WHITE SPOT SYNDROME VIRUS

THE ECONOMIC, ENVIRONMENTAL AND TECHNICAL IMPLICATIONS ON THE DEVELOPMENT OF LATIN AMERICAN SHRIMP FARMING

Master of Arts in Law and Diplomacy Thesis

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ABSTRACT

In the past twenty years, export oriented shrimp farming in Latin America and throughout the world has boomed—diversifying national trade, while providing a much needed boost to poor coastal economies. The industry is praised from within, while emphatically lambasted by many international activists who cite the destruction of mangrove ecosystems and coastal fisheries, gains in the hands of a few and politically corrupt structures guiding an ultimately unsustainable extractive industry. In 1999, the White Spot Syndrome Virus (WSSV) epizootic quickly spread through nine Pacific coast Latin American countries, costing billions of dollars in regional export earnings of which most of the economies have yet to recover. However, in all countries, university scientists, farm owners and technicians, NGOs and international development agencies are working on solution to survive with WSSV. This investigation first seeks to account for the short term devastation of the disease, and then examines its long-term effects on the sustainability, both ecologically and economically, of the Latin American shrimp farming industry. Sustainability is examined by analysis of the economic, technical, legal and environmental changes that can be attributed to the disease shock. Data and research was gathered through government and NGO reports and analysis, industry publications and numerous interviews through coastal Peru, Ecuador and Mexico. The experiences of these three countries are explored as representative case studies of the region. It is concluded that on average the disease has left the industry, though crippled, an ecologically more sound, legally more controlled, politically more integrated and overall more sustainable structure than in the past. The massive profits wrought from the low control and hastily planned boom days of the 1980s and 1990s are those of the past. The WSSV has accelerated existing industry trends towards efficiency and scientific understanding to increase profits and survive future challenges while simultaneously decreasing negative externalities.

INTRODUCTION

For the first time in recorded history, world fisheries catches have reached a plateau and perhaps even declined.[1] Until recent years, increased fishing pressure on the world's "limitless" oceans meant increased production. *Give a man a fish; you have fed him for a day. Teach a man to fish he'll eat for a lifetime.* However, talk to fishers anywhere from Gloucester, Massachusetts to Sulawesi, Indonesia and find that the above proverb is true no longer. Since the 1950s, industrial scale fishing has helped increase four-fold both capture fisheries production and pressure on its oceanic support system. The recent crashes in commercial fisheries stocks have shifted world attention to aquaculture as a renewed source for the continued promise of our ancient guiding maxim. Since 1970, aquaculture production has increased at nearly 10% per year and currently supplies 27.3% of global fish supply.[2] The Food and Agriculture Organization (FAO) projects that by 2030 nearly half of global fish production will be accounted for by aquaculture. As the world's increasing demand transforms the way it thinks about the ocean, and the sustenance it renders, policy makers must be fully informed of all implications to steer the proper course.

Marine biodiversity, increasingly threatened by pressure from fishing vessels world-wide, now faces its next challenger. In some fisheries, aquaculture does indeed hold promise to lessen net impact on global stocks. However, certain species groups, including shrimp, have been identified by fishers, governments and environmental organizations as

[1] This is highly dependent on the accuracy of statistics in China; without China, world production has dropped, with China it has increased. There is much skepticism regarding the accuracy of China's figures.
[2] FAO. 2002. *The State of World Fisheries and Aquaculture.* Accessed from: http://www.fao.org/sof/sofia/index_en.htm

increasingly problematic due to the negative externalities involved in their production.[3] From 1970 until 2000 shrimp capture grew at a consistent rate of 3.8% a year, but in 2001 began to show signs of faltering as production decreased for the first time in over a decade. On the other hand, Farmed shrimp production increased at a pace nearly five times that—and currently constitutes over one quarter of global shrimp production.[4] Driven by the high prices this luxury seafood demands in the United States, Europe and Japan, shrimp production is also the most valuable marine product traded in world markets accounting for $7.9 Billion in 2001[5], though only constituting roughly 3% of over all volume (4.2 million tons).[6] The high value and increasing demand for shrimp in developed countries is likely to further shift supply of production to lower cost, less variable and risk-adverse shrimp farms versus wild stocks. As a result many international aid agencies and developing country governments seeking foreign exchange have and continue to devote large sums of money towards shrimp aquaculture development. The World Bank has already allocated over one billion dollars to shrimp farming projects throughout the tropical developing countries of the world.[7]

In the past decade, disease incidences in shrimp farms world-wide have been on the rise. From 1999 - 2000 Ecuador alone lost over $1 Billion in export earnings from an disease of Asian origin known as the White Spot Syndrome Virus (WSSV). Diseases pose a real

[3] The Audubon has placed shrimp in the "do not eat" category of it's *Seafood Wallet Card*
[4] Tacon, Albert G.J. "Thematic Overview of Feeds and Feed Management Practices in Shrimp Aquaculture." World Bank, Network of Aquaculture Centres in Asia-Pacific, WWF, FAO and the UN Consortium Program on Shrimp Farming and the Environment. (2002) Accessed from: www.enaca.org/shrimp
[5] FAO. 2003. FishStat Plus: Universal software for fishery statistical time series. http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp
[6] Tacon et. al.
[7] World Bank. 1998. *Shrimp Farming and the Environment: Can Shrimp Farming Be Undertaken Sustainably?* Accessed from: http://www.enaca.org/Shrimp/Publications/WBfinal.pdf

and immanent threat to the continued development of the shrimp farming industry. In the midst of this crisis, patterns are beginning to emerge—countries with better environmental records and better regulated industries are surviving the disease with less aggregate economic impact and efforts made to address disease are also increasingly in line with appeals for environmental sustainability in the industry.

This paper will seek to address the changes taking place as a result of the Latin American outbreak of WSSV in 1999. Case studies from Ecuador, Peru and Mexico are used to account first for economic losses, then the changes that were put in place to address the problem. Analysis focuses first on the net environmental impact of the disease, and second on establishing causation for the markedly different experiences with the WSSV virus throughout the case studies. It is suggested by this paper that while the WSSV outbreak created short-term economic losses, in the long run it has induced technical, political and legal changes that have led to overall increase in the environmental sustainability of the Latin American industry.

History and Development of Shrimp Farming

While traditional shrimp farming has been practiced on a subsistence level for centuries in coastal Asia, only in the past two decades has the practice been industrialized for economically significant output. Current shrimp aquaculture practices emerged from 1930s experiments on spawning the kuruma shrimp (*Panaeus japonicus)* in captivity by Motosaku Fujinaga in Japan. By 1968 the economic potential of shrimp aquaculture was beginning to be realized as there were "in the tropics vast unused mangrove regions, some of which could be turned into pond complexes."[8] The techniques soon crossed the Sea of Japan, eliminated nearly five percent of the world's mangrove resources, while driving positive accumulation of foreign exchange and development; first for East Asian, then Latin American economies. As the industry expanded to over fifty countries, it uniquely reinvented itself many times, creating a vast and diverse range of culture practices and techniques. Depending on a variety of region specific conditions, including infrastructure development, socio-economic circumstances and investment capital available, farming was pursued in three relatively distinct levels of intensity: Extensive, Semi-intensive and Intensive.

