector farms. For example, several individuals whose main enterprise is in transportation own a farm near Mazatlán. In Nayarit, a group that consists of several accountants, an economist, and an agricultural engineer entered into an association with a wealthy former member of an ejido. One of the largest farms in the country reportedly has some investors, mainly from Mexico City, who are both politically and economically influential.

In another case, investors from Mexico City joined forces with one of the largest farms in Honduras to propose construction of a large farm in the state of Campeche. Although permission to build this farm was denied by SEMARNAP at the end of 1999, it illustrates a common trend in the country. Several of the hatcheries also have substantial foreign investors. Individuals or corporations from Thailand, Venezuela, Canada, the United States, and France have also established joint ventures with Mexican private investors for either shrimp farms or hatcheries.

Banks within Mexico will provide loans for aquaculture, but interest rates are prohibitive. In early 2000, producers reported that banks were charging annual interest rates of about 45%. BANCOMER, SERFIN, Banco del Atlantico, and BITAL are among the private banks with whom producers in Nayarit are working.

Another substantial source of private investment that is difficult to quantify is drug money, which is laundered through legitimate businesses. Although, for obvious reasons, not much probing about this source of financing was done, many people suggested that drug money was being invested in some farms. Cases were reported in which individuals connected with the shrimp industry were murdered. These individuals were connected with drug smuggling, it was suggested, or they refused to cooperate with people involved in drugs.

Government Sources

For the cooperative/ejido sector, government sources of credit have been critical. The National Fund to Support Solidarity Enterprises (FONAES)–or Fundo Nacional de Apoyo para las Empresas de Solidaridad–is probably the most important of these. FONAES is designed to provide support for productive activities that will benefit people who live in extreme poverty. The goal is to improve the

capabilities and potential of resource-poor people and bring them into the social development of the country (see website at: http://www.fonaes.gob.mx/presentacion.htm). FONAES holds shares in the enterprises it funds, thus sharing the risk with the people who will benefit from the project.

FONAES contributed 7.6 million pesos of capital, for example, to help establish the cooperative/ejido sector aquaculture parks in Sonora (which were also supported by state funds). FONAES has also been trying to assist the cooperatives in Nayarit to establish or improve shrimp farming.

The National Bank of Rural Credit (BANRURAL)–or Banco Nacional de Crédito Rural–has long provided credit for rural development in Mexico. BANRURAL is a part of the Ministry of the Treasury and Public Credit (SHCP)—or Secretaría de Hacienda y Crédito Público. With the neoliberal reforms of the last several presidencies, BANRURAL has substantially less money to invest in projects than it had when the government was involved in every aspect of rural development; the goal is for BANRURAL to be self-financing. The result is that much more careful screening of projects occurs to ensure that loans will be repaid. Because aquaculture is seen as a very profitable enterprise, it is a main object of investment for BANRURAL's funds. BANRURAL has provided credit to many of the cooperative/ejido sector projects in Sonora and Sinaloa. BANRURAL, for example, is helping to finance the establishment of the feed-producing plant for the El Patagüe park in Sinaloa.

Another important government initiative in aquacualture is supported by the Trusts Instituted in Relation to Agriculture–Fideicomisos Instituidos en Relación con la Agricultura (FIRA). FIRA essentially authorizes credit for construction and working capital, with the actual loans made by BANRURAL. FIRA provides credit on 3-15-year repayment terms for fixed and semipermanent investments (construction, pumps, etc.), as well as working capital (feed, labor and other inputs) on repayment terms of up to 2 years. FIRA was mainly established to support the cooperative/ejido sector but it has also worked with private companies, particularly in Nayarit.

The Capitalization Fund for Rural Investment (FOCIR)–or Fondo de Capitalización de la Inversión Rural–is a public trust of the Mexican federal government whose functions are promoting the capitalization of the rural sector and the formation of agricultural associations. FOCIR supports rural and agroindustrial projects by investing capital in profitable projects (and holding shares) with long-term viability, by making strategic partnerships that encourage entrepreneurship, and by providing greater capitalization of rural producers in the private sector. FOCIR has a special program designed to assist the development of aquaculture in Mexico (see website at http://www.focir.gob.mx/prog_acu.htm). Sources reported to us that about 100 million pesos annually, an estimated 20–25% of the total amount of credit provided by FOCIR, is directed to the aquaculture sector.

FOCIR acts as a minority shareholder in the projects that it supports, providing up to 25% of the capital for a period of up to seven years. By the end of that period, FOCIR expects that its shares will be purchased and that it will withdraw as a shareholder. Based on the interview data, FOCIR has invested in about 10 private shrimp farms in Sinaloa.

Another source of capital for the private sector is the Banco Nacional de Comercio Exterior (BANCOMEXT). BANCOMEXT is the main export development bank in Mexico and is currently providing credit for six shrimp farms in Sinaloa, and a smaller number of farms in Sonora. Officials of BANCOMEXT reported that they viewed aquaculture as an extraordinarily remunerative activity and that the bank has had positive experiences investing in this sector. For that reason, during the year 2000, the bank expects to begin a program to invest in 300 new aquacultural enterprises, with the largest investment in shrimp farming.

Although BANCOMEXT provides credit mainly for the private sector, it has funded some operations in the cooperative/ejido sector. For example, BANCOMEXT and BANRURAL were the principal funders of the construction of the supply canal for the El Patagüe aquaculture park. Although this park provides water for both cooperative/ejido and private sector operations, the cooperative/ejido sector controls access to the water from the main supply canal. Because this loan has achieved such good results, BANCOMEXT is also participating in funding construction of a plant to produce balanced shrimp feed in El Patagüe.

Another indicator of the importance of BANCOMEXT for the aquaculture sector is that since 1999, it has owned Ocean Garden Products, Inc.

Participation Associations

In Mexico, it has been estimated that cooperatives and agrarian reform communities (ejidos) have rights to about 80% of the prime areas for aquaculture development. Although modifications made to the Mexican Constitution in 1992 now make it possible for these communities to sell their land, many communities have been reluctant to do so. In order for development to occur on these lands, an increasingly common arrangement has been for participation associations (Asociaciones en participación) to be created between a private producer and a cooperative/ejido sector community.

Under one arrangement, the owner of a packing plant in Los Mochis, Sinaloa, has helped to rescue five failing aquaculture farms. He pays off the farm's debt, rehabilitates the farm, and manages the operation for 5-15 years. During that period, the members of the ejido or cooperative receive 5% of the profits, and at the end of the contract end up with full rights over the farm.

Under another arrangement, a corporation has been negotiating with several agrarian reform communities to gain access to land well suited to development. The corporation will develop the farms and share profits with the ejidos. Another type of arrangement has private capital develop the entire infrastructure for a farm on ejido land. The investors operate half of the farm, and members of the agrarian reform community operate the other half. Although they share infrastructure like the supply and drainage canals, the operations are otherwise independent.

Corporate Sources of Support

The major suppliers and marketers for the shrimp industry (primariliy Ocean Garden Products) also provide credit to producers. As the largest marketer of shrimp exported from Mexico, Ocean Garden borrows from U.S. and European banks and then loan to producers, cooperatives, fishermen, packing plants, and others. The company has an annual credit line of 150 million dollars, and according to its executive president, with revolving funds from repayments, their annual amount for financing is between US$800 to US$900 million (El Financiero 2000). According to officials at the company, they provide loans at the prime plus 2 percentage points, which means their credit is substantially less expensive than commercial rates in Mexico. The company has individuals in 13 regional offices around Mexico, and they are able to evaluate producers to determine whether their operations are sustainable. The company's main reason for making such loans is to ensure a steady supply of shrimp to market.

Many producers refuse to take loans from Ocean Garden, because they argue that, if you borrow from the company, you are obligated to sell your product to them. Although interest rates for Ocean Garden loans are lower than from other sources, producers say that the company typically pays 10 centavos less per kilo than other buyers. Producers who can want to keep their options open to sell to the buyer offering the best price when the shrimp are harvested.

Other buyers of shrimp also engage in similar lending operations, including Meridian, Crest, Pacífico, Ocean Creel, and Ahome Village. In practice, many producers borrow from Ocean Garden and still sell their product to other buyers while in the middle of a production cycle.

An individual from Guadalajara controls most of the domestic market for shrimp. He employs a large number of men and women who buy shrimp at the pond. At the time of the harvest, trucks from the company show up to immediately take possession of the product. This type of "operating credit" is what allows many of the smaller producers to remain in the industry.

Suppliers of shrimp PL and the major feed producers also make a practice of providing their inputs and waiting for payment at the time of the harvest. Some producers reported that they switched between feed suppliers so that they would not run up huge debts with any one supplier. In practice, these kinds of credit arrangements are crucial for both small and large producers. Surprisingly few complaints about the system were expressed. As mentioned, several producers reported not dealing with Ocean Garden because they offered lower prices to those to whom they had lent money. Producers do have other alternatives and take advantage of these.

Only one individual reported a problem with the system of credit for producers. He said that he thought there is an agreement among the largest supplier of shrimp PL (Super Shrimp), the largest supplier of feed (Purina), and the largest buyer (Ocean Garden). The three would make loans in tandem, but only if the product was eventually sold to Ocean Garden.

Production Systems

The way in which all of these factors play out can be conveyed by discussing several individual aquaculture operations. Because of the wide variety of shrimp farming operations in Mexico, it is not possible to adequately represent all of them with a few examples, but this section conveys some of the variation that exists.

A Semi-Intensive Farm

One of the most highly developed semi-intensive farms researched for this project is located near Guasave in Sinaloa. The principal shareholder of PEASA S.A. de C.V. was elected in early 2000 as the president of the Aquaculture Specialized Section of the Camara Nacional de la Industria Pesquera (CANAINPES)–the National Chamber of the Fishing Industry. This is the major commodity organization that represents the interests of private sector shrimp farmers.

The farm began operating in 1991 and is located on about 200 ha of land, with nearly 150 ha in ponds. The farm has 28 ponds that are each 5 ha in size, plus 7 nursery ponds, each one hectare in size. It has four pumps capable of pumping 1,800 liters per second, and the manager reports that water exchange is a maximum of 5% daily. The feed conversion rate is reported to be about 2:1, and the farm does use a chemical fertilizer (Fertibloom®).

In 1999, PEASA used only PL from hatcheries, purchasing from several different suppliers. The managers reported that they stocked PL at a density of 17 per square meter, and that they had an average survival rate of 50%. In contrast to most farms in Mexico, PEASA maintains continuous production and averages 2.3 cycles per year. The company both harvests from a pond and establishes a new production pond on a weekly basis. Average yields per hectare are between 1500 and 2000 kilograms. Although the farm has had Taura Syndrome, they have not had any outbreaks of White Spot Virus Disease.

Farm managers report that they maintain a distance of 150 meters from mangroves that are near their property. Although they do not treat their wastewater, they monitor the quality of water leaving the property and report that it does not exceed the norms established under Mexican law. The president of the company says that they release better-quality water back into the estuaries than they pump out of it.

The farm is in the process of attempting to obtain ISO 9000 total quality management certification, and ISO 14000 environmental certification. PEASA has hired the consulting company Perry Johnson to help them with this process. So far as is known, this is the only aquaculture operation in Mexico that is attempting to meet both of these certification standards.

An Intensive Farm

One of the intensive farms researched is located in the southern part of Sinaloa. The main shareholder in the farm, and the principal decision-maker, is a graduate of the Biochemical Engineering program of ITESM in Guaymas. The farm is located on family land, passed down to the owner from his grandfather and father. Its site has very sandy soil, but its location right on the Pacific Ocean means that it has good access to clean water.

Developing the farm in that location meant that a substantial investment had to be made in lining the ponds with plastic, then covering the plastic with clay soil. The owner reported, however, that he was interested in building a farm that his children and their children could operate. The farm now has 42 ha of ponds, and the typical density of PL they stock is about 50 per square meter. The farm empties its drainage directly into the Pacific Ocean, a problem that has led the National Water Commission to file a legal complaint against the farm. The owner reports that he would eventually like to shift the farm to a closed cycle in which he would neither use water from, nor release water into, the ocean.

The farm employs about 25 people, adding 10 more at harvest time. When the farm began operating in 1989, it regularly produced yields of more than 5 MT/ha. It produces two harvests a year, with approximately three months of down time to repair the ponds and prepare for the next two cycles. In recent years, this farm has been hit very hard with disease problems. The low yields combined with high operating costs have resulted in the operation reportedly being in jeopardy of going bankrupt.

A Semi-Intensive Cooperative/Ejido Sector Aquaculture Park

The Union of Aquacultural Ejidos of Southern Sonora (UEASS)—or Unión de Ejidos Acuícolas del Sur de Sonora is the umbrella organization for 17 farms run by 605 ejido members operating 1052 ha in three aquaculture parks near Ciudad Obregón. Because the Unión keeps careful records concerning its operations, it is possible to give a fairly accurate picture of the economics of production for its farms (see UEASS 1999). In the following example, the case of the Ejido José María Encinas, part of La Atanasia aquaculture park, is discussed.

The UEASS is a part of the Unión General Obrero Campesina y Popular (UGOCP), a political organization established to assist the resource-poor farmers and fishermen in Sonora. It organizes joint efforts in agriculture, livestock, and aquacultural activities. The UEASS employs office workers in Cd. Obregón as well as a technical staff who operate the aquaculture parks and their farms. There is a strict code of conduct for the members of the ejido, who perform most of the unskilled jobs in the parks.

The ejido of José María Encinas had 62 ha of ponds in operation in 1999. The total operating budget for the farm in 1999 was estimated to be US$889,413. The farm received authorizations for credit from BANRURAL, Ocean Garden Products, and Purina that covered about two-thirds of its operating costs (see Table 5). Of this authorized credit, the farm actually used only a small amount, paying for most of its

operating costs from the earnings of previous years. In addition, the ejido received a credit from BANRURAL to replace some equipment.

Table 5. Estimated Production Costs and Profits of an Ejido, 1999

	Authorized	Utilized	
Credit (in US$)			
BANRURAL	147,500	0	
Ocean Garden	160,000	117,000	
Purina	260,000	64,169	
Maintenance Credit (in US$)			
BANRURAL	101,249	64,169	
Inputs			
PL		60,677	
Feed		249,809	
Land Tax (predial)		30,567	
Labor		461,280	
Other		116,698	
Total Operating Cost (in US$)			**889,413**
Production Revenue (in kg)			
1st partial harvest		12,524	
2nd partial harvest		15,004	
Final harvest		135,222	
Total (US$)		162,750	**(1,421,406)**
PROFIT			**US$ 531,993**

The costs and estimated yields in Table 5 are based on the experience of prior years. These estimates were contained in a report prepared for the ejido members approximately halfway through the production cycle. Costs for purchasing PL are in the report to members and are presumably accurate. Feed costs are estimated based on the estimated feed conversion rate of 2.45:1 and the negotiated price at which Agribrands Purina sold to the UEASS.

Shrimp farms annually pay an estimated average of US$ 800 in wages for every hectare in production (Dirección General de Acuicultura 1999), labor costs in Table 5 use this estimate. Although this estimate may be somewhat inflated for the aquaculture parks, it does provide a sense of labor costs in relation to other inputs.

The farms employ one worker for every 5 ha of ponds. In addition, at the well-constructed barracks where the workers live during the production cycle, two cooks and two other individuals are employed. A security service guards the entrance to the park year-round, utilizing two-way radios to communicate with their main office.

Like the other farms within La Atanasia aquaculture park, the ejido of José María Encinas used *Penaeus stylirostris* (blue shrimp) purchased from the Super Shrimp hatchery. This ejido used a mix of PL, about 14% of a new variety named X-10 and the rest the traditional variety sold by the hatchery. The density of stocking that occurred in April was 15 per square meter. The estimated PL survival rate was 61.5%.

The farm was projected to obtain an average production of 2625 kilograms per hectare.[14] There were two partial harvests, one after 140 days and the other after 168 days. The final harvest was projected to occur after 210 days. As reported in Table 5, the estimated profit for this ejido-run farm was over half a million dollars for 1999.

[14] The general manager of the farm reported in early 2000 that yields were actually closer to 2,700 kg per hectare for the whole aquaculture park. The profits estimated in Table 5 are thus lower than actual profits.

Conclusions

The shrimp farming sector in Mexico developed later than in other Latin American countries because of the complexity of land tenure and property rights laws. Ejidos and cooperatives had exclusive rights to exploit and process shrimp until 1992. Opening the possibility for private producers to get into the shrimp business and declaring the end of agrarian reform have resulted in considerable expansion of the shrimp aquaculture sector. Many prime pieces of land on which to develop farms exist in Mexico, but property rights problems still exist. Private, ejido, communal and federal lands all exist side by side, and in some cases several parties claim to own the same parcels of land.

Mexico's use of hatchery PL is extensive, with about 90% of production using this source. In part, the extensive use of PL came about because much of the production occurs in northern areas of Mexico, where wild PL are not always available when producers want to stock their ponds. The appearance of diseases in recent years has further stimulated producers to use hatchery-raised PL.

An extensive network of packing plants processes the product in Mexico. These packing plants were developed for the wild capture fisheries, but are now processing farm-raised shrimp as well. In recent years, the packing plants have adopted HACCP standards, leading to the closure of several smaller operations. However, the remaining plants are meeting health standards.

There is an excellent domestic market for shrimp in Mexico. Although one domestic buyer dominates the internal market, and Ocean Garden Products dominates the export market, there is competition in the sector. This keeps prices to producers relatively high.

Getting access to capital for the expensive process of shrimp production is one of the principal problems reported by producers. People from the private sector complain that most of the capital is available only to the cooperative/ejido sector, while those from the cooperative/ejido sector make the opposite claim. Because of the potential for substantial profits in the industry, it is apparent to us that it is far easier to get a loan for aquaculture than for most agriculture or livestock operations. There is a diversity of investment sources for both cooperative/ejido sector and private sector producers, including loans to construct shrimp farms, hatcheries, feed plants, and other operations, as well as to provide operating capital after the facilities are in place. Borrowers would like to have more sources, more capital, and lower interest rates, of course, but these wishes would be expressed in any sector of the economy.