Extensive, or "Traditional," aquaculture is generally pursued in poorer regions, with low cost land, lax government control on marine resource commons and a decentralized structure of shrimp farmers. Water, food and waste recycling is regulated by tidal flow, survival rates are low, and labor, capital and energy costs are minimal. The most significant externalities of extensive farms are the destruction of mangrove forests they displace. Although estimates vary, one study estimates that 59% of shrimp farms world-wide are extensive.[9] Semi-intensive farms involve an increased amount of labor and capital input costs. Water is exchanged at a much higher rate with pumps, while food, fertilizers, hormones, and other aquaculture chemicals are added to the ponds to increase productivity. While shrimp production is significantly increased by a factor of ten and land utilization is significantly decreased, new threats to sustainability are raised including chemical additions, heightened disease prevalence, introduced exotic species

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[8] Bardach, John E. "Aquaculture." *Science*.161. (1968) 1098 – 1106
[9] World Bank et. al.

and increased waste output. Semi-intensive production accounts for over a quarter of the world's shrimp farms.[10] Finally, intensive farms again increase production by another factor of ten—by aerating water, optimizing feeding procedures and lining ponds with plastic to prevent introduction of unwanted materials. State of the art water quality analysis is utilized by highly trained professionals incurring even higher labor and capital costs. Again, the same problems introduced with semi-intensive systems are elevated, while land area is again decreased. Roughly a tenth of the world's shrimp farms are categorized as intensive. Although many less farms and a much smaller amount of land area is consumed by semi-intensive and intensive farming, the two practices produce well over eighty percent of the world product.[11] Though not yet commercially viable, experimental "super-intensive" systems are currently being investigated to further increase production by another factor of ten, while not depending on any water input from natural systems and utilizing specific disease resilient shrimp.[12]

There are generally two methods pursued for 'seeding' farms with post-larval shrimp. The first, which is practiced by all extensive and many semi-intensive farms is the extraction of post-larval shrimp from neighboring mangroves and coastal waters. While this is low cost, it exerts a tremendous pressure on local ecosystems and subjects shrimp to any disease that may be carried in the local stock. Alternatively, some semi-intensive and nearly all intensive farms rely on laboratory raised post-larvae. Laboratories raise disease-free and healthy post-larval shrimp that are independent from local circumstances and sell them to producers for a higher cost.

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[10] Tacon et al.
[11] Ibid.
[12] World Bank et. al.

Growth in the shrimp-farming sector has resulted primarily from either an increase in semi-intensive and intensive farms being seeded from laboratories and fed commercially produced feed or increased land conversion and extensification.

The Alternative: Shrimp Trawling

Absent aquaculture, increasing global demand would simply result in a further intensification of destructive trawling operations. Shrimp trawlers have made enemies on many sides ranging from bans on imports to the United States to a declaration by the Environmental Justice Foundation that shrimp trawling is "one of the most wasteful, destructive and inequitable ways to exploit the oceans."[13] Two destructive elements of the practice make it arguably the worst in the fishing industry. First, by-catch levels in the tropics have frequently been documented at over twenty times the amount of shrimp biomass collected.[14] Second, the nets themselves drag along the bottom, destroying extremely biodiverse coastal benthic ecosystems, including coral reefs.

The by-catch issue has received a great deal of world attention due to the unprecedented massacre of charismatic and endangered species unintentionally caught in trawlers' nets. Over a half million sea turtles used to nest on the beaches of Gahimatha, India, but no longer return. As many as 50,000 Olive Ridley sea turtles are estimated to be killed

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13 Aish, Annebelle, Trent, Steve and Williams, Juliette. 2003. *Squandering the Seas: How shrimp trawling is threatening ecological integrity and food security around the world.*
Environmental Justice Foundation.
Accessed from: http://www.ejfoundation.org/pdfs/squandering_the_seas.pdf
14 Ibid.

offshore India each year drowned in shrimp-trawling nets.[15] All seven species of sea turtles are listed on the IUCN redlist as endangered and data points to their populations in continuous decline world-wide. In 1996, the United States began to ban shrimp imports that were taken without Turtle Exclusion Devices (TEDs).[16] Although modifications were made to their ban, significant portions were upheld by the WTO and TEDs have begun to be widespread throughout many exporting countries. Seahorses also rely on shallow coastal ecosystems and have in the past year been placed on the CITES for their endangered status. While their trade has been made illegal, there is no way to exclude this similar sized organism from the shrimp nets and trawling has been blamed for much of their decline. These are but two species groups amongst thousands that reside in the same ecosystem as shrimp and risk being threatened to extinction by trawling pressure.

Sylvia Earle states, "Trawling is like bulldozing a forest to catch songbirds."[17] Proof of the decline of marine biodiversity due to trawling is evident in the coastal politics of Indonesia. In 1980, the Indonesian government was forced to introduce an all-out ban on trawlers, still in force today, as local artisan fishers were literally taking up arms to prevent the industrial scale fishers from entering their waters, due to the massive degradation of the coastal ecosystems.[18] Unfortunately, ten years later, artisan fishers managed to create the same adverse effects by increasing their own pressures. In the Gulf of Fonseca region, El Salvador and Nicaragua are this month about to impose an all out ban on shrimp fishing in an effort to restore a devastated ecosystem. Finally, fishing

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[15] Fugazzoto, Peter. "Recipe for Extinction." *Earth Island Journal* 14(3) (1999)
[16] Schaffer, Gregory. "United States-Import Prohibition of Certain Shrimp and Shrimp Products." WTO Doc. WT/DS58/AB/R. *American Journal of International Law.* 93 (1999) 507 – 514
[17] Fugazzoto et al.
[18] Bailey, Conner. "Lessons from Indonesia's 1980 Trawler Ban." *Marine Policy.* 21(3) (1997) 225 – 235

pressure by shrimp trawlers has in many places increased as the price of shrimp is stabilized by the farming industry while the supply of wild shrimp decreases.[19] Declining biodiversity now faces ever increasing devastation of habitat by trawlers.