What is notable about the capital invested in the shrimp industry in Mexico is that most is derived from Mexican sources. Private capital and national banks and financial institutions have provided most of the money invested. Despite the North American Free Trade Agreement, little capital from the United States has been invested in enterprises in Mexico. Foreign investment from Thailand, France, Honduras, Venezuela, Canada, and the United States is present in the sector, but most of the capital is domestic in origin.

Social and Environmental Impacts

Introduction

The social impacts of shrimp aquaculture have been discussed by a variety of observers (Bailey 1988; DeWalt et al. 1996; Tobey et al. 1998). In general, the social impacts vary depending on the kind of aquaculture practiced and how effectively governments develop policies to regulate its development. The long-term sustainability of shrimp aquaculture depends on how the industry responds to the necessity for ecosystem management and for minimizing environmental impacts. In this chapter, the social and environmental effects that the shrimp aquaculture industry has had in Mexico are examined.

Employment

Farmers, fishermen, and officials from banks, state government, and municipalities in every state visited were all in accord that shrimp aquaculture is one of the few positive economic developments that has occurred in coastal regions. Prices of most agricultural commodities have declined, the livestock industry has not prospered, and both have been affected by several years of drought in northwest Mexico. Industrial development in the northwestern states has been stagnant in recent years. Aquaculture is generating employment, profits for both private and cooperative/ejido sector producers, and multiplier effects in associated industries and commercial enterprises.

It is difficult to accurately estimate employment in the shrimp industry. Although farms do employ permanent workers, there is also a great deal of temporary employment, particularly during the harvest. In addition, shrimp farm construction creates opportunities for machine operators; many individuals are also employed in the feed industry, in hatcheries, in processing plants (which also handle other seafood products); in transportation; and other industries. The following paragraphs provide some estimates of employment.

In Sonora, at the first forum on shrimp aquaculture, a SEMARNAP official reported that the industry had generated 3,250 permanent jobs (Noriega 2000), and in Sinaloa, 6,450 jobs (DeWalt 2000). The equivalent estimate for Nayarít was 2,700 jobs (Gonzalez 2000). These estimates total approximately 12,400 jobs on shrimp farms on the northwest coast.

National data from SEMARNAP indicated some 23,505 people employed in “controlled systems” producing fish and seafood products (SEMARNAP 1998). Of these, an estimated 2,057 were employed in Sonora; 6,798 in Sinaloa; and 1,239 in Nayarit. Because the aquaculture in these states is primarily shrimp farming, it can be assumed that almost all of these people are employed in the industry. With relatively few people employed in shrimp aquaculture in other states, the SEMARNAP figures suggest that the total employment generated is on the order of about 10,000. The wide discrepancies in the figures indicates that official sources are using rough estimates rather than precise counts.

A December 1997 report by SEMARNAP estimated that shrimp aquaculture had generated 7,076 jobs on the farms. The report also indicated that the average ratio of jobs per hectare was 3 positions for every 10 ha on semi-intensive or extensive farms, and 6 persons for every 10 ha on intensive farms (Dirección General de Acuicultura 1999).

Another way of estimating employment is to consider several examples provided by producers interviewed (Table 6). The estimates vary quite widely, with one private sector farm in Chiapas indicating that it used one employee per hectare, including office workers. The farm was in the process of rapid expansion. The intensive, 45 ha farm in Yucatán reported that it employed 40 people at the production ponds, with a total of 120 employees, including office workers and those employed in its PL hatchery and feed mill. At the other extreme, a farm in Sinaloa indicated that it needed only 1 permanent employee per

70 ha. (This farm employed a substantial amount of temporary labor.) The farm manager of the aquaculture park Atanasia in Sonora reported that they needed 1 person for every 5 ha in ponds, while others estimated 1 employee for every 4 ha.

Table 6. Permanent employees on shrimp aquaculture farms.

Farm	Location	Type	Pond Area (Ha)	Permanent Employees
El Patague	Sinaloa	Social Sector	1,150	300
Ramon Ahumada	Sinaloa	Private Sector	420	6
Acuacam	Tamaulipas	Private Sector	83	35
Acuicola Sn. Jorge	Sinaloa	Private Sector	200	70
Aquastrat	Sinaloa	Private Sector	42	20
America Aquatech	Chiapas	Private Sector	24	24
El Tobari	Sonora	Social Sector	555	111
Sisal	Yucatan	Private Sector	45	40

Source: Interviews with farm managers and owners.

These latter estimates are for farms in the cooperative/ejido and private sector that are relatively well capitalized. For cooperative/ejido sector farms such as those in Nayarít, the employment picture is even more complicated. There, the members of ejidos and cooperatives can work on an as-needed basis at the extensive farms. Most of the year, workers spend the majority of their time in agriculture or fishing, and the only work on the ponds consists of scaring away the birds and helping at harvest time.

If the estimate of 17,746 ha of shrimp ponds operated in 1998 is used, and we assume that there is one employee for every 4 ha, then this yields a direct employment figure of only 4,436. Thus, the range of estimated employment using these various methods goes from 4,436 to 12,400. The best estimate is that the total is probably around 8,000, if we also include office workers and hatchery workers in the total.

Employment Conditions

The permanent positions in shrimp aquaculture in Mexico are relatively well paid compared with other skilled and unskilled jobs. Salaries are much higher than either the Mexican minimum wage or the prevailing manual wage rates in agriculture. At the aquaculture parks in southern Sonora, for example, workers are paid 125 pesos per day (about US$13.50). The minimum wage in the region is only 38 pesos per day. In addition, aquaculture workers have a full complement of benefits. They get free meals when they are living at the aquaculture park, receive an allowance worth about 25 pesos per day (Vales de dispensa), and are covered by life insurance. Each December, they receive an additional month's pay as a bonus. Workers have to contribute to the social security system, a retirement plan, and a housing plan, payments for which are deducted from their pay.

Employment terms in other areas are similar. For example, in Chiapas, the minimum salary on one of the shrimp farms was 750 pesos per week (about US$80). In Tamaulipas, it was reported that shrimp farms paid 500 pesos per week for unskilled labor. Technicians with a university degree received 5,000 pesos per month at a farm near Mazatlán, while a farm in northern Sinaloa paid technicians 6,000 pesos a month. More skilled positions receive better remuneration, of course. One of the hatcheries in Mazatlán paid their biologist 20,000 pesos per month (about US$2150). In all of these cases, the same benefits mentioned above were provided for all employees.

An employee at one of the hatcheries that purchases nauplii and raises them to the PL stage, reported earning 6,000 pesos a month (about US$645), while the person in charge of the operation makes about 10,000 pesos (about US$1075) a month. They also get a production bonus if the survival rate is anything above 50%, and he reported that average survival rates have generally been between 50 and 70%.

In 1998, as a service to the owners of shrimp farms, the magazine Panaroma Acuícola published a table of average wages paid in similar sectors (e.g., production of chicken, pork, and agricultural inputs). The salaries ranged from a monthly wage (including benefits) of US$113 for a salaried laborer to US$5,700 a month for the general manager. On several farms visited, this table of salaries was either posted or otherwise made available to technicians.

In addition to salaries, it was common for shrimp farms to provide incentive bonuses. These bonuses differed from farm to farm. One private farm in Sinaloa, for example, paid a bonus to workers if PL survival rates were above 50%, of 30–45 days' extra pay, paid at the end of the year (Ramirez 2000).

On a cooperative/ejido farm in northern Sinaloa, the seven technicians who work full time receive a salary and shares (of the farm's ownership). One of the technicians reported that the profits for each of the 72 shareholders (including the technicians) average about 50,000 pesos per production cycle (i.e., about US$5,550, or more than US$11,000 per year). The technicians also receive a bonus if the production level is successful. All of the shareholders have the right to sell their shares in the aquaculture farm, with the price of a share established at US$22,220.

At the aquaculture parks in Sonora, technicians receive a bonus based on the production from the unit they supervise. A pool of money equivalent to 1.5% of the profits from each unit is created. From this, 15% goes into a reserve fund for future years, and the rest is distributed equally among the technicians. The technicians at another farm in Sinaloa said that they also received a bonus every year, but it did not matter what the production level was. They always received the same amount.

Irrespective of whether they work as salaried employees, all members of the ejidos comprising the aquaculture parks in Sonora receive a proportion of the profits. After costs are deducted and loan payments are made, the profits are distributed. In 1999, a very good production year, the average profit distributed to the ejidatarios (members of the ejidos) was 44,000 pesos (about US$4,730).

Temporary workers are not paid nearly so well as permanent employees. The typical wage mentioned for working during the shrimp harvest, for example, was twice the minimum wage–about 76 pesos per day. This is also the case for the workers in the packing plants. Women there can work up to 12 hours per day and reportedly were paid only 800 pesos per month.

Labor Market

Unskilled workers on the shrimp farms are local people who live in the zone in which the farm is located. Because unskilled laborers have few other sources of employment, there is little competition for their services in the labor market.

For skilled individuals who know some of the technical aspects of aquaculture, competition is more intense. Many individuals remarked about the scarcity of trained individuals in the sector. People who become dissatisfied with working conditions or wages always have the opportunity to move to other farms.

Other Social Benefits

In other countries, infrastructure improvements such as roads, electricity, and piped water systems have been constructed because of the presence of the shrimp industry. In general, Mexico already has a well-established infrastructure. Its road system, electrical grid, and piped water systems are quite extensive. Thus far, shrimp farms and associated facilities have tended to be established where these services already exist.

The coasts of Sinaloa and Sonora, for example, are already quite well developed because of the extensive irrigation works serving commercial agriculture that exist there. Nayarít's coast is less well developed, but roads and electrical lines are quite widespread.

The one area in which shrimp farms have reportedly improved infrastructure is in the Yucatán. The single farm operating there is located close to the community of Sisal. Because this town of 2,000 people lacked sufficient electrical power, the farm had to install its own electrical generators (800 KW), duplicating the electrical capacity of the community. The farm has also improved road access, works with municipal authorities to keep the community clean, and supports local sports teams. In addition to employing local people, the company provides training to upgrade the skills of the workers.

The shrimp farms that are developing around Pijijiapan in Chiapas have suffered in recent years because of the hurricane that destroyed much of the infrastructure a few years ago, undoubtedly slowing development of the industry there. In Tamaulipas, several individuals commented that shrimp farm development was concentrated in the southern part of the state because that is where the infrastructure exists.

Hatcheries have to be sited close to sources of clean water but also need road access and electricity. One hatchery owner in Mazatlán essentially identified such a site, then went out to negotiate to buy the property from an ejido. A pot-holed paved road now serves the site, but the owner expects the road to be improved next year. The road is being repaved because it is a major coastal route, not because the hatchery is located there. In another case, a hatchery owner in San Blas is establishing a second hatchery farther away from the town. He has become concerned that the polluted waters of the town may affect his operation, but he has found another site with all of the infrastructure he needs.

Thus, there have been a sufficient number of good sites that already have adequate infrastructure for shrimp farms in Mexico. After these sites are developed, expansion may occur into areas in which infrastructure does not yet exist. In these situations, more of the kind of ancillary benefits that were documented for the Yucatán may happen.

Social Conflicts Over Property Rights

Given the history of land tenure in Mexico, it is not surprising that the most significant source of social conflict concerns property rights. In many areas, the federal maritime zone is not adequately demarcated, ejidos and cooperatives have been given rights to exploit the land and sea resources, and private owners claim rights to specific parcels of land. Complicating the situation: the coastline is constantly shifting, so that areas mapped at one time may look quite different in the future. Some ejido lands, for example, that were distributed by presidential decree are now in areas considered to be part of the federal maritime zone. There are land and sea tenure problems in every state, but in some places these are more severe than in others.

Property rights are not well defined, particularly in the southern part of Sonora. State and SEMARNAP officials say that the major problem in bringing order to the aquaculture sector is sorting out all of the land tenure disputes. For example, on Santa Barbara Bay a private company has been in serious conflicts with local ejidos. Several areas of the aquaculture farm have ponds and other infrastructure improvement that lie incomplete. People from the ejidos have invaded the farm three times in the last few years, halting production. The farm employs armed guards and police dogs (at an estimated cost of more than US$ 50,000 a year) to protect its investments. At least one security guard has been killed in confrontations with members of the ejidos (Noriega 2000). Farm owners, ejidatarios, and local officials all complain that the federal government has been both slow and vacillating in resolving the conflict. Because the federal government has responsibility for the maritime zones, the state of Sonora is powerless to do much.

Another example of such a problem comes from the municipality of El Rosario, Sinaloa. There, a group of 32 agriculturalists and fishermen formed a cooperative at the end of the 1980s to try to establish a shrimp farm on 300 ha near the community where they all live. Many of these people had obtained part of their livelihood from fishing in the lagoon. The lagoon, however, has been shrinking, filling up with sand as a result of natural processes. Fishing resources have declined, so the community proposed to establish a shrimp farm. Because the group has only the resources contributed by its members, it has been very slow in acquiring the necessary permits. In the last few years, a private company with shrimp farms in other areas of Sinaloa decided to construct a farm in the same area. The overlap between the two farms proposed is shown in Figure 5. In both cases, the federal government (through ZOFEMAT) is being petitioned for a "concession for rights to use the federal maritime zone and/or lands recovered from the sea." The cooperative had been negotiating with ZOFEMAT, which suggested that it alter its proposal for the 130 ha in light gray on Figure 5.

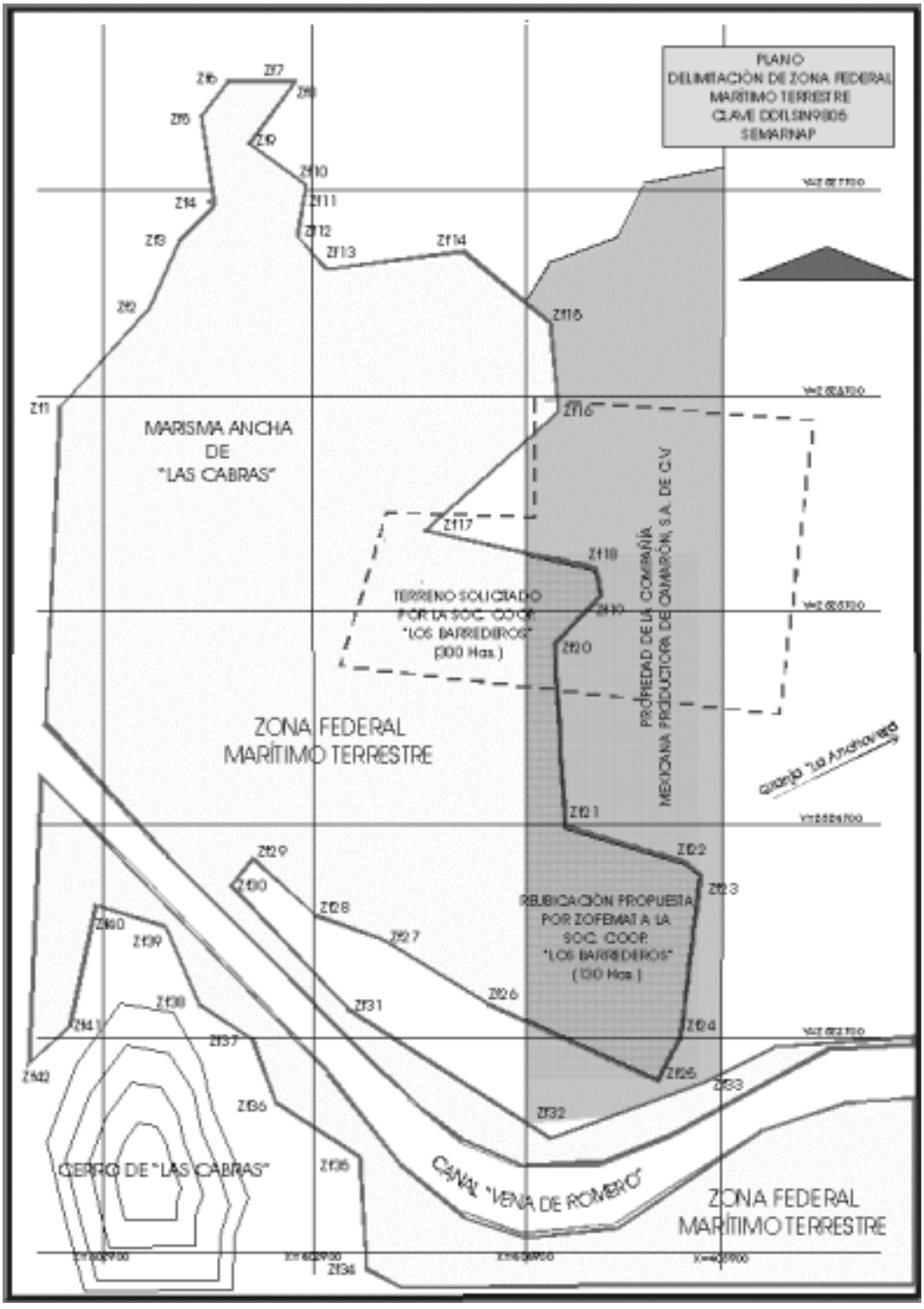

Figure 5. Disputed Zone in Sinaloa

The cooperative accepted this suggestion and had a topographic study done of the area. It has also commissioned an environmental impact study and begun the design of a farm. A small shelter was erected on the land, and one of the cooperative's members began living there. Meanwhile, the Figure 5 disputed

zone in Sinaloa private company has made the claim that they own the area outlined in dark gray, an area that overlaps substantially with the cooperative's petition.

The result has been an escalating conflict between the cooperative and the company. The company destroyed the shelter, took control of the property and erected a fence around it. The company has complained to authorities that the cooperative has destroyed parts of the fence and that its members have been invading the property. In February 2000, the company asked a judge to apprehend 10 members of the cooperative because they had invaded private property. The 10 individuals spent five days in jail before posting bond. The community claims that the fence is partially on land they believe they own and that it impedes their access to the Vena de Romero canal that they traditionally have used for fishing. As of March 2000, the case was embroiled in controversy. The federal government stated that the cooperative did not have a concession for the lands, and the private company was not (and could not be) the owner of the land. At the same time, the government conceded that there were areas in which competing interests had overlapping concessions in federal maritime zones.

Because ejidos and cooperatives are in control of areas that are well-suited to aquaculture, private companies have reached different kinds of accommodations with them. One of the organizational mechanisms that has been used to link private and cooperative/ejido sector producers is called a Participation Association. With this kind of agreement, the ejido or cooperative allows access to the land as their contribution to the enterprise. At this point, several different models have been used.

In one, a private company develops the infrastructure and usually operates the farm. The members of the cooperative share in the profits according to the number of shares they received for their land. A farm near Los Mochis in Sinaloa is using this mechanism. In another case in Sinaloa recounted by a SEMARNAP official, a private sector farmer began by trying to purchase land or just take over land from ejidos. After experiencing substantial conflict with the local people, this individual decided to create an Asociación de Participación with them. He built the shrimp farm, and the local people operate it and receive a portion of the profits.

In another arrangement a private sector entrepreneur builds the infrastructure for a large farm. The company operates its own farm on part of the land, while the other part is given to the cooperative to build on and operate on its own. Several examples of this structure exist in Sinaloa.

The largest shrimp farm in Nayarít has used a third model. In this case, the ejido sold its land rights to the farm for 15,000 pesos per hectare in 1993. In addition, the company also helped to create two companies to be run by the ejido. One company transports PL from hatcheries in Sonora to the farm in Nayarít. The second company owns and operates the heavy equipment used to maintain the ponds.

While the companies established in this last case have had some success, the farm continues to have problems with its neighbors. Some of the members of the ejidos from which the company purchased land continue to insist that they are part of the enterprise and deserve some of the profits from the farm.

Another option that is being used by some farmers is to rent or lease ejido land. One group of investors, for example, has rented land from the cooperative/ejido sector and operates a farm in the El Patagüe aquaculture park, under a 10 year rental agreement. In Chiapas, Thai and American investors have obtained a 99 year lease of 100 ha from an ejido. The people who own the land receive 5% of the gross production each year as payment for the lease.

Cases were documented of individuals in Sonora, Sinaloa, and Tamaulipas who had purchased land from ejidos or from individual members of ejidos. In 1999 in Tamaulipas, for example, an individual reported having paid 20,000 pesos (about US$2150) per hectare during the last year. In these cases, the individuals

involved said that they had not experienced any difficulties. In another case, a businessman from Mazatlán reported that several years ago he purchased land from a member of an ejido. He purchased the land rights and actually became an ejidatario, a status he still holds. In another case, a member of an ejido in Nayarít has become a member of a company mainly composed of investors from Tepic and Guadalajara. This individual is providing the land and will help manage the farm, while the other shareholders provide the capital to develop the operation.

In spite of these successful cases, however, there is no question that the land tenure question has slowed the expansion of shrimp aquaculture in Mexico. Many of the cooperatives and ejidos would prefer to maintain rights and either develop their own enterprises or enter into associations with private individuals. Nearly everyone we interviewed in the private sector who had not already become involved in working with the cooperative/ejido sector, however, said that they had absolutely no interest in doing so–the difficulties were just too great.

The privatization of ejido lands as a result of the 1992 Constitutional Reform is still going on. PROCEDE, the Program for Certification of Ejido Land Rights and Titling of Urban House Plots, continues its work, and members of many ejidos are choosing to obtain individual titles to their land. While this may facilitate the transfer of some properties to private owners, in most cases the lands that can be developed for aquaculture continue to be held communally (because they were not worked as individual plots beforehand). It will likely be some time before significant amounts of communal land are sold to private owners.

Social Conflicts Related to Theft from Farms

Worries about theft from shrimp farms exist in all parts of the country. Probably the most severe problems, however, exist in the state of Nayarít, where thefts of both shrimp and equipment are common. Reportedly, there are at least five known bands in the municipality of San Blas that specialize in thefts from shrimp farms. Although the authorities claim that they know who is involved, the police say that “it is not worth apprehending them.” This is because the crimes are not considered important offenses and penalties are not very severe.

The companies that are affected, however, do not consider the crimes minor. One estimated that it loses 2-3 MT of shrimp per cycle. While all farms report that they have occasional problems with thefts by fishermen or members of ejidos, they are much more concerned wtih the larger quantities lost to organized bands like those in Nayarít. With both types of theft, the result is that all of the farms are having to invest more money in hiring guards and other methods to protect their investment.

A farm near Mazatlán reported an interesting way of controlling theft. The technicians on the farm knew which individual was causing them the most losses and decided that the best thing to do was employ the individual as a guard for the farm. They report that losses have dropped substantially since.

Because shrimp farms are generally located far from populated areas, technicians and laborers live on the premises during the production cycle. Most of the private sector farms, and the larger and more successful cooperative/ejido sector farms, build relatively permanent structures in which the workers live. Each ejido that is part of the aquaculture parks in Sonora has built a permanent barracks in which workers live. For the poorer cooperative/ejido sector farms, workers/guards may have only a primitive thatched-roof shelter in which to spend the night. The physical presence of workers, and the practice of checking ponds during the night, does help to discourage thieves.

Except for the small cooperative/ejido sector farms, almost all of the enterprises invest substantially in building barbed-wire fences for security. In the case of some very large farms, this can cause conflicts with individuals and communities who are cut off from resources they once used.

Social Conflicts Over Access Rights

As the El Rosario case discussed earlier indicates, some of the conflicts that occur have to do with farms cutting off traditional routes of access that community members have to coastal resources. Because of the high value of shrimp as a commodity, and because of thefts of shrimp and equipment, one of the first elements of infrastructure installed on most farms is a barbed-wire fence. When the farms are very large, this may mean that communities no longer have easy access to coastline, lagoons, and other resources they once exploited.

The largest shrimp farm in Nayarít, reportedly spread over 3,000 ha, has had substantial problems stemming from resource access. One community has been in constant conflict with the farm because their access to a source of pasture for their cattle has been cut off. In the past, they were able to take their cattle to Rey Island, only 2.5 kilometers away. Now that the farm has blocked their access route, the distance they have to cover is approximately 11.5 kilometers.

Fishermen from at least three other cooperatives complain that the same farm has cut off their access to lagoons in which they traditionally fished. In another complaint, a group of fishermen have said that one of their main fishing areas has been affected by changes in water flow caused by the same farm.

A slightly different conflict over property rights also comes from Nayarít, involving a fairly small farm and a neighboring ejido. The supply and drainage canals for the farm cross ejido land, so the members of the community want to charge the farm's owners a monthly fee for the passage of the water.

Environmental Impacts: Mangrove Destruction

The development of the shrimp industry in Mexico has not caused substantial destruction of mangroves. Several studies of lagoon systems in Sinaloa, for example, have shown that any reduction in mangrove area is not due to the construction of shrimp farms (Ramírez-Zavala 1998; Berlanga-Robles 1999). For example, around the Huizache-Caimanero system of Sinaloa, there are currently over 400 ha of shrimp ponds. The main effects on mangroves and dry forest in the region, however, are attributed to the growth of rural communities and agricultural practices (Ruiz and Berlanga 1999).

One reason that mangroves have not been destroyed relates to the ecology of the regions in which shrimp farming has developed. The coasts of Sinaloa and Sonora have extensive zones of salt flats that generally lie behind fringes of mangrove that line lagoons, bays, and estuaries. It is much easier to construct the ponds in these areas than to attempt to clear mangroves. Furthermore, most producers recognize that shrimp grow much better if ponds are not constructed where mangrove existed before. In addition, producers are conscious of the negative publicity about mangrove destruction in places ranging from Thailand to Ecuador and Honduras.

A second reason that mangroves have not been significantly affected by the shrimp industry is that environmental legislation in Mexico affords them special protection. The species *Rhizophora mangle* is considered rare, and *Laguncularia racemosa*, *Conocarpus erecta* and *Avicennia germinans* are all protected species (NOM 059 ECOL 1994). During the last several years, PROFEPA has brought legal actions against one farm in Sinaloa and one in Nayarít for having destroyed small areas of mangrove.

The case in Sinaloa is quite interesting because the private sector farm destroyed mangrove in the process of experimenting with a system to treat waste water from the ponds. The farm developed a serpentine

canal for its wastewater. The theory was that with a sinuous and prolonged drainage canal, more suspended solids would precipitate out of the water before reaching the bay. In constructing this canal, however, the farm cut through some mangrove areas. PROFEPA investigated, fined the farm, and asked them to restore the amount of mangrove destroyed. As a result, the farm has established its own mangrove nursery for plantings.

The second case involves the largest farm in Nayarít. This farm has generated considerable local opposition, including from an environmental organization called Mangrove Ecology Group (Grupo Ecológico el Manglar), which identified about 50 ha of mangrove that was dying on the property of the shrimp farm. Greenpeace also sent a letter of complaint. The farm signed an agreement with PROFEPA to investigate the cause of the mangrove die-off, and some nationally known scientists were brought in to investigate. After determining that the mangrove was being affected by the farm's operations, PROFEPA decided that the farm would have to replant an area at least as large as that destroyed. The farm had to establish a mangrove nursery and is required by PROFEPA to engage in expensive reforestation efforts. The Mangrove Ecology Group was not satisfied with this outcome, however, and in September of 2000 brought a formal complaint before the trinational Commission for Environmental Cooperation (see Mexico's Regulatory Structure and Institutional Development).

In some locations, people establishing shrimp farms are engaging in proactive efforts to protect mangroves. An individual in the process of building a farm in Tamaulipas (on an old cattle pasture) plans to send his wastewater into the mangrove surrounding the property before it flows into the lagoon. Mangrove forest can naturally treat such water without being harmed if the process is planned and monitored carefully. He is working with a group called Ocean Trust to re-establish mangrove on part of the property, as well.

In Nayarít, far more extensive areas of mangrove exist than in Sinaloa and Sonora. This mangrove is being threatened by several activities; the first of these are the natural processes affecting coastal areas that close off some openings to the sea and create others. The construction of dams upstream has also affected the amount of freshwater flowing into some areas, again altering the hydrological patterns. Agricultural expansion threatens other areas of mangrove, as people try to reclaim some coastal areas for crop production (González 2000). Aquacultural expansion will also alter the hydrology of the region and threaten some areas of mangrove. Right now, the biggest threat probably comes from small-scale cooperative/ejido sector producers who may not have access to the most suitable areas for aquaculture, and who may not have sufficient capital to construct ponds, supply canals, and drains in a way that protects the environment.

People acknowledge that in the early years of shrimp farming in Mexico, there was some destruction of mangroves. In part, this resulted from a general lack of care for the environment during the construction process. One individual from Guasave (Sinaloa), for example, acknowledged that during the process of constructing his farm, some of the heavy machinery had destroyed mangrove. People in the aquaculture park at Tobarí in Sonora reported that several years ago they used mangrove poles to build the platforms that extend into the ponds.

Although this situation may change, it must be concluded that shrimp farming has had a relatively minor impact on mangroves in Mexico. In the future, as aquaculture expands into the more tropical states of Chiapas, Oaxaca, Guerrero, Campeche, and Veracruz, the possibility of mangrove destruction will increase. Careful monitoring will be required to ensure that such impact is minimized.

Environmental Impacts: Water Pollution

Probably the most important effect to date, as well as the greatest future threat, of shrimp aquaculture has been its worsening of water pollution. Water exchange rates are on the order of 5–20% per day for most operations, and overutilization of feed is common in the industry, according to many scientists and several SEMARNAP officials interviewed. The water exchange and excess nutrients added to ponds mean that the water discharged into drainage canals, and eventually into the bays and lagoons, does have the potential to harm the environment. It is not clear how much this may be affecting the ecosystems, however, because little systematic monitoring of the effects is occurring.

Two pieces of environmental legislation exist that regulate the wastewater from activities like aquaculture (NOM 089 ECOL 1994; NOM ECOL 001 REC NAT 1999). These establish the maximum amount of dissolved solids and other measures of the quality of the water that can be released into national waters. Everyone acknowledges, however, that this legislation is not being enforced.

Some efforts to monitor water quality have begun. The Regional Center for Fisheries Investigations (CRIP), or Centro Regional de Investigaciones Pesqueras, in Mazatlán, for example, has undertaken studies of several lagoon systems in the state. In 1996, measurements were taken in the Chametla-Teacapán system; the Huizache-Caimanero system was studied in 1997 and 1998; and studies of the Ceuta Bay and the Navachiste-Macapule Bay were begun in 1999. CRIP technicians take monthly measurements of pH, temperature, dissolved oxygen, total ammonium, nitrates, nitrites, silicates, and phosphates in a number of sampling locations. They also measure sulfur near aquaculture operations, and in some places examine total solids, turbidity, and coliform. Only three individuals do this work for CRIP, and they acknowledge that they do not have the economic and personnel resources to perform permanent monitoring. The team has proposed setting up a permanent monitoring program, but so far have not received funding to implement it.

It was also reported that the National Water Commission (CNA) has 20 years of data on the chemicals and other efflients that agricultural drainage canals are putting into the marine and estuarine ecosystems in the northern part of Sinaloa. People outside the CNA report that they have never been able to get access to these data, and it is not clear whether they exist in usable form. Other institutions in the region have also been collecting water quality information, including the Universidad Autónoma de Sinaloa, the Universidad de Sonora, the Universidad Nacional Autónoma de México, the Secretary of the Navy, and others. Unfortunately, their information is not shared, and there have been no attempts to develop a common framework for monitoring water quality.

The Biogeographic Information Unit (UIB) of the Center for the Conservation and Utilization of Natural Resources (CECARENA) of the Monterrey Technological Institute of Advanced Studies (ITESM)–Guaymas Campus has developed an excellent database on the coastal areas of southern Sonora. UIB has a website that includes topographic, land tenure, and ecosystem threat maps for each of the principal lagoon systems. An example can be seen on Figure 6, the El Tobarí lagoon. There are only two aquaculture drains that currently empty into the lagoon, one at the northern and one at the southern end. In contrast, the system receives a substantial amount of human wastewater, several major agricultural drains empty into it, and the entrances to the lagoon are becoming clogged with silt. This and other maps produced by the UIB indicate the diversity of sources that threaten these coastal ecosystems. These maps can serve as a useful tool for addressing threats and monitoring, and they would be even more useful if linked with data on water quality.

CRIP-Mazatlán reported to us that at least 12 shrimp farms in Sinaloa provide some treatment of their water. The methods used are still fairly rudimentary, consisting mainly of oxidation ponds. CRIP is promoting several methods for water treatment, including oxidation ponds and filtration tanks that would

use oysters, mussels, and/or algae (under development). Some research work on this latter technology is occurring at the Center for Research on Food and Development (CIAD), or Centro de Investigación en Alimentación y Desarrollo, in Mazatlán. One of the farms near Mazatlán has cooperated in this research by digging holes every 20 meters in their drainage canals (to catch suspended solids) and placing oysters and mussels into the canals.

In 1999, a serious case of water pollution problems arose in the Chametla-Teacapán system in Sinaloa. When a large number of fish were found floating in the lagoon in December, CRIP–Mazatlán took water quality measurements to try to determine the cause of the fish kill. The research institute concluded that the problem was a drop in dissolved oxygen in the water, probably caused by heavy discharges of wastewater from households and from shrimp farms. It proposed three alternative potential origins of the problem, indicating the complexity of protecting lagoon ecosystems. The first possible cause, according to CRIP, was the indiscriminate use of shrimp feed by near-shore fishermen (Pescadores ribereños), causing eutrophication of the water. It is a common practice in the region for fishermen to use the feed to attract fish to an area, for easy capture. The second possible cause was an algal bloom that may have been triggered by wastewaters dumped from the city of Escuinapa. Finally, CRIP suggested, the kill might have resulted from near-shore fishermen using the plant Haba de San Ignacio (*Nox vomica*) in their fishing techniques. This plant is high in strychnine and is used to stun the fish.

In contrast, however, a representative of the Federation of Fishing Cooperatives of Southern Sinaloa said that the primary cause of the high fish mortality was that one of the farms had used cyanide to treat its ponds. CRIP did find high concentrations of iron in the water discharged from aquaculture farms in the area.

Conflicts over Pollution and Diminishing Resources

As the above example suggests, shrimp farmers and near-shore fishermen have come into conflict around many lagoon systems. There are three main sources of these conflicts. One claim made by near-shore fishermen is that the larger shrimp farms are pumping many fish fry, shrimp larvae, and other species of crustaceans from local waters into their supply canals and ponds. These juvenile forms are thus unable to repopulate the lagoons, bays, and estuaries. The consequence is that resources once exploited by the fishermen are disappearing. Fishing communities around the aquaculture park of Tobarí in Sonora have been especially vociferous in their protests. To address their concerns, the Union of Ejidos that operates the park has commissioned the Technological Institute of Sonora (ITSON) to do a study to determine the effects of pumping on resources in the bay. ITSON asked local fishermen to participate in the study so that they could be assured of the soundness of the results, but few fishermen have accepted.

A related claim made by fishermen is that the gathering of wild PL was affecting the populations of adult shrimp available for harvest. This claim was much more common when a substantial number of farms were utilizing wild post-larvae. Now that most farms in both the cooperative/ejido and private sectors are using hatchery PL, this source of conflict is largely subsiding.

The third claim made by fishermen in several places is that the pollution discharged by the shrimp farms is affecting fishing resources. The larger farms (like Acuanova in Nayarít) have had many problems with local fishing communities, and PROFEPA made an investigation to determine whether water pollution standards were being violated by Acuanova (they were not).

These resource conflicts, it seems, mainly stem from the relatively impoverished state of near-shore fishing communities. An estimated 12,000 near-shore fishermen live in Sinaloa alone. As this population has increased, the pressure on resources has also grown. Shrimp and fish catches have certainly declined in some areas, and in some years catches are worse than in others. Because the shrimp farms are a new

actor on the local scene, and because they have been economically successful, they are a target for criticism. While some seafood species' juveniles are probably affected by the pumping operations, this probably has relatively little effect on the adult populations. Now that hatchery PL have replaced wild sources, this should disappear as an issue. Finally, the water pollution from agricultural run-off laden with pesticide residues, and the raw sewage dumped by many municipalities, pose far more serious threats than shrimp farms do. This does not mean that shrimp farms should be complacent about treating their wastes, but in order to clean up coastal lagoons, bays, and estuaries, there are other culprits that merit more attention and should have higher priority.