Negative Environmental Externalities of Shrimp Farming

Jason Clay of the World Wildlife Fund for Nature (WWF) sums up the underlying cause of the problems associated with shrimp faming—"Aquaculture in 30 years is trying to do what agriculture did in 6,000."[20] Through this substantial evolution, agriculture has gone beyond expectations and contributed a substantial net increase in the production of food on this planet. However, this net increase in food product has come at a great loss to natural ecosystems. Two central difficulties present themselves in the attainment of this goal by aquaculturalists: its current heavy reliance on the health of the surrounding ecosystem and the increased awareness surrounding the impacts of human-related endeavors on the environment. Experts on all sides agree that the long-term sustainability of aquaculture depends on its ability to provide a net increase in food production for the human species, and in order to do so, it must sufficiently maintain the naturally biodiverse systems upon which it relies.[21,22] The major negative environmental externalities emphasized in the literature are: (1) Destruction of natural habitat, (2) Organic waste, eutrophication and chemical contamination in wastewaters, (3) Introduction of exotic species, (4) Fishmeal and fish oil content in feed, and (5) Harvest of post-larvae and broodstock.

[19] Fugazzoto et al.
[20] Live interview http://www.habitatmedia.org/tran-clay.html
[21] Naylor, R., Goldburg, R., Primavera, J., Kautsky, N., Beveridge, M., Clay, J., Folke, C., Lubchenco, R., Mooney H., and M. Troell, "Effect of aquaculture on world fish supplies", *Nature*, vol. 405, June 29 2000.
[22] Global Aquaculture Alliance www.gaalliance.org

Destruction of Natural Habitat

The most publicized and sensitive negative impact of the shrimp farming industry has been the widespread cutting of mangrove forest to build ponds, mostly by extensive farmers. This practice was especially prevalent in the early years of shrimp farming as governments encouraged the transformation of a previously unusable wetland into profit. Mangrove forest, found in tropical estuaries, create some of the most productive and biodiverse ecosystems in the world. They provide a great range of services to both the human and natural systems surrounding them. Most notably, they protect seashores from long-term erosion, provide safety and food for most tropical fish species, habitat for thousands of bird species, alter climate to allow for increased rainfall in drier regions, are extremely productive sources of mollusks, crabs, small fish, wood, charcoal and shrimp. Human coastal development has stripped away nearly half of this invaluable resource for a variety of reasons, most notably: agriculture, coastal development, fuel and building material collection and shrimp aquaculture. There is a loose consensus among the many available sources that shrimp harming has contributed to the destruction of 5% of total world mangrove forest coverage, roughly a million hectares.[23,24] Although, in shrimp producing countries the percentage can be quite higher. For example, 10% of mangrove loss in Honduras is attributed to shrimp farming.[25] That said, there is no doubt that the past development of shrimp farming has contributed to a massive decrease in biodiversity

[23] Global Aquaculture Alliance et al.
[24] World Bank et al.
[25] Dewalt, Billie R. "Shrimp Aquaculture Development and the Environment: People, Mangroves and Fisheries on the Gulf of Fonseca, Honduras." *World Development,* 24(7) (1996) 1193 – 1208

on this planet. The pertinent focus for policy makers currently is how to limit further damage to, and implement restoration of mangrove ecosystems.

There is considerable disagreement on this question. Many environmental organizations (Greenpeace, EJF, Mangrove Action Network) maintain that widespread destruction of mangrove forests continues to occur and typically label shrimp farming as a major cause for this loss, without actually citing specific statistics. On the other hand, pro-industry aquaculture organizations, such as the Global Aquaculture Alliance, tend to consider the problem a past wrong that is currently being corrected by replanting operations and conservation measures. Somewhere in the middle lies the truth, although no research effort has yet been funded to fully account for annual loss of mangroves throughout the world in a scientifically accurate and consistent manner.[26] Most tropical countries have established legislation to ban mangrove clear cutting for shrimp farming, as many have found the operation profitable in the short-term, but unsustainable and resulting in a net loss in the long-run.[27] Enforcement of legal codes in developing tropical countries is very difficult due to corruption and lack of the rule of law. There is no denying that mangrove destruction continues, especially in the poorest countries. Just this past year, in Bangledesh[28] and Indonesia[29], reports have surfaced that poverty and financial crisis have driven the poor to illegally build unsustainable extensive ponds in some of the few remaining large expanses of mangrove forest on this planet. On the other hand, satellite

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[26] This would require an extensive remote sensing project, with world-wide ground-truthing of satellite data to establish cause on an annual basis, and input into a GIS for spatial analysis, with extremely high costs

[27] Nautilus Consultants. (1993) *Comparative Economics of Land Use Options in The Mangrove of North Sumatra, Indonesia*. British Overseas Development Administration. Accessed from: www.agri-aqua.ait.ac.th/AQUA/readings/JHnaca.html

[28] *Fishery Information Service*. 2002 "Shrimp Farming Threatens World's Largest Mangrove Forest" October 7, 2002. *www.fis.com*

[29] *Jakarta Post*. "Shrimp Farmers Charged With Destroying Mangrove Forests." August 12, 2002

data in Ecuador and Honduras shows recovery of mangrove forest due to replanting efforts.[30] Finally, evidence from satellite data and research in Mexico, where shrimp farmers have been careful not to displace mangrove forests, suggests that mangrove forests proximate to shrimp farms are not as robust and diverse as those further away.[31]

Two other major drivers of habitat destruction: abandonment of farms and development of seasonal lagoons, are not as focused on in the literature, but also contribute to losses in biodiversity. Shrimp farmers often abandon their lands when disease outbreak, pollution or low production threatens their profits. It is relatively easier, especially in poorer countries, to build a new farm than try to rehabilitate an old one. In the worst case scenarios, some extensive low-tech farms are abandoned every 2-4 years.[32] Abandonment accelerates habitat destruction as new farms are built and old farms are left as wastelands. Second, as pressure has risen to stop the development of mangrove forests, the mudflats, that provide seasonal lagoons, are developed nearby the mangroves. Migrating birds, seabirds and scavengers rely on the annual flooding of these flats to provide food. As shrimp farms are developed there, a whole separate ecosystem is replaced.

Organic Wastes, Eutrophication and Chemical Contamination in Wastewaters

Ecosystems not directly displaced by aquaculture infrastructure face a variety of other threats from shrimp pond effluents, exchanged as frequently as every three days by intensive ponds. This waste water directly pollutes surrounding ecosystems by altering

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[30] Global Aquaculture Alliance et. al.
[31] Paez-Osuna, Federico et al. "The Environmental Impact of Shrimp Aquaculture and the Coastal Pollution in Mexico." *Marine Pollution Bulletin* 36(1) (1998) 65-76
[32] World Bank et al.
[34] Tobey et al.

tenuous balances in the nutrient load, dissolved oxygen, organic content, turbidity and other chemical and physical factors affecting the composition of estuarine waters. Eutrophication, or elevated nutrient levels, results from the organic and fecal waste of massive densities of shrimp within the ponds. If circulation is poor outside the outfall pipe, resulting harmful algae blooms out-compete local populations and dominate marine ecosystems. However, mangrove swamps, already regions of extremely high nutrients and production, are generally well adapted to handle some shocks. Consistent research has not yet been conducted on eutrophication world-wide, but some reports do demonstrate strong evidence of its occurrence.[34] Often many pressures are present in estuarine ecosystem, including agriculture, development, sewage and waste dumps, so it is difficult to single out the shrimp farming industry from the other polluters.