Use of Antibiotics

As disease problems have affected the industry in Mexico, shrimp farms have increasingly looked for methods to prevent or treat disease. All sorts of products have been tried, from antibiotics (general use or veterinary use, the latter is preferred) to mashed fresh garlic (Roque, personal communication 2000) or vitamin C. It is likely that as shrimp farming develops further, using antibiotics to try to prevent or cure shrimp diseases will become more common.

Currently, after harvests, producers dry their ponds and apply nitrogen fertilizer and lime. Almost all private sector farms, and many cooperative/ejido sector farms, use antibiotics as a preventative measure, most commonly oxytetracycline (which is widely available and cheap). A more expensive antibiotic is enrofloxacin, a liquid that is more commonly used for pigs and poultry. There is strong legislation on its use in Europe, because it acts directly on DNA. Another medicine that is potentially dangerous is chloramfenicol. Although this drug's use is prohibited, some producers reported that it is available under a different name from any supplier that sells to shrimp farmers.

Many farm operators are reluctant to admit that they use antibiotics, probably because they are aware of the potential for criticism. Several individuals also told us that they are privately concerned about the indiscriminate use of antibiotics, because of the potential danger they pose for coastal ecosystems and for future production of shrimp. Nevertheless, when pressed, most will say that they would prefer to use antibiotics in the short term, if it will help them ward off a disease outbreak.

Predator Control

Especially in areas close to mangroves, bird predation of shrimp stock is a problem. Producers report that cormorants are the most voracious predators, attacking in the morning and in the evening. In Sonora, where there are fewer mangroves and extensive agricultural areas and salt flats, fewer difficulties with predators are reported.

Scaring the birds away is the tactic used. In smaller operations, the most common technique employed is to station people around the ponds to use slingshots, throw rocks, and shout to keep the birds from landing. In larger operations, fireworks are often employed to drive away the birds. Almost everyone denied that people shoot the birds, but some suggestive comments indicated that this did sometimes occur.

Use of Exotic Species

A final environmental threat that should be discussed is the use of exotic species in shrimp aquaculture. As discussed earlier, this issue was one reason that construction of a large shrimp farm was denied a permit in the natural protected area of Laguna de Terminos in Campeche. Yet Pacific Coast species are commonly used in the Gulf Coast operations of Mexican shrimp producers. Some of the strains of shrimp being grown in Mexico come from operations in Venezuela, another country in which Pacific shrimp are used outside of their normal range. It is not known what kind of threat this poses to the native shrimp or other species.

From the perspective of Mexico, a far more serious threat is the risk of disease from introducing shrimp broodstock and PL from Central and South America. Many producers believe, probably correctly, that Taura Syndrome was introduced into the northwest of Mexico from PL imported from southern Mexico or Central America.

With the appearance of White Spot Syndrome Virus (WSSV), the country has established regulations to stop the spread of disease. Emergency regulations were enacted in March of 1999 (NOM-EM-001-PESC-1999) to prevent and control the spread of WSSV and Yellow Head Virus (YHV). Although its presence has never been recorded in Latin America, YHV has been found in US shrimp farms. This regulation specifically covers matters including:

- The importation and movement of shrimp in all its developmental phases. (only organisms entering the country or being moved from the Pacific coast to the Atlantic coast or vice versa).
- Certification of shrimp broodstock as being disease-free.
- Establishes quarantine measures for shrimp broodstock (the quarantine period equals the amount of time it takes for the viral diagnosis to produce results).
- Establishes a protective band in the southern states of Mexico; e.g., Chiapas and Oaxaca are not allowed to export shrimp or post-larvae to other regions of the country.
- Requires certification that inputs used in hatcheries are disease-free.
- Requires certification that shrimp and other crustaceans to be used in shellfish processing plants are disease-free.
- Establishes the use and standardization of diagnostic and sampling techniques, and recommends that at least two diagnostic techniques be used.
- Lists the laboratories certified by the National Aquacultural Health Service. (Roque 2000).

At the beginning of 2000, SEMARNAP officials were involved in discussions with the US Department of Commerce concerning regulations governing packing plants in Mexico. A major concern for Mexican officials was that Asian shrimp were being sent by US marketers to be processed and packed in Mexico. The country wanted to establish regulations to ensure that shrimp from Asia or elsewhere carried no disease and that waste products were disposed of in a proper manner. Disease is a special concern because it is thought that WSSV was introduced into Latin America from Asia.

Conclusions

Shrimp farming in Mexico has generated approximately 8,000 direct jobs in regions of the country that offer few other economic options. Additional indirect positions have been created in packing plants, feed operations, transport, and other activities related to shrimp farming. The strong historical presence of the cooperative/ejido sector on the coasts means that local resource-poor people benefit from the expansion of shrimp aquaculture. Many of the farms are still owned and operated by people from the cooperative/ejido sector, or cooperative/ejido sector producers have developed associations with producers from the private sector. When individuals from ejidos decide to sell their lands, those with desirable property are able to get more than US$2,000 per hectare.

As in other areas of the world, social conflicts have arisen around the shrimp farm industry. In Mexico, the issue of property rights is even more complicated than in many other countries. Federal zones, subdivided ejido lands, communal ejido lands, private property, and coastal areas in which cooperatives have been granted fishing rights may all exist in close proximity. Disputes among such stakeholders are common and are likely to become even more problematic as shrimp aquaculture expands. The federal government must make it a high priority to give ZOFEMAT sufficient resources to determine the boundaries of all federal

coastal zones. PROCEDE has made substantial progress in mapping and issuing titles for ejido lands but has avoided areas of conflict. In the future, it must devote resources to settling the disagreements in disputed areas (such as those in many coastal communities).

Social conflicts relating to resource use (and overuse) have also arisen in the country. Resource-poor fishermen have made the most extensive complaints, worrying that the shrimp farms will destroy their livelihood. The development of a lucrative economic enterprise in such close conjunction with fishermen living in poverty cannot help but generate jealousies and claims. However, the shrimp farmers believe they are being blamed for damages that in reality result from a variety of other causes (Rey In press) who discusses a similar situation in Texas). With the exception of the mega-project in Nayarít, the impacts of shrimp farms on local fishermen have not been great. In general, the conflicts of fishing communities against the shrimp aquaculture farms are more a symptom of the marginality of these communities than valid complaints. Shrimp aquaculturists, however, must be sensitive to the issues that concern fishermen, and should seek ways to work proactively with them and, whenever possible, help to enhance the productivity of the systems on which they depend.

Shrimp aquaculture in Mexico has thus far developed largely without the detrimental environmental effects seen in other countries of the world. Only a few instances of mangrove destruction have been documented. In part, the generally positive picture relates to the nature of the areas in which the majority of shrimp farming occurs in Mexico. Some prime areas never had much mangrove, and in other areas there are substantial salt flats that are easier to develop and more conducive to the practice of shrimp aquaculture. In part, the negative publicity about mangrove destruction in other parts of the world has made producers more conscious of the public relations disaster that would accompany this practice. Finally, the government's efforts to protect mangrove species has also had an effect. NGOs and communities have a legal mechanism that they have used effectively to denounce (and deter) mangrove destruction. As shrimp farming moves into more tropical areas of the country where mangrove is more abundant, careful monitoring must occur to ensure that this generally positive situation continues to prevail.

Probably the most serious potential environmental threat from shrimp aquaculture relates to impacts on water quality. As has been documented earlier, conflicts with other water resource users have already occurred. Aquaculture producers must continue to develop more closed systems, using less water from the estuaries and lagoons, and must especially develop treatment systems for wastewater. The aquaculture parks that have developed in some areas, and the parks planned for other regions, should help facilitate this process. Other point sources of pollution (municipal wastes, agricultural runoff, mining) are certainly greater threats than aquaculture to the coastal waters, and those problems must be solved. Federal, state, and local governments must develop a coordinated monitoring system for water quality in the critical lagoon systems to insure that these resources are protected.

Finally, the use of Pacific shrimp in aquaculture systems on the Gulf and Caribbean coasts is a potential problem. Pacific shrimp, however, are already being used in systems in the United States, Venezuela, and other countries. The effects of using exotic species are not clear, and research efforts should be devoted to an analysis. This point grows more relevant as genetic improvement of shrimp varieties becomes more common. Research should also be devoted to improving the potential for using native shrimp species in Gulf and Caribbean production farms.

Mexico's Regulatory Structure and Institutional Development

Introduction

As Tobey, Clay, and Vergne have written, "World experience in developed and developing nations alike, demonstrates that the greatest constraint to sustainable shrimp aquaculture is limited institutional capacity and ability to effectively practice ICM (Integrated Coastal Management)" (Tobey et al. 1998). The shrimp aquaculture industry has arisen in many places without adequate regulation by governments, without effective NGOs to serve as a counterbalance to the industry, and without ways for communities to monitor and evaluate resource use and over-use.

Given that Mexico's aquaculture industry was slow in developing, it may be that its institutional development and regulatory structure have been more adequate to the task of providing environmental and social protection than other countries'. In this chapter, the regulatory structure and the variety of institutions that have developed in Mexico are examined.

SEMARNAP

The organization responsible for aquaculture policy and development in Mexico is (SEMARNAP). This department was formed in 1995, merging agencies and offices from several different parts of the Mexican government. The Ministry of Fisheries (Secretaría de Pesca) had been a separate government ministry since 1976; it was responsible for the development of fisheries by providing technical assistance, developing technology, establishing a policy framework, and enforcing rules and regulations governing the sector. In addition, Fisheries also developed marketing (Ocean Garden Products, Inc.) and processing (Productos Pesqueros Mexicanos) arms for seafood products. Accusations of corruption and abuse of power circulated constantly about this agency until it was incorporated into SEMARNAP.

One knowledgeable observer from a leading nongovernmental organization (NGO) in Mexico characterized the merging of Fisheries with other organizations and agencies as a "complex undertaking." Among other elements, the new SEMARNAP ministry incorporated Forestry from the Agriculture Ministry, the Institute of Ecology from the Urban Development and Ecology Ministry, food safety offices from the Ministry of Health, as well as the huge and politically powerful National Water Commission (Comisión Nacional de Agua). The NGO official said that a major challenge is the political task of overcoming the struggle for power that is occurring within the new agency. It also means overcoming years of inertia that had accumulated within some of the previously separate agencies and effectively blending them into one functioning unit.

Within SEMARNAP, the majority of resources, staff, and power came from fisheries, forestry, and the water commission. These units were accustomed to playing an important **development role**, working closely with banks and producer groups, and supporting research to develop new technology. A large part of the mission of SEMARNAP, however, involved playing a **policy and regulatory role** for the utilization and protection of natural resources in the country. SEMARNAP is supposed to play a direct role in **environmental protection,** as it also administers the national parks and protected areas. Yet the agencies incorporated into the new department that had environmental training and capabilities had few resources, scant personnel, and little power. Finally, the office of the Attorney General for Environmental Protection (PROFEPA) was added to SEMARNAP. This **enforcement office** was supposed to strengthen the new department, but so far, PROFEPA has had little money and few staff members to carry out its functions. Several people commented to us that PROFEPA could not enforce any of the environmental laws or regulations in the country. Reportedly, in some parts of the country, PROFEPA personnel ask those bringing a complaint to pay for their transportation, per diem fees, and other costs of an investigation.

Some individuals who deal with SEMARNAP are discouraged about the lack of progress within the institution. One NGO leader said that, for example, the fisheries staff do not really believe in environmental issues and concerns. They still view their primary function as supporting development. He also said most of the leaders in the NWC do not really support the idea of developing watershed advisory groups (Consejos de cuenca). He said they are much more interested in selling water as a commodity than thinking about conservation.

Having economic development, regulation, protection, and enforcement within the same agency seems to make little sense for achieving a balance of powers. This is particularly the case when most of the financial and human capacity is charged with developing resources rather than protecting them. Individuals within SEMARNAP said that the net result is that many important decisions ultimately end up being made by the Secretary of SEMARNAP (Currently Julia Carabias). The Secretary ends up deciding among the competing recommendations made by representatives of the different offices within the same organization.

A good example of these internal tensions is found in a proposal to build a very large shrimp farm in the Laguna de Terminos region of the state of Campeche. One of the largest shrimp farms in Honduras proposed to partner with Mexican investors to eventually develop a 3,000 ha farm. The state government pushed the project strongly because of its economic development potential. The proposal planned to build the farm in a Natural Protected Area (ANP) and to use *Penaeus vannamei* (an introduced species from the west coast of Mexico), so the company asked SEMARNAP for an early determination about whether such a project was at all possible. Although a management plan for the ANP does not yet exist, the National Ecology Institute (INE) reported that there was no explicit prohibition against development there. Furthermore, land use plans for the state indicated that the site proposed was one of the best places to locate a shrimp farm, and so the company was encouraged to go ahead with its plans.

The company commissioned an expensive (and according to individuals who evaluated it, a very good) environmental impact assessment. In addition, the company began working with the local board of directors of the ANP to address their concerns, eventually persuading them to approve the project. One of the concessions apparently made by the company was to do some experimentation with *Penaeus setiferus*, a Gulf Coast shrimp species.[15] Meanwhile, an NGO in the region began mobilizing opposition to the project on ecological grounds, focusing attention on the planned use of an exotic species within an ANP. Thus, among others, officials from the INE, the sub-directorate of fisheries, and the ANP were all involved in the debate within SEMARNAP. Finally, in December 1999, the Secretary made her determination that the project should not be approved because it proposed use of an exotic species.[16]

Opinion in Mexico about SEMARNAP is divided. Some informed observers think that the internal contradictions that flow from implementing development, protection, regulation and enforcement are problematic and ultimately detrimental to developing sustainable use of natural resources in Mexico. Others view these multiple functions and contradictions as something that would not work in most countries but may work in Mexico, where long-term one-party rule has tried to incorporate internal debate from many different sectors.

[15] The National Fisheries Institute (INP) has done some work with *Penaeus setiferus*. Although it can be produced in captivity, survival and growth rates are not sufficient to make it economically productive.

[16] People from the company proposing the project, many state officials, and others in the shrimp industry were furious with the ruling. They pointed out that a smaller project on the border of the ANP in Campeche has been approved, although it will use *Penaeus vannamei*. Existing Gulf and Caribbean coast farms in Veracruz, Tamaulipas, and the Yucatán are all using west coast shrimp in their operations.

It is apparent that SEMARNAP has made remarkable progress in its brief existence. Much of this progress is probably due to the abilities of the current secretary, who has gained substantial respect from a wide variety of individuals and organizations in the country. She has seemingly been able to successfully navigate the minefield of competing powers within SEMARNAP. What is not clear is what will happen when she leaves office. As the electoral campaign in early 2000 was going on, many rumors and speculations about the future of SEMARNAP were circulating. Almost everyone agreed that the department would be dismembered, irrespective of which party won the election. In the short run, this instability will probably impede some of the progress that has been made in developing greater environmental protection mechanisms within Mexico.

General Directorate of Agriculture

Within SEMARNAP, there is now a Division of Fisheries. Just as when it was its own ministry, Fisheries has delegates in each state who make and implement particular regulations (e.g., establishing fishing seasons) as well as carrying out federal programs. In Mexico City, the General Directorate of Aquaculture (DGA), or Dirección General de Acuacultura, is the organization within Fisheries that works in the aquaculture sector. This directorate contains five departments, responsible for, respectively, engineering, health, development, special projects and social organization. The current Director General of Aquaculture has created two additional departments, one on the environment and the other on management. Both depend directly on his office, and he expects that they will be abolished when his term ends.

Anyone wanting to establish a shrimp farm or other aquaculture operation in Mexico must apply to the DGA. Prior to 1990, the permitting process for aquaculture was lengthy and complicated, requiring as many as 20 separate reviews, approvals, or permits from several different agencies. The DGA has created a “single window” method that greatly facilitates the process. The single window takes the applicant through the permissions required for: use of federal maritime or other national lands, use of waters (also national property), and a concession to establish an aquaculture operation. In reviewing proposals, the DGA is responsible for evaluating the technical and financial aspects of the project. Applicants also have to prepare an environmental impact assessment that is evaluated by the National Institute of Ecology (INE). Recently, the DGA and INE decided that the three evaluations will occur simultaneously so that those proposing projects will receive a definite answer relatively quickly. In most cases, an answer is given to applicants within 5–6 months, significantly less than the (average) 30 months the process took only a few years ago (KBN Engineering 1994).

In order to further facilitate the development of this sector, the DGA has also commissioned a series of land use planning studies to determine the most suitable places in which to locate aquaculture ventures. Studies have been completed for Chiapas, Oaxaca, Nayarít, Sinaloa, Campeche, Tamaulipas and Michoacán. These studies will now be discussed with state and local governments, with the ultimate goal of developing zoning plans for each state. Once these draft plans are completed, public comments are to be solicited before they are approved. Presumably, once the land use plans exist, the required environmental impact assessments will be shorter and simpler for areas already identified as appropriate for aquaculture.

Despite the significant advances of recent years in simplifying and facilitating the permitting process, many older aquaculture ventures do not have all of the documentation now required. Construction of some farms is begun before all permits are obtained, sometimes without even the intention of complying with the regulations. Adequate enforcement is still problematic. The DGA has begun a process by which they hope to “regularize” all aquaculture operations in the country. The first effort in Sinaloa is a program to examine the juridical situation and do an ecosystem diagnosis of all aquaculture farms – National Diagnostic Progam for Coastal Ecosystems and the Legal Situation of Shrimp Production Units (PNDEC)—or Program Nacional de Diagnóstico de los Ecosistemas Costeros y Situación Jurídica de las

Unidades de Producción Camaronícola. The project will provide permissions to farms that have not previously obtained them, will document the infrastructure and technology used by the farm, and will include the farm's physical layout on a 1:50,000 scale map. Producers will be charged 84 pesos per hectare to cover the costs of the studies and procedures to regularize their holdings. The plan is to use the data to determine the possible aquacultural carrying capacity of coastal ecosystems, as well. After testing the system in Sinaloa, the DGA will apply these procedures in other states.

ZOFEMAT

There is one other body within SEMARNAP that has important jurisdictional authority over coastal areas. The federal government theoretically controls property rights over all coastal areas that are subject to tidal forces or connect with marine waters. This land is the Federal Maritime Terrestrial Zone (Zona Federal Marítimo Terrestre), governed by an agency called ZOFEMAT.

This zone extends 20 meters from the high tide mark. One of the major difficulties with determining the boundaries of this zone is that they are constantly shifting as coastal areas are formed and re-formed by the actions of the ocean. Some lands are cut off from the sea and the tides, and they are then no longer subject to ZOFEMAT. Other lands become subject to tidal forces and become part of the federal zone.

This shifting land and seascape creates a nightmare of determining property rights. As discussed above, land disputes in and around the federal maritime zone are common. A major problem is that, although the delimitation of the maritime boundary has been made a priority by the Zedillo Administration, the amount of funds available for this work is quite small.

Part of the PNDEC program that SEMARNAP is carrying out in Sinaloa will include the delimitation of the Federal Maritime Terrestrial Zone in that state. Municipalities along the coast are given authority charge fees for the right to use the zone. Of the amount collected, 70% will stay with the municipality and 30% will go to ZOFEMAT. In 1999, ZOFEMAT officials reported that eight of the ten coastal municipalities in Sinaloa were assessing these fees. Once the process of delimiting the boundaries is concluded, the Secretary of Agrarian Reform will be asked to resolve any conflicts that exist.

The Mexico Aquaculture Project (MAP)

During the mid-1990s, the World Bank and SEMARNAP developed the Mexico Aquaculture Project (MAP) to help stimulate and regulate the development of aquaculture. Key components of the project were assisting SEMARNAP in developing a regulatory structure, establishing a system of environmental monitoring, conducting resource management planning, and providing technical and financial assistance to help resource poor individuals develop aquaculture parks. The senior author of this report did the social assessment for an early version of the project and helped develop some of the components oriented toward the cooperative/ejido sector. After several years of delays due to redesigns of the project, it was finally approved in 1996 for a much smaller amount of money than originally contemplated. The final loan of US$40 million allocated roughly US$10 million regulatory work and the rest for project investment (mainly for the cooperative/ejido sector).

By early 2000, less than one million dollars of the budget had been spent. The major stumbling block seemed to be that personnel in Mexico's Ministry of the Treasury and Public (SHCP) did not support the part of the project oriented toward the cooperative/ejido sector. The MAP had called for prospective cooperative/ejido sector aquaculture producers to put up 20% of the capital for projects (in the form of their property rights). The MAP would then put up the other 80% in the form of loans. Once the projects got going, the plan was for the cooperative/ejido sector producers to begin repaying the loans and eventually assume control of the projects. Because repayment rates from the cooperative/ejido sector have historically been poor in Mexico, the SHCP adopted a policy of providing only 49% of project funding as

loans. If the cooperative/ejido sector could provide only 20% of the capital, then the other 31% for investment would have to come from the private sector. World Bank officials would not agree to this structure because they feared that it would mean that the projects would ultimately be controlled by private investors rather than the cooperatives/ejidos sector. This impasse meant that the SHCP never included the US$40 million plus an agreed-upon US$18 million of matching funds in its budget allocations to SEMARNAP.

SEMARNAP attempted to restructure the project, but World Bank officials never accepted the plans. Because of these ongoing disagreements, the Government of Mexico finally decided to terminate the World Bank MAP project in March 2000.

Ironically, in spite of how little money was expended, the project had a positive impact. Many of its elements, particularly those pertaining to regulatory structure, have been implemented by SEMARNAP. The ministry has devoted normal budgeted funds to developing a regulatory structure, to commissioning land use planning studies, and to establishing monitoring systems. Investment in the development of aquaculture parks for the cooperative/ejido sector continues. The MAP would probably have allowed these development activities to occur at a faster pace, and in several areas that currently lack such parks because of a lack of funding.

Other Federal Government Institutions

The major environmental regulations that apply to aquaculture are part of the Ley General de Equilibrio Ecológico y Protección del Ambiente–General Law of Ecological Equilibrium and Environmental Protection (LGEEPA)–passed in 1988. This law and associated regulations stipulate that SEMARNAP devote its efforts to the sustainable management of flora and fauna. The Instituto Nacional de Ecologia–National Institute of Ecology (INE)–is responsible for evaluating the environmental impact of aquacultural and fishery activities. Now part of SEMARNAP, INE approves or rejects the environmental impact statements required for the establishment of any aquaculture operation in Mexico. INE is also responsible for approving the land use plans that establish preferred uses for the nation's coastal zones, commissioned by SEMARNAP. PROFEPA, also part of SEMARNAP, is responsible for insuring compliance with federal regulations and the requirements that INE establishes in response to the environmental impact statements submitted to it.

The Ministry of Agrarian Reform (SRA)—or Secretaría de Reforma Agraria–has some responsibilities relating to ejidos that include near-shore fishermen. Right now, its most important program relating to aquaculture involves PROCEDE, the Program for Certification of Ejido Land Rights and Titling of Urban House Plots. This is the unit that is charged with working with ejidos to privatize land rights in the country. If ejidos choose to privatize land plots, their members can sell, rent, or lease land. Ejidos can also choose to sell communal lands to private investors. It is under these conditions that land along the coast is now being purchased or rented for shrimp aquaculture and other purposes.

Of course, many other federal government ministries are involved in particular aspects of aquaculture. The Ministry of Labor, for example, establishes labor laws and regulations that govern workers. The Ministry of the Treasury is responsible for some of the government banks and programs that lend funds to aquaculture. The Ministry of Agriculture and Hydraulic Resources and the Ministry of Health have health and sanitation regulations that pertain to some aspects of shrimp farming.

State Government

Municipal level authorities are given authority to impose conditions on land use, approve construction licenses, and ensure satisfactory compliance with environmental impact assessments.

At the state level, regulations and agencies often parallel those at the federal level. The states are primarily responsible for developing local ecological planning, usually via a state commission that seeks interinstitutional coordination. For example, the State Commission on Ecology in Nayarít has as members the governor, the secretary of planning and development (who coordinates the group), the state secretary of ecology and urban development, the director of ecology, and up to ten representatives of the private and cooperative/ejido sectors.

Recently, the governor of the state of Sinaloa established an Institute of Aquaculture, a similar commission that includes representatives of the various stakeholders who participate in and monitor shrimp farming. The objectives of the institute are to seek resolution of the industry's problems by supporting research, technological development, inspections and vigilance, environmental improvement, and development of appropriate financial mechanisms. Private sector farms have committed to levying a small fee on every kilogram of shrimp produced to support the functioning of the institute.

The government of the state of Sonora has also begun investing resources to promote more sustainable development of shrimp farming. In September 1999, the government funded a study by the Monterrey Technological Institute of Advanced Studies–Guaymas campus, with the goal of more "harmonious development." Its objective is to "Develop an instrument with spatial components (based on a geographic information system) that is useful to decision makers. It will permit them to locate, characterize, and monitor the shrimp farms located in the south of Sonora, and serve to support decisions about the location of new projects while minimizing conflicts." Preliminary results from this study were presented at the state-sponsored Forum on Shrimp Aquaculture 2000, held in March (Noriega 2000).

In Oaxaca, a state that has seen little development of aquaculture until recently, the Committee for the Evaluation and Selection of State Aquaculture Projects was formed in 1999. This committee includes representatives of the State Fisheries Council, the Regional Delegation of CONACYT (Mexico's National Science and Technology Foundation), the National Institute of Fisheries, and SEMARNAP. Among the purposes of this committee is promoting research studies that will help develop technology and planning methods to improve shrimp cultivation in the state.

As these efforts suggest, there is considerable state-level interest in shrimp farming as well as concern about the kinds of conflicts that may arise from its development. The state-level commissions being developed are quite timely. If they are able to incorporate the concerns of diverse stakeholders in coastal ecosystems into better planning for future development, they can be effective mechanisms for avoiding the conflicts that have plagued aquacultural development in other countries.

Educational Institutions and Research Institutes

As the involvement of the University of Sonora in the early shrimp farming efforts in Mexico suggests, educational institutions have played and are playing an important role in the development of this industry. Another institutional influence in the early development of shrimp aquaculture was a program in biochemical engineering at the Instituto Tecnológico de Estudios Superiores de Monterrey – Guaymas campus. Although this program has now been closed, many of the owners and operators of shrimp farms in Sonora and Sinaloa received their training there.

The strongest institutional programs that support shrimp aquaculture have developed in Sonora. CICTUS at the University of Sonora worked with the University of Arizona (in the US) on the first experiments in

Mexico on shrimp farming. The center has become the Department of Scientific and Technological Research (DICTUS), and its personnel continue to do research on aquaculture, particularly in the northern and central parts of the state. The department has a master's degree program that trains researchers to work on problems related to aquaculture and coastal development. DICTUS has approximately 25 researchers who, among other tasks, produce bulletins on the establishment and operation of shrimp farms.

The Instituto Tecnológico de Estudios Superiores de Monterrey – Guaymas campus, despite having closed the program that produced many of the pioneers in Mexican shrimp production, continues to be an important institution. In particular, its Center for Conservation and Utilization of Natural Resources (Centro de Conservación para el Aprovechamiento de los Recursos Naturales, or CECARENA) has been extraordinarily active in using GIS data for identifying problem areas, developing a strategic management plan, and monitoring coastal development in southern Sonora. This work is based on earlier research done by CECARENA (see Valdes-Casillas, et al. 1994; Valdes-Casillas, et al. 1996). A strategic management plan was developed for the 13 wetland systems in southern Sonora in August 1996; this plan has been incorporated into the state's land use planning program. CECARENA has an impressive web site (http://uib.gym.itesm.mx/hs/) that already contains resources that can be utilized by domestic and international parties to monitor shrimp farm and other development activities on the southern coast of Sonora. Figure 6 is an example of their work, showing the principal problems affecting the El Tobarí Lagoon system in Sonora. The research team has produced a preliminary diagnosis of the problems and the potential for shrimp farming in the region (Licón-Gonzalez 2000).

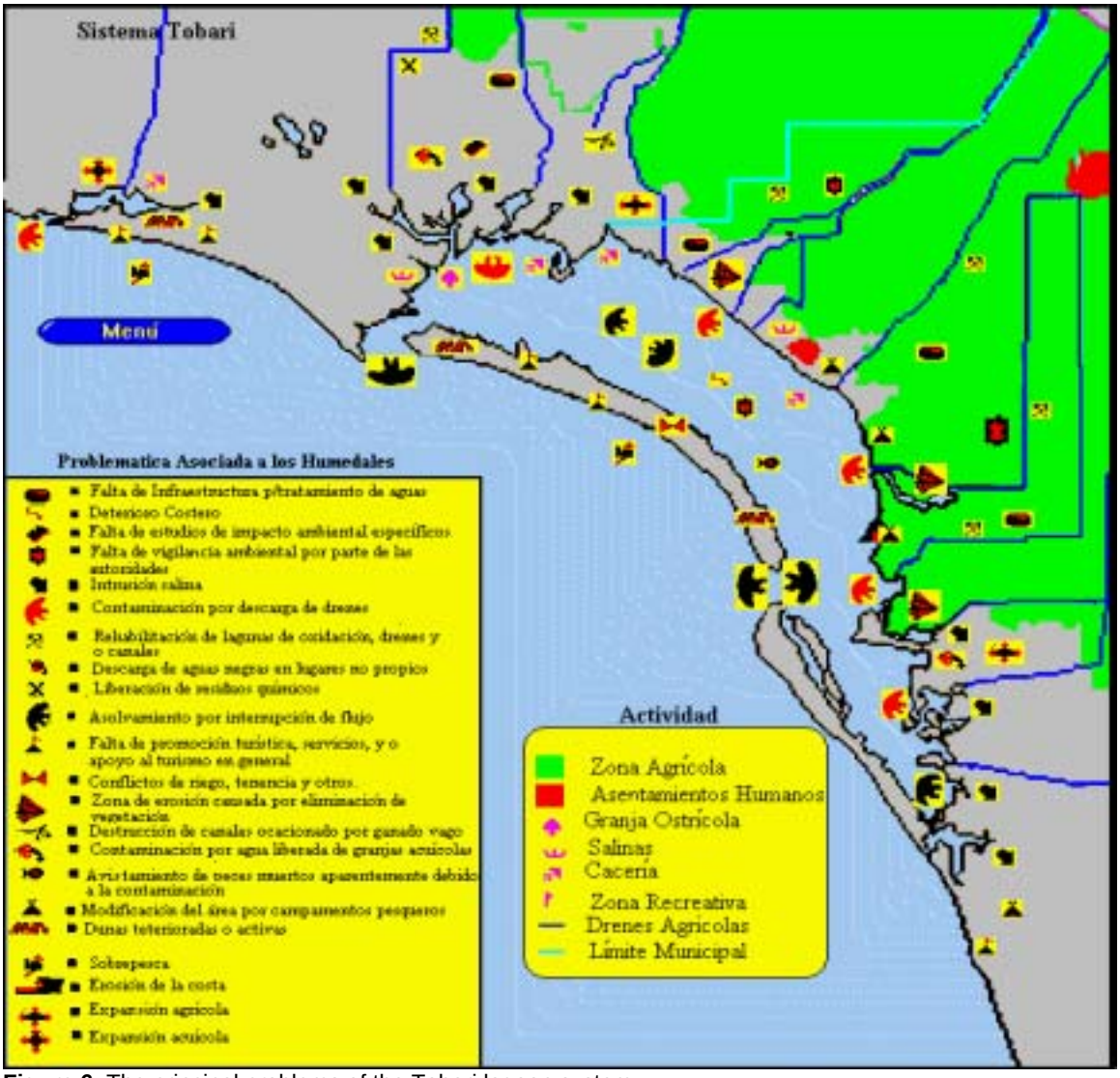

Figure 6. The principal problems of the Tobari lagoon system

Another research institute that is engaged in important work is the Northwest Center for Biological Research (CIBNOR), headquartered La Paz, Baja California, but with a station in Guaymas, Sonora. One of 27 centers in a system coordinated by the Department of Education and the National Council of Science and Technology in Mexico, it conducts scientific research on the desert ecosystems of the Baja Peninsula and the Sonoran Desert as well as work on the ocean resources of the Sea of Cortés (http://www.cibnor.org/icibhome.html). CIBNOR has both master's and Ph.D. programs. This Center has 108 researchers dedicated to exploring the fields of aquaculture, agriculture, environmental impact, climatology, marine and terrestrial biotechnology. With regard to aquaculture, the center does research, consulting, and analysis for the shrimp industry. Perhaps the most important service that CIBNOR provides is certifying products and organisms as being free of shrimp pathogens, one of only two laboratories in the country that are authorized by SEMARNAP to do so. Last year, researchers from the center conducted a study to evaluate current WSSV trends in Mexico. CIBNOR is also working under contract with SEMARNAP to carry out the PNDEC program in Sinaloa.

Several of the researchers at the Technology Institute of Sonora (ITSON), located in Ciudad Obregon, have been researching the effects of shrimp farms on the fish and shellfish resources near the El Tobarí

aquaculture park. The Institute also has a postgraduate course in environmental biotechnology and aquaculture, and plans in the next academic year to open a licenciado (undergraduate) level professional program in aquaculture. The Institute is also working to establish a professional organization of aquaculturists, as well as to begin publishing a bulletin on a trimester basis.

CIAD, the Center for Research in Food and Development, has large research facilities in Hermosillo, Sonora, and Mazatlán, Sinaloa, with a smaller office in Guaymas, Sonora. CIAD provides research, consulting, and technical training on livestock, crop production, food processing and aquaculture. Most of the researchers connected with CIAD have doctoral training from prominent universities around the world. CIAD conducts relevant research in aquacultural biotechnology, disease pathology, shrimp immune systems (Vargas-Albores and Yepiz-Plascencia 1998; Montaño-Pérez et al. 1999), water quality (Franco-Nava et al. no date) and monitoring of farms using aerial photography and GIS procedures (Ruiz & Espino 1999; Ruiz & Cornejo 1999).

The last area of research is particularly useful for monitoring the impacts of individual shrimp farms. Ruiz Luna and his collaborators have produced plots of each farm in the areas they have studied that include water intake sources, drainage canals, layout of ponds, production system, original use of the land, surrounding vegetation and a general assessment of environmental impact (see Figure 7 for an example of this work). CIAD will be collaborating with CIBNOR and SEMARNAP to carry out the PNDEC program in Sinaloa.

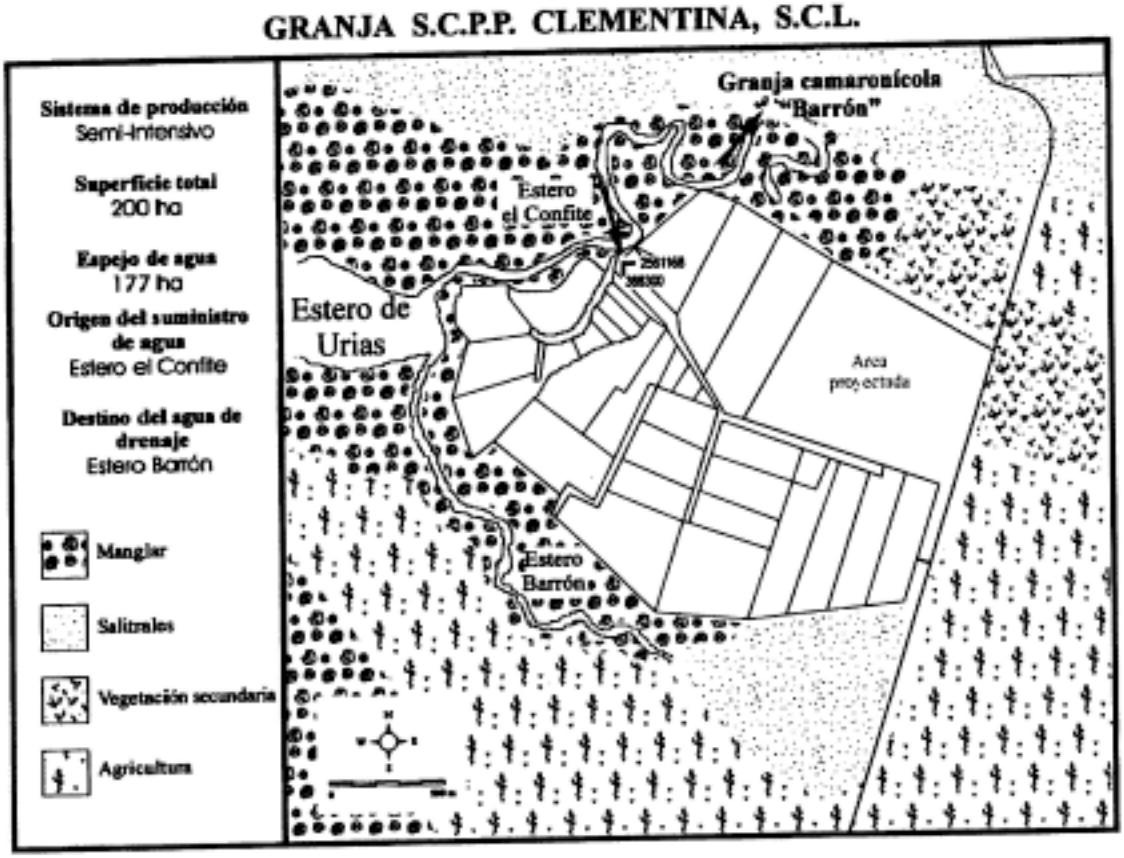

Figure 7. Example: Granja Clementina

In Sonora, three other institutions are now training people to work in the aquacultural sector. Two of these, the Centro de Estudios Superiores del Estado de Sonora (CESUES) and the Instituto Tecnológico del Mar, Guaymas (ITMAR), have undergraduate programs; ITMAR also has a graduate program. The Centro de Estudios Tecnológicos del Mar offers training for technicians.