Additionally, a variety of chemicals are input into shrimp ponds with indeterminate effects on the surrounding ecosystems. These include fertilizers, pesticides, herbicides, antibiotics, disinfectants, anesthetics, growth hormones, water quality treatments and feed additives. It would take a lengthy dissertation to accurately document the effects on biodiversity of every chemical used in shrimp farming, or to just determine exactly what has been put into shrimp ponds.[35] International actions by the United States[36] and European Union[37] have already begun to address this issue by banning shrimp imports containing certain antibiotics. The trade restrictions, which focus primarily on the carcinogenic chloramphenicol, currently are being debated in the WTO.

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[35] A shrimp farmer in Peru told me that he heard of other farmers putting gasoline into their ponds to prevent disease.
[36] *Financial Times Information*. "U.S. to Add Protective Measures Against Prawn Importers." January 27, 2003
[37] *Bangkok Post*. "EU Ban Unfair", March 28, 2003

Recent research has developed zero-discharge, recirculation and purification systems that recycle all nutrients through the use of filters and artificial wetlands.[38] While costly, the application of zero discharge systems could eliminate many but not all of the negative externalities resulting from the discharge of pollutants by the shrimp farming industry.[39] Other solutions to the wastewater problem involve settlement ponds that allow waste particles to settle prior to output in the natural ecosystem and water treatment plants purify wastewater output to the estuary.

Introduction of Exotic Species

Disease outbreaks, such as the Asian WSSV, now occur more often as species are transported around the world for development of a 'more productive' shrimp farming industry. The introduction of new species by aquaculture could be a major unrealized threat to regional biodiversity as alien species slowly adapt and begin to survive in foreign ecosystems. Recently, a group of South American scientists wrote *Nature* petitioning international organizations to "stop promoting technological packages using exotic species and instead help the development of culture technologies for native species…"[41] The same letter suggests several of the harmful effects that exotics can have on marine biodiversity: hybridization and competition with local species with a similar life history and food-web destruction. Globally, numerous examples demonstrate

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[38] Lin, Ying-Feng. "The potential use of constructed wetlands in a recirculating aquaculture system for shrimp culture." *Environmental Pollution* 123 (2003) 107-113
[39] Dewalt et al.
[41] Perez, Julio E. et al. "Aquaculture: Part of the Problem, Not a Solution." *Nature* 408 (2000) 514

destruction of regional biodiversity attributable to exotics.[42] Although it has not yet happened with shrimp populations, except for the viral strains they spread, the possibility will always loom as long as the industry exists.

Fishmeal and Fish Oil Content in Feed

One of the greatest debates surrounding the aquaculture industry is whether or not it will actually become a net producer of protein for the planet, or continue to deplete our ocean resources. Aquaculturists argue with data that the industry is already well on its way to this goal,[43] while naysayers have developed scientific and statistical analyses stating that the objective can never be achieved.[44] The thesis of the latter group is that the aquaculture industry ultimately depends on the ocean as a source for food and the transaction cost of catching fish to then feed farmed fish (or shrimp) only further limits what the ocean can provide for humans. In reality, the future is more uncertain. As argued by Naylor et al., "If public and private interests act jointly to reduce external costs generated by farming systems, present trends (negative) may be reversed and the net contribution of aquaculture to global fish supplies can become increasingly positive. Without this shared vision an expanded aquaculture industry poses a threat, not only to ocean fisheries, but also to itself"[45]

The key to understanding the complexity of this issue lies in the composition of the feeds used in aquaculture. Aquafeeds are industrially produced compounds that combine soy-

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[42] Zebra mussles, Kudzu etc.
[43] Global Aquaculture Alliance et al.
[44] Hannesson, Ronvaldur. "Aquaculture and Fisheries." *Marine Policy*. 27 (2003) 169 – 178
[45] Naylor, Rosamond et al.

meal, fishmeal, fish oil and various chemicals, nutrients and other additives to most efficiently nurture farmed shrimp. Fishmeal and fish oil constitute on 25-35% of these feeds, though five times that weight in live fish is required to make the dried meal. Shrimp consume twice their final body weight in dried aquafeed through a growth cycle. Some intensive farms have been able to get this ratio, called the Food Conversion Ratio (FCR) to nearly 1:1, while other farms are doing much worse. Thus, one kilogram of shrimp currently takes anywhere from two to three kilograms of wild-caught seafood for its production.[46] Clearly, this does not add net gain to global fisheries production. The results are more favorable when compared to general trophic relationships, where it is generally theorized that one organism consumes up to ten times its body mass in a life cycle. For example, FCRs for average cattle average around 7:1.[47] Additionally, feed scientists are working to reduce the amount of fish product necessary in feeds by adding other animal proteins such as waste product from land farms. The white legged shrimp (*P. vannamei*) has already been successfully harvested on feed that contains only 6% fish product, without net loss in productivity.[48] This calculates to a three fold increase in protein production from wild-caught fisheries and a definite net gain for the world's oceans. Additionally, it is important to recognize that 80% of fishmeal and fish oil production is consumed by the hog, chicken and beef producers around the world, and increases in demand by aquaculture have merely forced these producers to purchase

[46] Tacon et al.
[47] Basarab, John. "Net Feed Intake in Beef Cattle Update." *Western Forage/Beef Group*. Sept. 24, 2001. Accessed from: http://www1.agric.gov.ab.ca/$department/newslett.nsf/all/wfbg43?OpenDocument
[48] Ibid.

cheaper soy-meal, while global supply and prices for fishmeal have remained relatively the same through the growth of the shrimp farming industry.[49]

Harvest of Post-Larvae and Broodstock

The most important input to the industry is the shrimp larvae themselves. Post-larvae are harvested to 'seed' the majority of shrimp ponds, while others are seeded by the eggs from a broodstock of fertilized females in hatcheries. The best equipped operations rely on laboratory raised post-larval stock that originate from a cultured, fertile adult broodstock, now many generations removed from the natural cycle. The harvesting of post-larvae has incurred major losses to estuarine populations world-wide. Typically small scale artisan fishers will use one to three small nets and tow by hand along beaches, rivers and mangrove swamps for the post-larval stock. The nets catch many shrimp, but also everything else in the water as by-catch ratios by weight are reported as high as 300:1.[50] Such ecosystem damage has forced both Bangladesh and Ecuador to recently ban the practice.[51,52] Pressure of diseases has pushed for increased development of laboratory strains of shrimp that would breed independent from ocean stocks.

[49] Ibid.
[50] *The Independent*. "Bangladesh Shrimp Fry Collection Going Unchecked Defying Ban." March 24, 2003
[51] Lin, Ying-Feng et. al.
[52] Foreign Trade Ministry of Ecuador: Fisheries Resources Secretary. 2002 *New Ecuadorian Law Prohibiting Harvest of Wild Shrimp Larvae*. October 17, 2002

History of Global Disease Outbreaks

At the same time as environmental concerns have increased, many diseases have proliferated to threaten the shrimp farming industry. In 1989 there existed only six world-wide shrimp viruses—by 1996 the number rose to over twenty.[53] The first outbreak of viruses on a large scale hit Taiwan in 1987, when production was at 37 million pounds. By 1998, less than 1 million pounds were produced in Taiwan due to continued disease outbreaks.[54] Thus, the most important threat to the long-term sustainability of any shrimp farming economy are these epizooitcs. Patterns of disease infection and expansion accentuate the global character of the current production of farmed shrimp. Diseases that arise in one species of shrimp have quickly crossed oceans and infected other species, even human cells, in the extreme laboratory situation. The threat is very real. In the mid-1990s, it was estimated that every year, over $3 billion US dollars were lost to various diseases, stunting 40% of world-wide production.[55] The threat worsened later that decade, as Ecuador alone accounted for nearly a billion dollars in export losses due to the advent of the White Spot Syndrome Virus in 1999 and 2000. In 2000 the FAO estimated that various diseases continued to cost the shrimp farming industry world wide $3 Billion per year.[56] Figures x and x demonstrates the productivity losses resulting from five major epizootics in the most affected Asian and Latin

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[53] Hernández-Rodríguez, A., Alceste-Oliviero, C., Sanchez, R., Jory, D., Vidal, L. & Constain-Franco, L.-F. 2001. *Aquaculture development trends in Latin America and the Caribbean.* In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 317-340. NACA, Bangkok and FAO, Rome. Accessed from: http://www.fao.org/DOCREP/003/AB412E/ab412e20.htm

[54] Batker, David K. and Isabel de la Torre. 1999. *WTO: But What Are We Trading Away? Asia Pacific Environmental Exchange.* Accessed from: http://www.shrimpaction.com/WTORep.PDF

[55] Lundin, Carl Gustaf. 1995. *Global Attempts to Address Shrimp Disease.* Land Water and Natural Habitats Division. The World Bank. Accessed from: http://www.enaca.org/shrimp/Publications/ShrimpDisease.pdf

[56] Hernandez-Rodriguez, et al.

American economies. However, true estimates of the global costs of disease are most likely very low, considering the amount of economic activity that is reliant on shrimp farming. Backwards production related linkages including post-larvae breeding, construction, feed production, product distribution etc. and forwards linkages including processing and value added production all are increasingly affected by production losses on the farm. The following chapter accounts for the various impact and spread of the five major shrimp aquaculture epizootics. This section elucidates the relative importance of the WSSV outbreaks in the world and specifically Latin America, and the context in which the outbreak began in early 1999. All figures originate from the Food and Agriculture's FishStat+ database[57], unless otherwise documented.

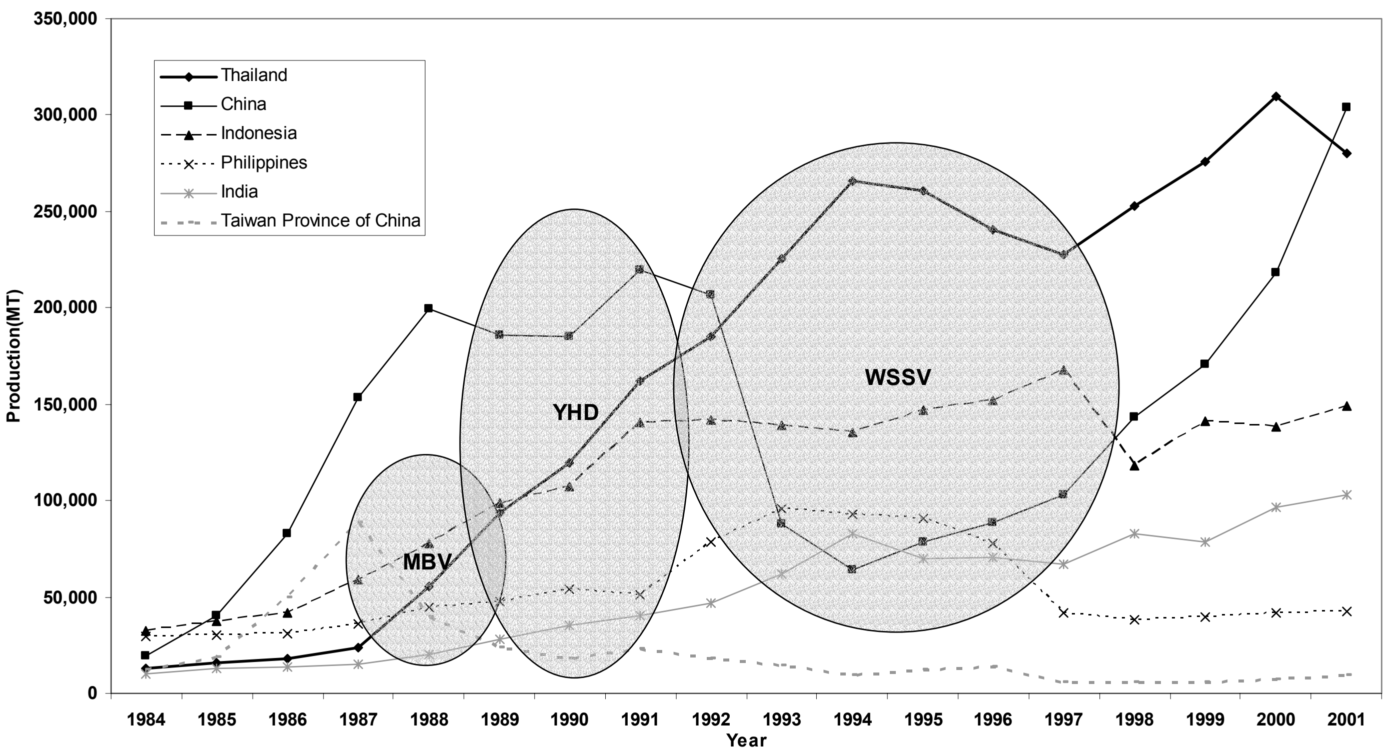

Figure 1. Asian Shrimp Production and Important Diseases. *Data Source (FISHSTAT)*

[57] FAO, 2003. *FishStat Plus* et al.