In Sinaloa, the Universidad Autónoma de Sinaloa (UAS) has an oceanography faculty. Several of these faculty members do research and/or technical assistance in the aquaculture sector. Many of the technicians employed as biologists by shrimp farms in the state are graduates of the UAS.

In Nayarít, the Universidad Autónoma de Nayarít and the Instituto Tecnológico de Tepic both have groups of researchers working on environmental problems in the state. With the growing importance of aquaculture, a number of these investigators have turned their attention to problems related to the sector. Compared with the staff at institutions in Sinaloa and especially in Sonora, these researchers are much younger, have had less experience, and are much less likely to have doctorates or to have been educated outside of Mexico.

It should also be mentioned that the Universidad Nacional Autónoma de México has research laboratories scattered around the country, including those in Campeche, Sinaloa, and Baja California. Although UNAM is reportedly involved in work on shrimp aquaculture and/or environmental problems, no in-depth knowledge of their work was acquired.

The marine research capacity in Mexico is quite impressive, with researchers who have been trained at the highest levels in research institutions around the world. As of a few years ago, the National Fisheries Institute reported that there were 641 researchers at some 163 public and private research and educational institutions who were members of its National Network of Aquacultural Research (SEMARNAP no date). The National Science and Technology Council provides grants to some of these individuals on a competitive basis for basic and applied research. SEMARNAP has some money to support applied projects by institutional researchers. This program began about five years ago to provide funding to centers and universities that agree to provide services to producers. While the agreements have covered work only on shrimp aquaculture in the past, some funds are now being invested in research on other species.

Producer Associations

In Mexico, regional producers have created a number of "unions" and "integrating associations" that are working effectively on reducing costs, sharing infrastructure, engaging in dialogue with the government, and developing cooperative means to resolve conflicts and problems. One of the most successful of these is the UEASS. UEASS is part of the Unión General Obrero Campesina y Popular (UGOCP), a political organization established to assist the resource-poor farmers and fishermen in Sonora. The UEASS is probably the most centrally directed of these kinds of organizations. With government-backed financing, it developed three aquacultural parks that in 2000 included 17 ejidos. The UEASS hires technicians who control every aspect of the production systems in the three parks, manage the common supply and drainage canals for the park, purchase inputs in bulk and at reduced prices, and manage the finances for all of the ejidos. The parks have been extraordinarily successful. One of the ejidos obtained average yields of 2,768 kg per hectare on its 43 ha in 1999, only its second year of operation (Anaya 2000).

A somewhat more loosely structured union is represented by the Unión de Empresas Acuícolas de Guasave (UEAG) in the state of Sinaloa, Mexico. This union originally was charged in 1995 with assisting 16 cooperative/ejido sector farms to develop. It did this primarily by providing them with technical assistance, as well as by buying inputs at much lower prices than those that would be paid by any one farm. Unlike the UEASS, the UEAG has never provided management for the farms. Because of its success, in 1998 a separate organization was formed that operates out of the same offices and has the same director. Acuacultores de Guasave is an integrating business (Empresa integradora), essentially a buying cooperative. Acuacultores de Guasave included 24 farms in October of 2000, but was poised to admit another 12 farms to membership. Its membership includes both private and cooperative/ejido farms, with the former making up about 30% of the membership. The organization negotiates discounts on inputs like feed, calcium, and PL with half the savings used to fund the offices and administration and the other half passed back to the farms. Acuacultores de Guasave is continuing to expand its activities by acting as an intermediary in acquiring insurance for its members, providing laboratory services, and developing agreements with farms concerning common management practices (mainly common dates for stocking ponds and harvesting). In 2001, it hopes to have available a line of credit that it can use to provide timely credit to its members.

A final example that should be mentioned is an organization formed in mid-2000, Acuacultores de Ahome. It is also an integrating business, with a membership of 24 farms, 70% of them private and the other 30% from the cooperative/ejido sector. The organization provides the services of a buying cooperative, but also holds weekly meetings of technicians from the farms to talk about environmental health, biosecurity, disease prevention, and other topics. Acuacultores de Ahome has pulled together eight farms in one area to develop plans for a common drainage canal to help resolve problems with wastewater. The organization developed the plans, negotiated a contract, financed the construction by charging each farm based on land area, and is supervising the construction.

Commodity Groups

The private fisheries sector in Mexico has formed the National Chamber of the Fishing Industry (Camara Nacional de la Industria Pesquera, or CANAINPES), an association that represents and lobbies for its interests. A few years ago, the private sector aquaculturists founded the Aquaculture Specialized Section (Sección Especializada de Acuacultura) within CANAINPES.

The Aquaculture Specialized Section brings together leading shrimp farm producers, hatchery owners, packing plant operators, and other interested parties from around the country. The Section elects a president each year, has delegates from the major shrimp-producing states, and has formed commissions on sustainable aquaculture, research and technology development, aquacultural health, wild post-larvae, and aquacultural domestication. Representatives of the Section seem to have good relations with officials in SEMARNAP in Mexico CIty, as well as SEMARNAP offices in the various states.

Members of the Aquaculture Specialized Section reported that it is still a relatively weak organization, however. The membership is perhaps about 30 people, a relatively small percentage of those in the industry. The commissions that were established mainly reflect the personal interests of individuals, and accomplish little in any organized fashion.

Several of the states also have organized groups of producers. For example, there is a Federation of Mexican Aquaculturalists (Federación de Acuacultores de Mexico) that is based in Culiacan. Despite the large number of producers in Sinaloa, the active membership of this organization is also quite small there.

In Tamaulipas, the four or five largest producers have formed an organization called the Consultative Committee of Shrimp Cultivators (Comite Consultivo de Camaronicultores). They meet on an occasional basis and try to coordinate and develop policies regarding salaries and working conditions. The goal there is to prevent people from jumping from one farm to another to obtain better working conditions or remuneration. The committee also tries to set common norms and standards for sources of PL, to negotiate common contracts for feed, and to offer opinions to the state SEMARNAP office about whether other farms can and should be established (and where). In early 2000, for example, they had decided on a common policy of avoiding importing shrimp PL from the Pacific, to try to prevent the spread of White Spot Disease. They also have agreed not to use wild PL of Gulf shrimp as a precaution. They will all import post-larvae for 2000 from a hatchery in Texas.

The growing importance of aquaculture in Mexico has also seen the founding of a specialized magazine for the sector. Panorama Acuícola made its debut in 1996 and is published bimonthly in Ciudad Obregón, Sonora. It covers experiences with aquaculture in Mexico, comparative information from other countries in Latin America and around the world, and updates on shrimp and other seafood prices from major markets. The current cost for subscribers is US$53 per year; 55% of the readership comes from Mexico, 22% from South America, and about 10% from the United States and Central America (each). The major input suppliers and marketers advertise their products and services in the magazine. As of March 2000, Panorama Acuícola had 500 subscribers and distributed an additional 3500 copies free of charge (see http://www.fis.com/panoramacuicola/).

Nongovernmental Organizations

During the past decade, the number of registered nonprofit organizations in Mexico grew from approximately 600 to over 7,000. Groups working on environmental issues constituted approximately 10% of the total in 2000. In every region of the country, there are now groups working on environmental issues. Most of these organizations are relatively small and do not encompass a large cross-section of the population. In addition, several of the major worldwide environmental organizations have offices and projects based in Mexico.

NGOs have had some involvement with the aquaculture sector (reviewed below). In general, however, the regional, national, and global environmental organizations have not dedicated substantial resources or energy to issues related to shrimp aquaculture. Notably, local and regional environmental organizations have had almost no role in working on aquaculture issues in Sonora and Sinaloa. The few organizations that have mobilized to work against, or negotiate with, the acquaculture sector have been in states like Nayarít and Campeche, where the sector is less developed.

PRONATURA

PRONATURA is the most visible national environmental organization in Mexico. While personnel connected with PRONATURA believe that problems–including destruction of mangroves, pollution of lagoons, and loss of marine environments–in the country, the organization has not directly focused on aquaculture.

PRONATURA works closely with the national government and private industry, and rarely uses confrontational tactics. The governing board of the organization comprises approximately 100 businesspeople, and much of its support comes from corporate sponsorship. Although it produces a glossy magazine, PRONATURA actually has a relatively small membership base. PRONATURA has alliances with many national and international organizations, and participates as a partner in efforts with organizations like the World Wildlife Fund (WWF) and Conservation International (CI).

Conservation International

Mexico's Conservation International (CI) office began in 1987 and was initially directed from headquarters in Washington. By 1993, CI had two projects; one was on the Gulf of Baja California, the other in the Lacandon Rainforest of southern Mexico. In that year, CI consolidated its Mexican operations and in 1994 hired a director for an office in Mexico City. Senior officials of CI reported that it tries to keep a low profile, commenting to governmental authorities when asked but avoiding joining confrontational coalitions about environmental problems. They see themselves as an implementing agency trying to broker solutions rather than a watchdog organization that gets involved in opposing development. CI actively seeks to build associations and coalitions with the private sector.

Of relevance to the aquaculture sector, CI has begun a project in the ecologically sensitive Bahía de Santa María in Sinaloa near the city of Culiacan. The Bahía de Santa María is an extensive lagoon-wetland complex whose extensive mangrove ecosystem is considered one of the 32 priority wetlands in Mexico by the National Commission on the Study and Use of Biodiversity (CONABIO). In 1992, the Bahía Santa María was nominated by the Government of Mexico to be an international site for the Hemispheric Network of Reserves for Shorebirds (Coastal Resources Center 1999).

The project receives cooperation and support from the Coastal Resources Center of the University of Rhode Island, the Universidad Autónoma de Sinaloa (UAS), Monterrey Tech, Ducks Unlimited of Mexico (DUMAC) and PRONATURA of Sonora. The North American Wetlands Conservation Council is providing some funding, and the Packard Foundation has recently made a planning grant to the Coastal Resources Center to support their efforts.

The project seeks to find and implement good practices in shrimp farming and in natural resource management generally. First, researchers are gathering opinions from the various stakeholders–fishermen, shrimp farmers, duck hunting guides, agriculturalists, and others–to try to develop natural resource management solutions. A GIS laboratory is being built at the UAS to develop a database for this work.

The CI project is an extremely important effort. By seeking common solutions to natural resource issues, the project may be able to move coastal stakeholders beyond the confrontations that now characterize the

sector. CI and its partners are interested in developing a sustainable aquaculture industry that can exist in harmony with the larger economic and environmental systems.

Greenpeace

Greenpeace has been the most confrontational environmental organization in Mexico. Along with other environmental organizations, it recently was involved in the successful fight against further development of salt production in the San Ignacio Lagoon of Baja California.

Greenpeace has been involved in some of the higher-profile disputes concerning the development of aquaculture in Mexico (see section on Social and Environmental Impacts). The organization seems to operate primarily by writing letters supporting the positions of local environmental groups, as well as helping to organize meetings to negotiate with local and national authorities. Greenpeace was one of the principal sponsors of meetings in Juchitán, Oaxaca, in November 1999 and in San Blas, Nayarít, in May 2000. These meetings brought together fisher folk and NGOs to discuss the problems related to fishing, shrimp aquaculture, and coastal development. Both resulted in declarations calling for defending mangroves (see below).

According to people from other environmental organizations, Greenpeace Mexico has suffered from a lack of continuity in leadership; has had three directors since 1995.

Local Organizations

At the local level, the most visible and effective group has been the Grupo Ecológico el Manglar based in San Blas, Nayarít. Although the group represents itself as fighting to save mangroves and their ecosystems, many other people see it as a political tool being used by a politician (the mayor of the town in 2000).

The group has fought on behalf of the unlicensed near-shore fishermen and has been especially critical of the development of a huge aquaculture operation in the region (Granjas Aquanova). It has secured the active support of Greenpeace and brought the case of mangrove destruction by Aquanova before the Congress of the State.

Because it has not been satisfied with the response of the state and national governments to its complaints regarding the Granjas Aquanova shrimp farm, the Grupo Ecológico el Manglar has brought the dispute to the Commission for Environmental Cooperation (the organization set up to address environmental issues by the NAFTA agreement). The Secretariat of the Commission has determined that the development of a factual record is warranted with respect to the citizen submission brought forward by the Mangrove Ecology Group. The submission regarding Granjas Aquanova "…alleges that Mexico has failed to enforce effectively its General Law of Ecological Equilibrium and Environmental Protection (Ley General del Equilibrio Ecológico y la Protección al Ambiente), the Forestry Act (Ley Forestal) and the Law of National Waters (Ley de Aguas Nacionales), among others, pertaining to the protection of jungles and tropical rainforests, particularly mangrove and migratory bird species; wastewater discharge, and provisions for prevention and control of water pollution and use; and provisions on fisheries and the introduction of an alien shrimp species" (Submissions on Enforcement Matters Unit, Commission for Environmental Cooperation, Montreal, Quebec, Canada; press release, 7 September 2000). The case will be investigated further and can be monitored on the Commission for Environmental Cooperation web site (http://www.cec.org).

A coordinating group comprising mainly NGOs called the Red de Pescadores Ribereños (Network of Near-Shore Fishermen) that was active in the mid 1990s has dissolved in recent years. This network had some support from the Friedrich Ebert Stiftung (a German foundation), but leaders told me that the

challenge of keeping together such a far-flung organization proved too difficult. Many of the local groups still exist, but the overall coordination among them is now lacking.

Declarations of Juchitán and of San Blas

The most visible manifestations of the attitude of many fishing people and some national and international organizations toward shrimp farming in Mexico are the Declaration of Juchitán, Oaxaca (issued on November 27, 1999); and the Declaration of San Blas for the Defense of the Mangroves (issued on May 7, 2000). These meetings resulted from a previous forum of national and international environmental organizations held in Choluteca, Honduras, which created in the Declaration of Choluteca. In this Declaration, 21 NGOs from Latin America, India, the US, and Sweden called for a global moratorium on new shrimp farm construction. The Oaxaca and San Blas meetings included representatives from a variety of Mexican organizations, along with a few individuals from other countries.[17]

The declarations state that the groups are opposed to industrial shrimp farming because "it threatens the immediate environment by destroying wetlands, mangrove forests, and the natural, environmental, and social future of fishing communities." The groups did declare their support for "…aquaculture actions where minimum infrastructure, harmonic with the environment, and from gradual character predominate, which allow a transition from traditional fisheries to integral cultures by respecting the nature of ecosystems and always with the **participation** of social organizations" (Declaration of San Blas 2000). The Declaration of Juchitán goes on to outline recommendations for methodology, research, technical assistance, financing, and legislation.

The meeting in San Blas was prompted by the major problems faced by this coastal zone. Among the threats listed by the delegates who attended: erosion caused by deforestation, the sedimentation of the Rey Estuary, changes in hydrology because of the construction of the San Blas-Guadalupe Victoria road, increased demographic growth, improper fishing methods, and the shrimp industry. Special attention was devoted to the problems of mangrove destruction and decline in fisheries that have been caused by the reported 4,000 ha of shrimp ponds in the municipality. The shrimp mega-project Acuanova came in for special criticism.

Conclusions

During the last decade, aquaculture in Mexico has flourished. This growth in the number of farms and production levels has been accompanied by an equally impressive increase in the number of organizations concerned with the sector. The government sector has been reorganized so that fisheries and aquaculture are included within a broader ministry governing the environment and natural resources. The number of NGOs focused on environmental issues has also grown, and some of these have worked on aquacultural topics. Organizations of producers are in their infancy but can be expected to grow in size and importance.

It must be remembered that the main development, regulatory, and enforcement organization–SEMARNAP–is of recent origin. It includes the old (and powerful) "development functions" and ties to commodity producers in fisheries and forestry, plus the powerful National Water Commission. It also includes regulatory bodies from the Ministry of Urban Development and Ecology, along with the sanitation office from the Ministry of Health.

This contradiction (and imbalance in power and money) between development interests on the one hand, and regulation and enforcement on the other, are still being overcome within SEMARNAP. Given the enormity of the task of integrating these functions effectively, substantial progress has been made. A

[17] Copies of the Declarations of Juchitán and San Blas can be found at the web site http://www.pitt.edu/~brdewalt/project

reasonable structure of legal requirements, regulations, and standards exists. Enforcement is still a problem but appears to be getting better.

Within the directorate of aquaculture, there are now individuals in place who are sympathetic to and capable of handling issues related to environmental protection and monitoring. In general, the aquaculture directorate seems to be moving in a positive direction even though it is still not adequately staffed in comparison with other parts of the department. Greater coordination between the aquaculture directorate and the National Institute of Ecology is helping speed the overall assessment of projects. SEMARNAP evaluates the financial and technical aspects, while INE evaluates the environmental aspects. The development of a National Diagnostic Program for Coastal Ecosystems that will be tested in Sinaloa is a positive step forward. The land use planning documents now in process for seven states are also a positive development.