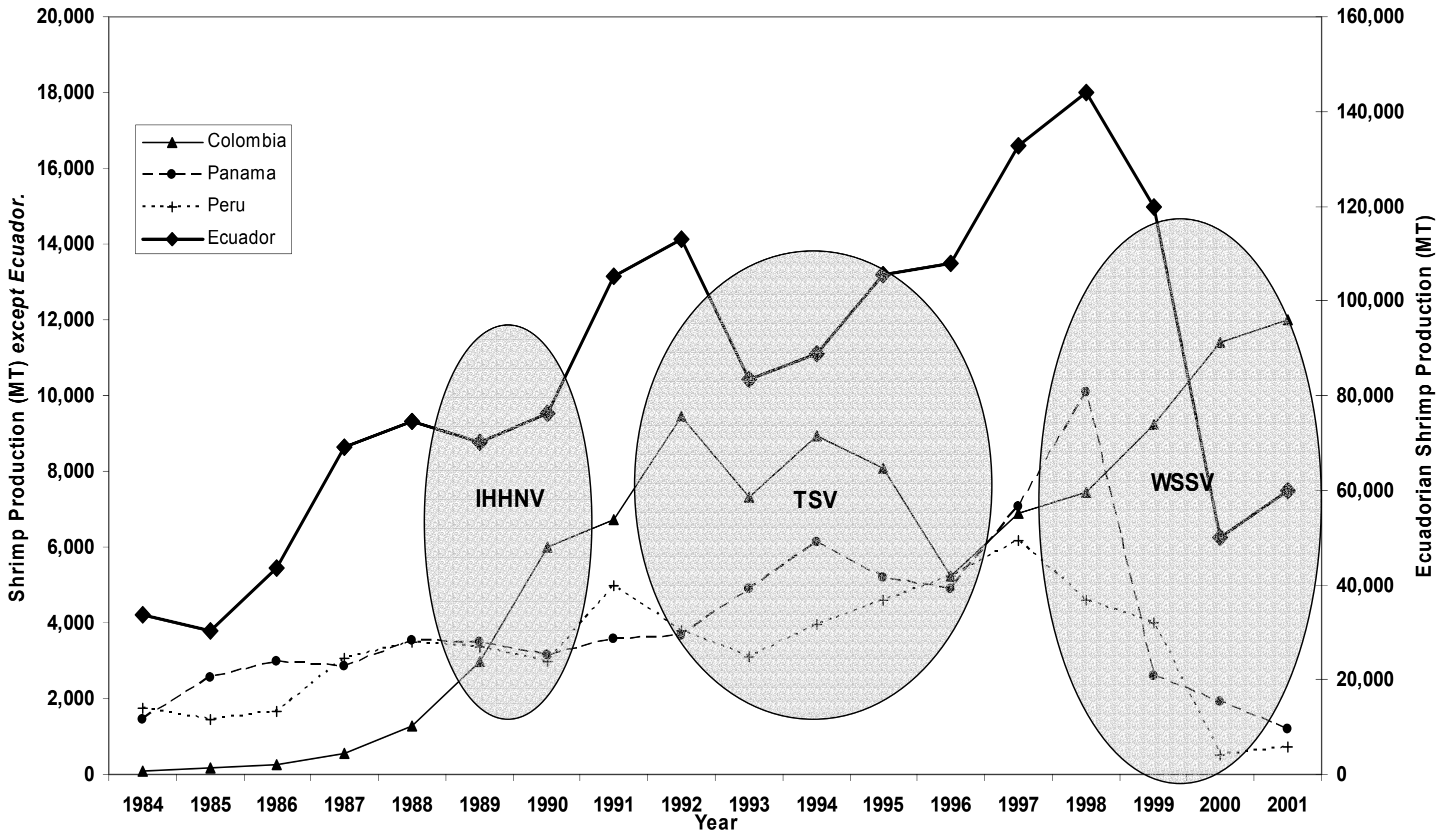

Figure 2. Latin American Shrimp Production and Important Diseases. *Data Source (FISHSTAT)*

All the diseases that are known to exist are either assumed, or have been proven, to have some low level prevalence in natural wild populations. The risks are known to be exacerbated by increased intensification and proximity of farmed shrimp. Additionally, environmental stress has been demonstrated to increase the risks of disease outbreaks. Figure 3 shows a model of shrimp aquatic disease developed by Dr. Sniezko.[58] His model includes to three adjacent spheres—the host, the environment and the pathogens themselves. When one sphere grows in importance and size, this sphere begins to

[58]Lightner, D.V. and Redman, R.M."Shrimp diseases and current diagnostic methods." *Aquaculture*, 164(1998):201-220.

intersect with the others, such that the greater intersection creates a tendency for disease. If all three spheres are to intersect, such that the environmental conditions are right, there are suitable pathogens and the population is large enough the disease will begin to spread. Wild populations tend to avoid these problems, even though all factors may be present, while aquaculture encourages them by amplifying the presence of each variable. It is the task of the shrimp farmer to keep the three adjacent spheres from intersecting. By either controlling environmental variables, securing all pathways of pathogen introduction, or keeping populations low. Obviously, for reasons of profitability, it is the former two spheres that are primarily focused on, such that production can remain high. Once a pond has been infected, many diseases are potent enough to destroy the crop within a little less than a week, rendering farmers penniless.

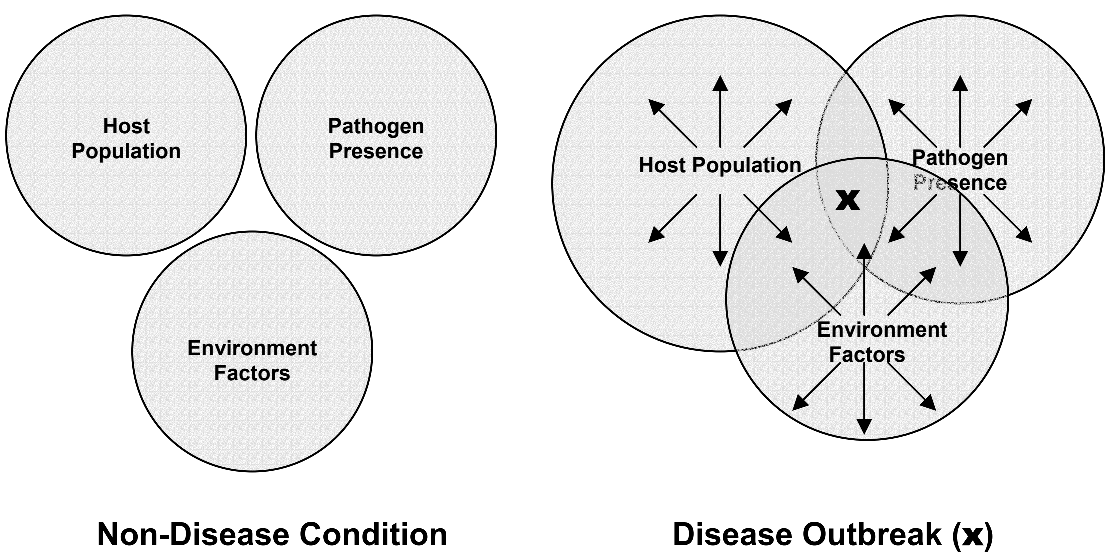

Figure 3. Model of Aquatic Pathogens (*Adapted from:Dr. Sniezko in Lightner et al. 1998*)

Of the many diseases that exist today, their causes fall under five major categories (Table 1.)—environmental, parasital, fungal, bacterial and viral (see table 1 below).

Environmental symptoms result from mismanagement of pond water quality and shrimp health. Parasital, or protozoan diseases, such as Epicommensals, Gregarines and Microsporidians latch on to farmed shrimp and are only of minor impact. Fungal diseases, such as Rickettsia, Larval mycosis and Fusariosis again are treatable and of low impact. Bacterial diseases are generally from the genus Vibrio, and demonstrate various symptoms and are generally treated with anti-biotics.[59,60] While the previous four types of diseases have caused problems for the industry, it is the viruses that have been most destructive to crop world-wide. In particular, there are five viruses that will be the focus of the rest of this chapter for their historical and economic importance—Monodon Baculovirus (MBV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Taura Syndrome Virus(TSV), Yellowhead Disease (YHD) and White Spot Syndrome Virus.

Table 1. Major diseases of penaeid shrimp (adapted from Lightner and Redman, 1998)

Viral diseases	Bacterial	Fungal	Parasital	Other
WSSV	Vibriosis:	Rickettsia	Epicommensals:	Microsporidians
Yellow Head Virus	-septic HP necrosis	Larval mycosis	-*Leucothrix mucor*	Nutritional Imbalance
BMN	-hatchery vibriosis	Fusariosis	-peritrich protozoans	Toxic syndromes
MBV	-lumunescent vibrio		Gregarines	Environmental
IHHNV	-'Sindrome Gaviota'			syndromes
HPV	-shell disease			One month death syndrome
REO	NHP bacterium			
Taura syndrome				Zoea II syndrome
BP group				

Monodon Baculovirus

Monodon Baculovirus is a DNA type virus with greatest impact and mortality in Larval, Post-Larval and Juvenile farmed shrimp. First discovered in the early 1980s in *Penaeus*

59 Lightner and Redman et al.

monodon, the disease has now spread throughout populations of many shrimp species: *Penaeus merguiensis, Penaeus semisulcatus, Penaeus kerathurus, Penaeus vannamei, Penaeus esculentus, Penaeus penicillatus, Penaeus plebejus, Metapenaeus ensis.* Symptoms of the disease include a reduction of feeding and growth levels, reduction in activity, and dark growth on the gills of surface of the shrimp. Currently there is no known treatment for the disease, although prevention and detection has gone a long way to reduce mortality. The disease is able to create high levels of mortality when a population is otherwise stressed, with environmental conditions, or other disease prevalence.[61]

Out of the 1980s, Taiwan emerged out of decades of aquaculture development as the leader, along with China, in gross shrimp production. As the industry grew on the small island, pressure to intensify production caused proximate farms on the west coast to begin to discharge their effluent into the intake of other farms. Additionally, intensive ponds were susceptible to a build up of sludge bottoms that would have to be reconstructed after every cycle. Thus, along the west coast of Taiwan in 1987 and 1988 shrimp farms began noticing large mortalities in their product. The disease began to cripple the industry, and soon Taiwanese farmers would evacuate the island and spread their production techniques, and associated diseases and problems, throughout Asia. MBV was detected as early as 1986 in Indonesia and 1988 in Sri Lanka and Malaysia.[62] At this early phase, little was known about treatment and care for this disease. Today, it is possible to raise

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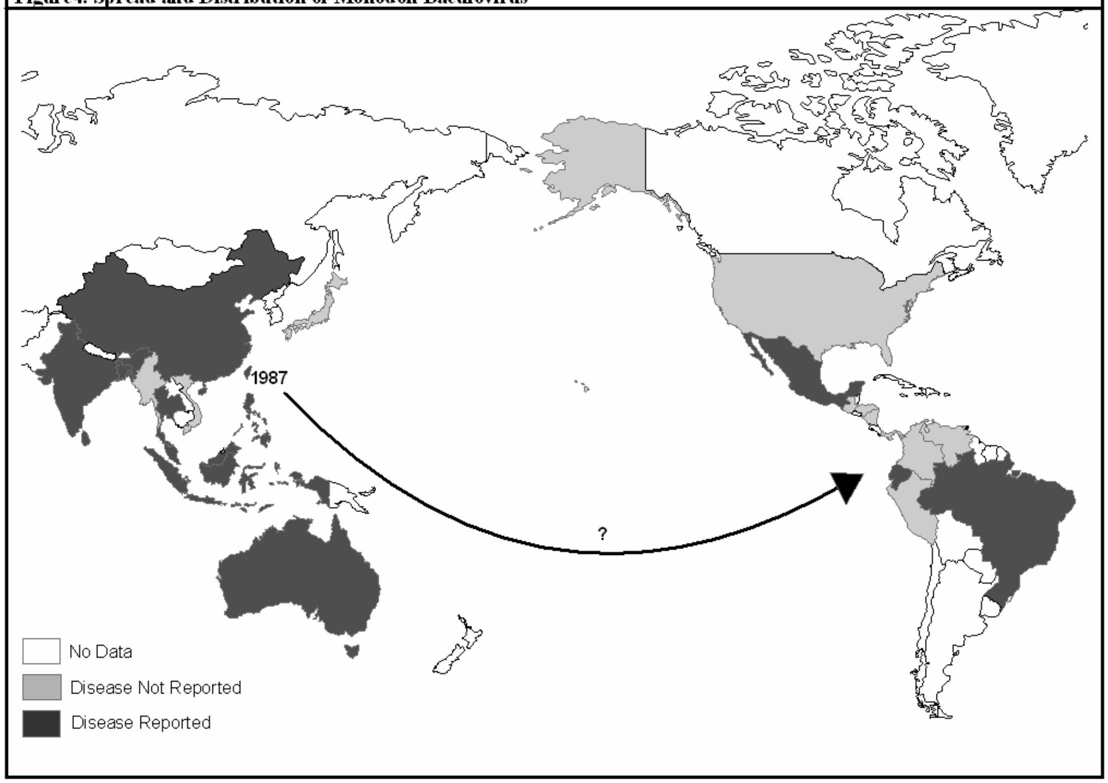
[61] Bower, S.M. 1996. *Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish*: Accessed From: http://www.pac.dfo-mpo.gc.ca/sci/shelldis/

[62] Subasinghe, R.P., Artur, J.R., Phillips, M.J. and Reantaso, M.B. 1999. *Thematic Review on Management Strategies for Major Diseases in Shrimp Aquaculture*: Accessed from: www.enaca.org/shrimp

infected shrimp through the production cycle with MBV, if proper precautions are taken. Some reports have indicated that MBV has recently been introduced to Latin America. (Figure. 4)

Figure4. Spread and Distribution of Monodon Baculovirus



Taiwan was the only country to be devastated by this disease such that it created a noticeable dip in production. In concert with other bacterial and viral problems, from 1987 to 1990, production dropped 80%, costing the industry nearly $700 million. While solutions were developed to help the industry slightly recover in 1991, continued problems with new diseases have left the industry with production at just 10% of its 1987 high. In other countries, it is more difficult to account for macroeconomic consequences of MBV, although massive mortalities were reported in China, Thailand and Philippines among other countries as a result of the disease. As the disease spread throughout susceptible populations around the world, continuous efforts must be taken to avoid mortalities of this ever-present disease in Asia.