The number of universities and research institutes involved with aquaculture research and technical assistance is very impressive. These universities and centers are working with the various levels of government, with private and cooperative/ejido sector producers, and with NGOs. Researchers with impressive international credentials are engaged in both basic and applied research related to shrimp aquaculture. While further coordination of these efforts is desirable, especially in water quality monitoring and land use planning, great potential exists. As the universities develop better and more effective courses of study on aquaculture, the professional competence of shrimp farm operators and managers will also improve.

Mexico's tradition of peasant unions is being transformed into producer associations that have considerable potential for improving aquacultural practices. Several variants of these unions or cooperatives now exist in northwest Mexico, ranging from buying cooperatives to unions that control every aspect of aquacultural production. As the organizations are consolidated, they are beginning to forge common solutions to address problems of water supply, wastewater disposal, disease prevention, and availability of financing.

Compared with other countries, Mexico has many NGOs. Many of the major global environmental organizations have a presence in Mexico, and local environmental organizations exist in several regions. Although a number of these organizations met in Juchitán, Oaxaca, and in San Blas, Nayarít, and produced declarations on aquaculture (follow-ups to the Choluteca Declaration), there has been relatively little systematic opposition to shrimp farming in the country. For the major NGOs, other industries and issues have a higher priority than does shrimp aquaculture. This probably reflects the relatively benign effects of aquaculture on coastal Mexico to this point. Some local opposition to aquaculture megaprojects has been mobilized and has been effective. Greenpeace Mexico has been involved in some of these battles.

A project being led by CI in Sinaloa is a very positive development. This effort aims to bring together the various stakeholders with interests in one of the most important lagoon systems in the state to try to come up with common natural resource protection strategies. As the next chapter will show, such agreement is of critical importance for the further development of aquaculture in Mexico.

Recommendations

Introduction

This generally positive report on the evolution of shrimp aquaculture in Mexico indicates that much has been accomplished in the government, NGO, academic and private sectors, and that the industry has developed without widespread ecological destruction. In order to build on these accomplishments, several measures can and should be taken so that shrimp aquaculture can become an economically, socially and ecologically sustainable industry for Mexico.

Establish an Effective Farm-Level Monitoring System

The establishment of an effective farm-level monitoring system is important for several reasons. Government agencies need to know where farms are located, what their level of infrastructure is, who owns them, and how they are being managed. With this basic cadastral information, the government sector can more adequately establish taxation systems or user fees (e.g. for water and land use), create incentive schemes (e.g. for water treatment), better understand the needs for technical assistance or technological development, and monitor how production occurs and whether it might affect other users (e.g., where runoff goes and its nutrient loading, where wild or hatchery PL is being used and whether disease outbreaks occur).

The National Diagnostic Program for Coastal Ecosystems (PNDEC) being developed for Sinaloa is a positive advance; it must be completed and eventually applied to other states. It should be accompanied by the development of geo-referenced maps of the kind done by Ruiz Luna and Hernández Cornejo (1999). Coordination of the government sector with research institutes and universities that have the capabilities to establish a farm level monitoring system could benefit both.

Establish an Effective Coastal Ecosystem Monitoring Program

The establishment of an effective coastal ecosystem-monitoring program is obviously a high priority. The PNDEC provides a start in determining how shrimp aquaculture may be affecting coastal ecosystems, but there are many other actors and influences that must also be taken into account. The number of different institutions that are already doing some monitoring of coastal areas is quite impressive. A very high priority must be put on bringing these institutions together to establish a coordinated monitoring system that is based on GIS technology, that includes a shared strategy for sampling locations, and that agrees to use a minimum set of key indicators. The UIB of ITESM in Guaymas may be the most appropriate institution to lead such a coordinated effort.

Establishing a GIS for all of the major coastal ecosystems of Mexico would enable monitoring of mangroves; would show how bays, estuaries and lagoons are being altered by natural and human forces; and would support the land use planning systems being developed. The GIS could also be used to develop a sampling frame for water quality monitoring sites. If it were linked with regularly updated data on fish and shrimp catches, the system could also be used to monitor changes in natural resource distribution over time.

Charge Producer Fees to Fund an Adequate Planning, Monitoring, and Enforcement System

Shrimp aquaculture can be an extraordinarily profitable business. Government can and should charge reasonable fees that will enable it to recoup some of the costs of an adequate planning and zoning system, to monitor the effects of shrimp aquaculture, and to enforce norms and regulations. Although producers are likely to resist paying such fees initially, in the long term such measures should result in a more sustainable industry. It is in everyone’s interests to maintain the quality of water, to keep the density of

operations at a level that minimizes the risks of disease, and to reduce or avoid impinging on the rights of other stakeholders in the regions where shrimp aquaculture develops.

Provide Incentives for Institutional Cooperation

Mexico has an impressive infrastructure of research institutes, centers, and universities, with many investigators already conducting research related to shrimp aquaculture. SEMARNAP has developed joint relationships with some institutions, and CONACYT encourages applied research through its grant programs. Whenever possible, these and other institutions should encourage collaboration among researchers. As the prior two points suggest, while numerous institutions are doing work on farm level and ecosystem monitoring, this work is less useful than it could be because of the lack of coordination among researchers.

Ensure that Investment in Cooperative/Ejido Sector Aquaculture Continues

Because the cooperative/ejido sector still produces approximately half of the shrimp from aquaculture in Mexico, this industry can play an important social development role. Government agencies, government and private banks, and conservation-oriented NGOs should continue to work intensively with the cooperative/ejido sector to help them improve their operations (Technical, economic and ecological aspects). The cooperative/ejido sector aquaculture parks have been successful. Further study is needed about how and why they have succeeded, and the models should be extended to other areas of the country.

Create Incentives for Further Development of Aquaculture Parks and Producer Associations

There is great interest in aquaculture parks and producer associations in both the private and cooperative/ejido sector. Development of a common infrastructure, joint purchases of inputs, and coordinated production and marketing of the product can benefit all parties. Costs can be reduced substantially, profits increased, and the ecological effects of the shrimp farms can be reduced and/or mitigated.

While cooperation is often difficult to achieve, the government may be able to offer tax incentives, reduce resource use charges, or tie permits to farms participating in parks or producer associations, to stimulate further cooperation.

Provide Incentives to Encourage Farms and Hatcheries to Adopt More Closed Systems

Disease problems have made hatchery owners in particular interested in developing more closed systems, for example raising their own broodstock, trying to recycle water whenever possible, and taking every measure they can to reduce the interaction of their operations with the world outside the hatchery. So far, such efforts have been seen as a means to protect themselves from diseases and other problems rather than a way to reduce their impacts on the natural environment.

Some farms are now interested in adopting more closed systems as another means of protecting their investments from problems that might arise outside their farms. Most are already purchasing hatchery-raised PL, and some are recycling water. The government may be able to speed these shifts by creating incentives (or enforcing disincentives) for producers. Charging water use fees or charging fees for dumping wastewater into bays and lagoons, for example, would encourage farms to develop more closed systems. These changes may eventually lead to greater vertical integration of the industry as farmers produce more of their own inputs (e.g. feed, PL) and do more of their own processing.

Disease problems are the greatest immediate threat to a sustainable shrimp aquaculture industry in Mexico. Reducing the threats from disease will require continued government regulation of PL

production, handling, and transfer; the development and maintenance of healthy ponds by producers; and improved understanding and research in shrimp genetics by hatchery owners.

Develop NGO Competence and Concern Regarding the Aquaculture Sector

NGOs can play a positive role in monitoring the aquaculture industry and in helping the industry to be more socially and ecologically responsible. Neither local, national and international NGOs have been very active thus far in Mexico, though some have set good examples. The role of Ocean Trust in working with private sector farms to plant and use mangrove in treating wastewater in Tamaulipas is one such effort. CI is developing a project in Sinaloa to encourage stakeholders around a lagoon system to develop common solutions to problems. Greenpeace has taken a strong activist role when mangrove destruction has been alleged and when protected natural areas are threatened.

Support Timely and Peaceful Resolution of Land/Sea Tenure Disputes

It is apparent that one of the major difficulties facing the development of the industry is conflict over property rights. In Mexico, resolution of these kinds of disputes tends to be slow, often fraught with allegations of abuses by the powerful. Such disputes are likely to become violent. ZOFEMAT and SEMARNAP need to work with the courts to establish a more effective system for dealing with these conflicts.

Invest in Improved Educational and Research Systems

We have cited the important role that the ITESM–Guaymas program in Biochemical Engineering played in educating many of the individuals now prominent in the shrimp farming industry in Mexico. It is unfortunate that this program was closed. Other institutions, including the state universities of Sonora and Sinaloa and CIBNOR in Baja California Sur, have established programs that are partially meeting the needs for trained shrimp farming researchers and technicians. Further investigation is required to determine the strengths and weaknesses of these programs, but they seem primarily focused on the physical principles of oceanography, aquaculture, and animal nutrition. Strengthening some of these programs to incorporate more ecology, coastal zone management, and integrated rural development content would be of great use in the future, as Mexico grapples with issues of sustainable development.

A special plea must be made to social science educational programs in Mexico to focus more research and teaching on issues related to policies affecting coastal zone populations. Although Mexico now has a large number of anthropologists and sociologists, including a few who focus on fishing communities, there is a paucity of individuals who are knowledgeable about or interested in the problems of aquacultural development and its effects on local communities. As this report has shown, resource conflicts among shrimp farmers, fishing communities, tourism developers, hunters, farmers, conservationists, and other groups are already quite severe in coastal regions and are likely to grow worse in the near future. Resolving these conflicts will require sociocultural understanding and skills that are currently in scarce supply in Mexico.

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Appendix A: Overview of Shrimp Aquaculture in Various States

The overall panorama of shrimp farming in Mexico masks considerable variation among the different states. As a well-known text of a generation ago hinted in its title, there are "Many Mexicos." Eventually, as the number of farms increases, several of the states in Mexico will easily surpass most of the countries of Central and South America in both area and shrimp production. This appendix covers states in which shrimp aquaculture production is now occurring, as well as the circumstances in other states that have great potential for future aquacultural activities.

Sonora

The origins of shrimp aquaculture in Mexico date from the 1970s when an agreement was signed between CICTUS and the University of Arizona. During this early period, Coca-Cola™ of Mexico also contributed some money to the joint venture. Its chairman reputedly thought that there was great potential to sell farm-raised shrimp to McDonald's. Eventually, Coca-Cola withdrew from the enterprise.

Under the agreement, an experimental farm that continues functioning to this day as a part of the University of Sonora was constructed in Puerto Peñasco. The first experiments were done with blue shrimp (*Penaeus stylirostris*) using intensive methods. After good results were obtained, CICTUS began experiments at its Kino Experiment Station, this time using extensive and semi-intensive methods. Production rates of .77–.81 kg/m^2 were obtained in rudimentary tanks of 200m^2 (Garmendia-Nuñez, 1997). Based on these experiments, and the success of shrimp farming in Ecuador, Panama, and other countries, a few private producers in Sinaloa began shrimp aquaculture farms in the early 1980s.

Promotion of shrimp farming in Sonora did not begin until the end of the 1980s. The success of commercial agriculture in the state had created considerable demands from landless people for access to land. The state government was under significant pressure, as at least 16,000 people were demanding land. Because the government could not or would not expropriate and redistribute land, the only lands available were the largely sterile soils along the coast. The government began promoting aquaculture as a potentially productive alternative, since these lands were unsuited to agriculture.

The Integrated Agriculture Program of Sonora (PAIS) was established in 1988; one goal was creating four shrimp aquaculture parks in the Yaqui and Mayo valleys in the southern part of the state. The objective was to use approximately 5,500 ha of lands that were otherwise of little use to create employment in the region. Construction of the infrastructure for the Siári Park began in 1989. At the same time, the state government also created the Fund for Aquaculture Development in the State of Sonora (FFAES), or Fondo de Fomento a la Acuicultura en el Estado de Sonora, to assist in the parks' development and to provide technical and administrative assistance to the ejidos.

Construction of the first parks was completed by 1991; after this, the commercial cultivation of shrimp in Sonora really began. Initial results were not especially successful. Because of Sonora's northern location, only one harvest a year was practical, and yields averaged only around 850 kg/ha. These yields were insufficient to make much progress in paying off the substantial debts incurred in building the infrastructure. Because of this, the project was restructured in 1992 to create the Administrative Council of Atanasia. The council included representatives of FFAES, Bancomer, FIRA (Trusts Instituted in Relation to Agriculture, or Fideicomisos Instituidos en Relación con la Agricultura of the Banco de México), Fomento Pesquero, Comisión Agraria Mixta, and the ejidos involved. The participation of the state government of Sonora was crucial in bringing about this agreement because it provided credit guarantees that allowed the debts to be restructured over a longer period of time. Without this timely intervention, the project would have failed after just one year of operation (Garmendia-Nuñez 1997).

With the stability afforded by restructuring the debt, the ejidos have gradually improved their production systems. During the production cycle of 1999, average yields were approximately 2500 kg/ha. The increased yields have allowed the ejidos to pay off their debt, and their increased financial security led to the majority of them leaving the FFAES in 1998. The producers have formed their own shrimp production ejido unions with the support of larger farmer unions. The two major groups are the Unión General Obrero Campesina y Popular (UGOCP) and the Unión General Obrero Campesina de México (UGOCM) [Villa-Ibarra, 1998]. The shrimp production unions contract skilled personnel to operate the farms, while the members of the ejido provide the less skilled labor needed.

Table A-1 shows the current situation of the four major cooperative/ejido sector aquaculture parks. The number of ha refers to the total land area of the operation, not to the hectares in ponds. The number of ejidos that actually have aquaculture operations is also much smaller than indicated in the table. Eventual expansion may include that many groups. However, a large number of ejido groups participate in the parks, and the number of people who have benefited has been substantial, as well.

Table A-1. The four major Cooperative/Ejido sector parks in Sonora.

Park	Location	Hectares	Ejido groups	Personal
La Atanasia	Mun de Bacum	2,257	21	813
El Tobari	Mun de Cajeme	2,086	22	750
El Siari	Mun de Etchojoa	1,172	9	437
Los Melgados	Mun de Guaymas	1,504	13	440
TOTAL		**7,019**	**65**	**2,440**

In 1999, there were 17 shrimp farms operating as part of the Unión de Ejidos Acuícolas del Sur de Sonora (part of UGOCP) in the three aquacultural parks of La Atanasia, El Tóbari, and El Siári. These farms had 1,055 ha in operation and produced 2574 MT of shrimp. Of this, 1,978 MT were exported. The 410 producers from these 17 producing communities received an average profit of about $10,200, and they were able to pay back a substantial amount of the debt owed for the construction of the parks (Castro Cossío 2000).

The good results obtained by the cooperative/ejido sector aquaculture parks have led private sector producers to begin to invest in what some people have taken to calling “pink gold” (Oro rosado). SEMARNAP reported that 47 plans for new farms or expansion of existing farms or hatcheries were being evaluated in late 1999, most for the private sector. The dynamism of the sector makes it difficult to say with precision how many private producers are operating at any specific time. In his annual report, the governor of the state, Armando López Nogales, indicated that a total of 4,500 ha of shrimp ponds in 1998 produced 8,375 MT. Although the number of hectares corresponds relatively well to SEMARNAP data, the governor reported production about 1,400 MT higher than that reported in Table 1-1. Irrespective of whether the governor’s figures (1.86 MT/ha) or SEMARNAP’s figures (1.57 MT/ha) are used, average production per hectare is higher in Sonora than in any of the other major producing states. In the aquaculture park of La Atanasia, average yields for the different ejidos ranged from 2.0 to 3.4 MT/ha.

With Sonora’s relatively cold waters and single crop cycle per year, ponds are generally stocked with post-larvae in February or March. A partial harvest or two is done in some of the aquaculture parks, but the major harvest usually occurs in November. The long cycle yields shrimp that are primarily large enough for the export market. After the harvest, ponds are dried out and preparations begin for the next cycle.

Hatchery development began quite early in Sonora. Its northern location also means that wild PL are not available during the optimum time for seeding ponds, encouraging the establishment of local hatcheries. As mentioned earlier, there are either 7 (Secretaría de Desarrollo Económico y Productividad para el Estado de Sonora 1997) or 13 hatcheries (Licón González 1999) in Sonora, depending on the source used

for the data. In part, the difference in these two figures reflects the fact that several hatcheries have been or are in the process of being established.

There are approximately 26 processing plants operating in the state of Sonora, 16 in the southern part of the state, located in Ciudad Obregon, Huatabampo, and Guaymas, while 6 others operate in Puerto Peñasco. Of these, 21 work primarily for Ocean Garden, and the other five also sometimes work for Ocean Garden on a contract basis (Ciapara, personal communication).

The success of shrimp farms has led to over-exuberance on the part of many people concerning the potential for aquaculture in the state. Licón-González (1999) reports that some individuals think that more than 100,000 additional hectares in Sonora may be used for the cultivation of shrimp. The effects that such a large production area would have make it unlikely that anything close to that number will actually be developed. Nevertheless, a boom in shrimp farm construction is occurring in Sonora, and this trend is likely to continue in the next several years.

Sinaloa

Sinaloa has an extensive coastline. One analyst has divided the coast into 16 systems extending over 157,710 ha (Contreras 1993). The southern coast has fewer lagoons and estuaries, and thus fewer protected areas that offer optimum conditions for shrimp aquaculture. The central and northern parts of the state have much more extensive lagoons, bays, and estuaries. Most notable are the ecosystems of the Bay of Santa Maria and the Bay of Ensenada de Pabellón in the center of the state.

The first shrimp farm in the north of Sinaloa began operating in 1984, near the mouth of the El Fuerte River. The siting, design, and operation of this farm were done by a Panamanian. The original effort was undertaken by a fishing cooperative (the Federación Regional de Cooperativas Pesqueras del Norte de Sinaloa), and the farm was constructed on lands rented from the Ejido Las Grullas Margen Derecha. The farm met with immediate success; within a few years the members of the ejido began to demand that they become incorporated into the cooperative. Eventually these demands led to the ejidatarios invading the farm and taking it over. The farm is still in operation, although it is now being rented to an individual who operates it as a private enterprise.

In southern Sinaloa, the first farm also was established in 1984, when a private individual obtained a concession to use federal lands. This farm has continued operating and has grown to about 200 ha.

The ponds that were constructed in these initial efforts were between 10 and 15 ha in area, with a depth of 60 to 80 centimeters. Wild post-larvae of blue shrimp (*Penaeus stylirostris*) were used to stock the ponds, using a density of about $10/m^2$.

From those initial efforts, shrimp farming in the state grew rapidly. As Table A-2 shows, production has grown from only 6 MT in 1984 to over 13,000 MT in 1998 (see also Table 1-6). Official SEMARNAP figures show 119 shrimp farms in Sinaloa, with average yields of about 1.24 MT per ha in 1998 (see Table 1-1). According to newspaper reports, however, there are closer to 300 farms, which produced over 13,000 MT of shrimp annually in 1998 and 1999 (*Noroeste*, 7 de marzo del 2000, página 7B).

Table A-2. History of Shrimp Aquaculture Production in Sinaloa

Year	Production (MT)
1984	6
1985	71
1986	88
1987	585
1988	901
1989	2,736
1990	2,884
1991	3,985
1992	6,499
1993	8,725
1994	8,610
1995	10,471
1996	7,763
1997	10,252
1998	13,484

Sources: Sexto Informe de Gobierno, 1998 (Anexo)
and SEMARNAP 1999

The appearance of the IHHNV virus after 1987 led to most producers shifting to the cultivation of white shrimp (*Penaeus vannamei*), because it was thought to be less susceptible to the pathogen (Escobedo, 1999). The appearance and spread of Taura Syndrome Virus after 1992 led to losses of 50–95% of production (Lightner 1995). Because the white shrimp is thought to be more susceptible to TSV, most producers shifted back to cultivating blue shrimp.

TSV also resulted in a rapid shift of producers from using wild post-larvae to using PL produced in hatcheries. In particular, the company Super Shrimp has met with great success in selling a blue shrimp variety that they claim is resistant to TSV, IHHN, and other pathogens. Approximately 90% of all PL used in shrimp farms in the state now come from hatcheries, almost a complete reversal from the situation at the beginning of the 1990s. In 1998, it was estimated that the 12 hatcheries in the state had the capability to produce 377 million PL per month (VI Informe de Gobierno del Ejecutivo Estatal, 1998).

A SEMARNAP official reported that there are 52 packing plants in Sinaloa, half of them located in Mazatlán (DeWalt 2000:February 1).

Nayarit

Shrimp aquaculture began in the state of Nayarit in the early 1980s. On the northern side of the Santiago River, the development of shrimp aquaculture was aided by the digging of the Cuautla Canal through a sand bar in 1975. This canal allowed greater water flow from the ocean into the Agua Brava Lagoon. With the improved water flow, several ejido communities began experimenting with building ponds. Natural tidal flows were used to fill the ponds with water and stock them with wild shrimp. Gates constructed on canals dug to the estuaries were used to control water flow. Little or no feeding was done, and yields were quite low. Some of the earliest communities to establish ponds were Pericos, Pimientillo, and Paso Hondo in the municipality of Rosamorada.

Closer to San Blas on the southern side of the Santiago River, private sector farms were established at about the same time. These operations were not much more sophisticated than those established by the ejidos. The ponds were better constructed, and use of shrimp feed was more common, but water exchange was also accomplished mainly with natural tidal processes.

Although official data from the national SEMARNAP office report only 75 shrimp farms in Nayarit, the state delegation reported 109 farms with a total of 3,062 ha of ponds in 1999 (Aguilar Tiznado, personal communication to Rosa Esthela González April 2000). Of these, 40% of the area cultivated was located in the municipality of Rosamorada, 38% in San Blas, 12% in Tecuala, and the remaining 10% in Acaponeta and Santiago Ixcuintla.

As Table A-3 shows, about 79% of the farms are operated by the cooperative/ejido sector, but they have only 25% of the area in ponds and receive only about 23% of the total shrimp production in the state. The average size of the cooperative/ejido sector farms is only about 7 ha. Yields from both private and cooperative/ejido sector farms in Sinaloa are relatively low. In 1997, production from cooperative/ejido sector farms averaged 592 kg/ha, while private farms harvested an average 631 kg/ha. One private operation–Boca Cegada de Acuanova–produced 913 MT of shrimp in 1997 (this case will be examined more closely later in the report). Removing this single farm leaves the other 20 private sector farms producing only 148 MT of shrimp during 1997. According to the data from the state SEMARNAP, 18% of total pond area was inactive during 1997.

Table A-3. Shrimp Aquaculture in Nayarit in 1997

	Number of farms	Hectares	Production
Cooperative/Ejido	81	562	333
Private Sector	21	1,680	1,061
Public Sector	1	13	-
Total	**103**	**2,275**	**1,394**

Source: SEMARNAP 1997

The extraordinarily low yields from shrimp aquaculture in Nayarit have prompted some action by the state to improve the situation. In 1998, SEPLADE began promoting the establishment of an aquaculture park in the municipality of San Blas. The park joins two existing cooperative/ejido sector and thirteen private sector farms with the one inactive public sector farm. It provides road access, electricity lines, and 16.8 miles of canals and drains constructed by the federal government. Planned second and third stages of the project would provide additional drainage and supply canals, a drainage canal that would reduce contamination from agricultural lands, and settling ponds that would treat wastewater before it enters the El Conchal estuary and the open sea.

In 1999, three hatcheries were operating in Nayarit. One of these has just opened, while the other two have been in operation for several years. There are only two packing plants. One of these (in Rosamorada) had been owned by a large cooperative but has now reportedly been taken over by Ocean Garden Products. The other packing plant is in the municipality of San Blas.

Colima

Colima is a small state on the west coast of Mexico. Unlike other areas, its coast does not have a continental shelf that is abundant in shrimp, although Colima has some estuaries and lagoons in which shrimp aquaculture might develop. As in other coastal states, property rights are unclear, and substantial conflicts have developed between private developers and the cooperative/ejido sector. For the most part, these disputes have centered around tourism, with the development of the Manzanillo resort and nearby areas. As private developers have appropriated and/or purchased land for development and altered the ecology of bays and lagoons in constructing marinas, they have inevitably come into conflict with fishing and other coastal communities (see Doyon 2000).

Thus far, the only shrimp aquaculture in the state, surprisingly, is occurring using freshwater at elevations of more than 400 m above sea level and more than 40 km from the coastline. In 1996, in Tecomán, a producer (Empresas Aquagranjas) of the langostino, *Macrobrachium rosenbergii*, began experimenting with growing *P. vannamei* in freshwater. This company has a hatchery and produces its own PL. The

technical director of the company reports that the key to success is adapting (not just acclimating) the PL to freshwater (Avila Tamayo 1998). The shrimp are produced in the same ponds that had earlier been used for langostino. Post-larvae seeding densities are between 12 and 24/m^2, survival rates are reported to be between 30 and 77%, feed conversion rates are about 1:1, harvests range between 1.0 and 1.5 MT/ha, and the disease problems that affect coastal shrimp have not appeared during the two years of production in Colima. Reportedly three producers in Colima, and others in the states of Michoacán and Guerrero, are using this technology to produce shrimp (Avila Tamayo 1998).

Tamaulipas

Shrimp farming on the east coast of Mexico is in its infancy. During the 1980s, the state and federal governments attempted to begin shrimp farming operations in Tamaulipas in the cooperative/ejido sector. These efforts were essentially failures, but by the late 1990s private investors were having some success with the industry. As Table 1 shows, SEMARNAP reported 10 farms in the state in 1998. In early 2000, state SEMARNAP officials reported 14 private farms, 2 cooperative/ejido sector farms, and a hatchery operated by the Universidad Autonoma de Tamaulipas. Neither of the cooperative/ejido sector farms had produced during 1999. There were 576 ha of ponds in the state, and farms ranged in area from 3 to 94 ha.

Most of the farms are located in the southern part of the state near Tampico, around the San Andres Lagoon. This area has warm enough water to produce two cycles per year, and there is greater access to infrastructure like roads, electricity, and markets than in other parts of Tamaulipas. Although there are extensive lagoons north of Soto La Marina, water temperatures there preclude more than one cycle per year of cultivation. The lack of infrastructure has also impeded development of farms in the northern part of the state.

The major problem reported by producers in Tamaulipas is the quality of water in the San Andres Lagoon, from which they take their water. In the past, three separate openings from the lagoon to the Gulf of Mexico provided excellent water circulation, but two of these have essentially been silted up. The result is that the water has high salinity levels (about 60 ppt), so oyster cultivation has ceased, fish populations have dropped, and the development of the shrimp industry has been impeded. An alliance of fishermen, oyster cultivators, and shrimp farmers is currently pressuring the government to dredge the lagoon entrances to improve water circulation.

Yields in Tamaulipas depend greatly on water quality. Producers reported that in years with low water salinity, they can harvest 2.5 to 3 MT/ha. In other years with high salinity, they are lucky to harvest 1 MT/ha.

The farms in Tamaulipas cultivate primarily shrimp species from the west coast of Mexico. They obtain PL mainly from hatcheries in Texas, but also from hatcheries in Sonora and Sinaloa. One producer reported that he would prefer to use hatcheries in Mexico but that, when the greater transportation costs are included, that option is more expensive than importing from Texas. Six permits are required to import PL from Texas, but producers did not indicate that this was a significant barrier for them. Producers reported that one of their biggest needs is a local hatchery.

Marketing of Tamaulipas shrimp occurs through processing plants in Tampico. The largest packing plant is Impulsora de Pescados y Mariscos, and Ocean Garden also has a facility there.

Several of the farms in the private sector have purchased their land from ejidos–not a difficult process, but relatively expensive. One producer reported paying nearly $2,000 per hectare for land but said that he expected the cost of land to increase greatly if the water quality problems in the lagoon are solved. The federal and state governments were involved in dredging operations in early 2000 to increase the size of

the lagoon openings to the Gulf of Mexico. SEMARNAP officials and producers were all predicting a substantial expansion of the shrimp industry in the state.

Yucatán

There is currently only one major shrimp aquaculture operation in the state of Yucatán. The company was started in 1994 but because of Mexico's economic crisis and other problems did not begin operations until 1997. Investors in the company include insurance and construction companies, but approximately 66% of investment funds came from the family that owns and operates the company. The farm is a very intensive operation, operating with ponds of 1.5 ha and using Pacific white shrimp (*Penaeus vannamei*). It has its own hatchery to produce PL and is engaging in genetic improvement of shrimp varieties. It recycles water, so its closed system has little influence on the environment. The company also has its own feed manufacturing facility.

In 2000, the farm had 45 ha in operation. Production in 1999 was 960 MT of shrimp, almost all of which was exported to the United States and France. The average yield was 21.33 MT/ha.

The company is very advanced technologically. It has formed a consulting company to advise other potential producers on establishing shrimp farms. Other producers may provide additional buyers for the shrimp feed and the PL it produces. Because of the current high costs of artemia from Utah, the company is also experimenting with substitutes from Russia and with a locally produced variety.

Because of its success, in early 2000 the company announced that it would invest another 80 million pesos (US$8.6 million) to construct two more farms, one in Champotón, Campeche, and the other in Dzilam, Yucatán. The plan is for each to produce another 500 MT of shrimp per year. The company also plans to invest another 10 million pesos (US$930,000) to build a packing plant (Moguel 2000).

Oaxaca

SEMARNAP reports that the principal seafood species exported from Oaxaca is shrimp. Almost all of the shrimp exported came from the high seas fishery (http://www.semarnap.gob.mx/oaxaca/index.htm) rather than from farms, however. In 1998, 573.85 MT were exported to the United States, with a value of nearly 66 million pesos ($6.1 million) 64% more than in 1993. Oaxaca also contains many lagoons, estuaries, and bays that may be suitable areas for aquaculture in the future. It is estimated that there are approximately 25,000 ha in the state where shrimp farming is possible (Santa Fonseca, personal communication).

Complicating potential aquaculture development in the state is that several different ethnic groups, including Zapotecs, Huave, Afro-Mexicans, and others, populate the coasts. There are severe conflicts within and between these ethnic groups that often take the form of disputes over rights to fishing areas within the bays and lagoons. Thus, ethnic conflict and uncertain land and sea rights will be significant obstacles to be overcome as aquaculture develops in Oaxaca.

Despite these obstacles, some initial efforts are under way to develop shrimp aquaculture. The state SEMARNAP has been assisting several communities to establish extensive shrimp farming operations. In the past, communities have often used barriers (tapas) to close off entrances to lagoons, thus trapping fish and shrimp that have entered during particularly high tides in rustic enclosures. The goal now is to begin a process in which fishing communities would increasingly move from this extractive approach to active shrimp farming. Table A-4 shows the experience of 10 communities, some of which began moving PL into ponds in 1996. Heavy rains during the past two years have affected a few of the communities; harvests have been lost when the levees surrounding the rustic ponds were breached.

Table A-4. Communities in Oaxaca beginning shrimp aquaculture

Community	Area Available	Year	Number of PL Utilized	Production (MT)
Huazantlan del Rio	93	1997	800,000	4.0
		1998	162,500	1.3
		1999	300,000	0.6
San Dionisio del Mar	19	1996	405,000	1.5
		1997	400,000	1.5
		1999	257,100	1.8
Huamucil	45.6	1997	1,800,000	0
		1998	352,100	2.5
		1999	-	-
Santa Maria del Mar	69	1996	2,015,000	4.5
		1997	6,500,000	2.3
		1998	437,500	3.5
		1999	-	-
San Francisco del Mar Pueblo Nuevo	160	1998	600,000	3.0
San Mateo del Mar	22	1998	-	-
		1999	-	-
Pesqueria Trejo	66.9	1998	400,000	2.0
		1999	700,000	0*
Pesqueria Conchalito	80.2	1998	1,000,000	7.0
		1999	1,600,000	13.0
Pesqueria Salinas	97.4	1998	2,000,000	9.0
		1999	2,000,000	14.0
Colonia Guadalupe Victoria	49	1998	12,000,000	10.0
		1999	860,000	0*
TOTAL	**700.8**		**23,789,200**	**81.5**

*These communities lost their harvest when heavy rains caused the levees to be breached.
Sources: SEMARNAP – Oaxaca 2000a, 2000b.

The goal of this SEMARNAP-supported project is for the communities to eventually produce about 300 kg/ha. Wild *Penaeus vannamei* PL will be stocked at a density of 6 per square meter, with an average mortality of about 50%. The production cycle will last one year, with the shrimp achieving an average size of 10 grams (SEMARNAP–Oaxaca 2000a, 2000b).

SEMARNAP has been providing technical assistance to these communities, as well as helping them to acquire the necessary permits to operate legally. One permit provides approval to utilize the federal maritime zone to build the ponds. Each community also had to prepare (and have approved) an environmental impact statement. Finally, a permit is required to gather shrimp post-larvae for seeding in ponds. In 1999, for the first time, the SEMARNAP delegation in Oaxaca issued 11 authorizations for the collection and seeding of shrimp PL in these extensive systems. SEMARNAP is working with four Zapotec and seven Huave communities (Anta, personal communication).

A Committee for the Evaluation and Selection of State Aquaculture Projects was also formed in 1999, including the representatives of the State Fisheries Council, the Regional Delegation of CONACYT (Mexico's National Science and Technology Foundation), the National Institute of Fisheries, and SEMARNAP. Among the purposes of this committee promoting research studies that will help develop technology and planning for improving shrimp cultivation in the state. Using resources from a World Bank loan, 590,000 pesos ($54,870) were used for specialized studies of ecological planning related to aquaculture and fisheries along the Isthmus of Tehuantepec, and a training program for shrimp producers of the Huave and Mar Muerto areas (http://www.semarnap.gob.mx/oaxaca/index. htm).

Chiapas

The coastal lagoons, bays, and estuaries of the Chiapas coast comprise an area of approximately 76,000 ha of productive but fragile resources. The important biosphere reserve of La Encrucijada contains the best-conserved mangrove areas in the municipalities of Pijijiapan, Mapastepec, Acapetahua and Villa Comaltitlan. The state SEMARNAP delegation reported that in 1998, it invested substantially in projects to give an impetus to shrimp cultivation. The investments included:

Development of a 600-ha shrimp aquaculture park on Mar Muerto	64.5 million pesos
A laboratory to promote mariculture	2.5 million pesos
An aquacultural health and pathology laboratory	2.5 million pesos

Assisting with 10 private semi-intensive and intensive shrimp operations
Assisting with 14 extensive shrimp operations

The stated goal of these projects was to develop 1,155 ha of extensive cultivation and another 1,064 ha of semi-intensive or intensive operations. If these projects were successful, then shrimp production in Chiapas would go from 500 MT per year to 1,500 MT per year (http://www.semarnap.gob.mx/ chiapas/).

There are a few private sector farms operating in Chiapas near Pijijiapan. These farms were affected by the hurricane that hit the state a few years ago, and it is probably for this reason that they were not listed in SEMARNAP's data for 1998.

Appendix B: Web sites

BANCOMEXT – http://mexico.businessline.gob.mx/

Banco de México – http://www.banxico.org.mx/

Centro de Investigación en Alimentación y Desarrollo, A.C. – http://victoria.ciad.mx/index.htm

CIBNOR – http://www.cibnor.org/icibhome.html

Coastal Resources Center of the University of Rhode Island (Latin American Program) – http://www.crc.uri.edu/field/lac/index.html

Conservation International – http://www.conservation.org/

Conservation International Gulf of California program home page – http://www.conservation.org/web/fieldact/regions/mcareg/Gulfcal.htm

El Financiero – www.elfinanciero.com.mx/

FOCIR (aquaculture program) – www.focir.gob.mex/prog_acu.htm

Global Aquaculture Alliance – http://www.gaalliance.org/

Greenpeace Mexico – http://www.greenpeace.org/~mexico/

LINKS – http://victoria.ciad.mx/taoa/shrimp/links1.htm (Links containing information related to aquaculture, marine biotechnology, publications, services and data bases)

Panorama Acuícola – http://www.sea-world.com/panoramacuicola/

Secretaría del Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP) – http://www.semarnap.gob.mx/

Shrimp Farming Home Page – http://www.shrimpfarming.org/

Unidad de Información Biogeográfica del Centro para la Conservación y Aprovechamiento de los Recursos Naturales, Instituto Tecnológico y de Estudios Superiores de Monterrey, Campus Guaymas – http://uib.gym.itesm.mx/hs/

World Wildlife Fund – http://www.worldwildlife.org/

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