Infectious Hypodermal and Hemotopoietic Necrosis Virus

IHHNV is a single stranded DNA type virus that originally was detected in *Penaeus stylirostris* in the early 1980s. This species is most susceptible to the disease, in which high rates of mortality are evident in both farmed and wild populations. Reports of mortality over 90% in some farms with *P. stylirostris* have been noted. *Penaeus vannamei* has also been able to contract the disease, but the symptoms have only resulted in reduced growth and defects, such as Runt Deformity Syndrome (RDS). Additionally, *Penaeus monodon* and 12 other commercial shrimp have been infected with the disease, but none with the mortality levels similar to *P. stylirostris.* Thus, the only detection available is careful monitoring of pond level growth rates. Transmission of the disease is both horizontal, by consumption of other infected origanisms, and vertical, by transmission through female eggs.[63]

Due to its lack of detection or significant economic impacts outside of the species *P. stylirostris,* the spread of IHHNV is more difficult to document than that of other species. It has now managed to spread around the world from its natural origin in Southeast Asian waters. However, not until it was introduced to Latin America was it detected as serious mortality resulted. In Mexican waters a 1990 investigation detected IHHNV in 46% of

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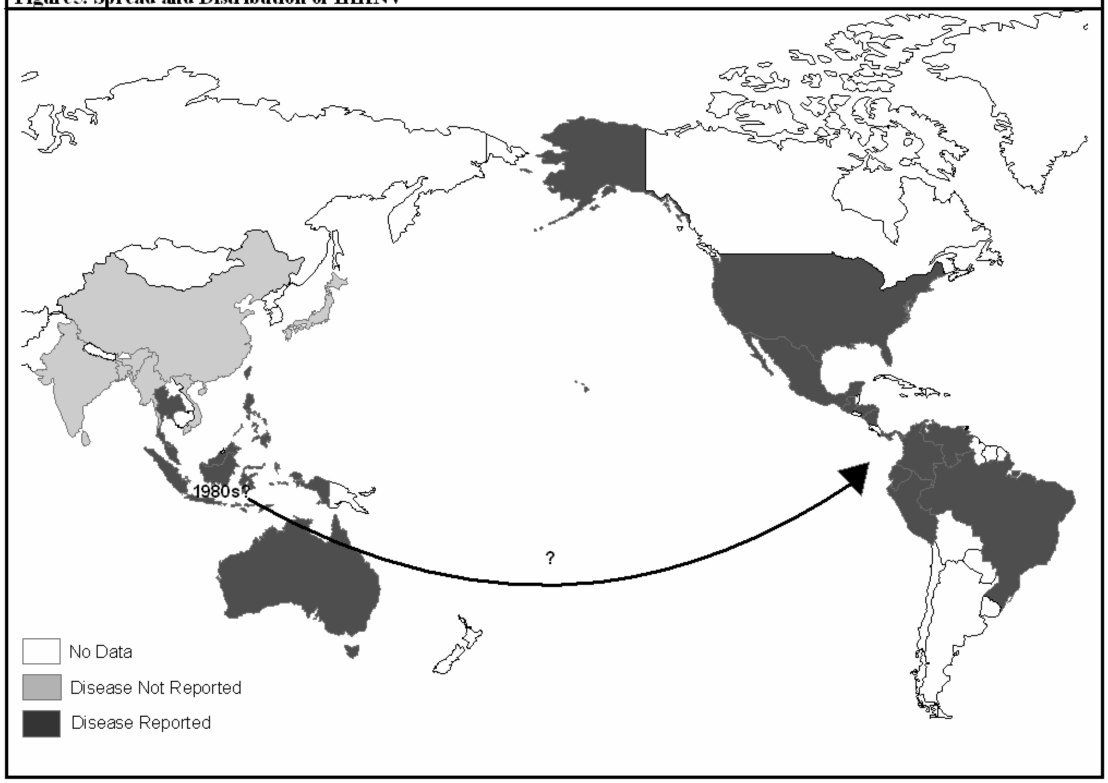
[63] Jimenez, R. Barniol, L. de Barniol & M. Machuca. "Infection of IHHN virus in two species of cultured penaeoid shrimp Litopenaeus vannamei (Boone) and Litopenaeus stylirostris (Stimpson) in Ecuador during El Niño 1997-98 R". *Aquaculture Research*
Volume 30 Issue 9 (1999) Page 695

wild *P. stylirostris* in the Gulf of California. (Pantoja, 1999) IHHV has been blamed for high mortality in wild shrimp populations of *P. stylirostris* off Mexico, Panama and Ecuador. (Figure 5)

Figure5. Spread and Distribution of IHHNV



IHHNV is responsible for shifting Latin American aquaculture away from *P. stylirostris* and towards *P. vannamei*, the more resistant species, a shift that was even further affected by the WSSV epizootic of the late 1990s. In 1979, 20% of Latin American aquaculture production was composed of *P. stylirostris*; by 1989, that number was down to 9.2%, and by 1999, 6.2%, mostly due to weakness of this species in the face of disease. Note: in 2000, due to WSSV, *P. stylirostrisi* dipped to below a third of one percent of Latin American production. In other parts of the world, it is difficult to assess with existing data the economic impacts of the disease, although some papers have reported economic losses on some farms, due to stunted growth of between 10 – 50%.[64]

Taura Syndrome Virus

TSV is a single stranded RNA type virus that was first detected in *P. vannamei* in the early 1990s. The virus produces high but variable rates of mortality at the pond level, from 5 -95% in *P. vannamei,* but has not posed a demonstrable threat to any other species. Although it has been detected in *P. stylirostris* and *P. seteferis*, no noticable impact has been exhibited. The virus begins to show itself in the juvenile stage, with symptoms ranging from empty stomachs to a proliferation of red color starting on the appendages and spreading around the body; for this reason, it is sometimes called Red Tail Disease. The juvenile shrimp will then die as they undergo the molting process. If they survive, it is then possible to show signs of recovery, and mortality is then less likely, though they are still carriers of the disease and further symptoms of brown spotting can occur. Transmission of the disease can happen horizontally through the consumption of a diseased shrimp, or from transport of infected seed post-Larvae. Infection can also result from carriers such as certain water insects that can be infected, or birds that may have consumed infected tissue. In addition, the disease can survive being frozen multiple times such that shipments of infected shrimp for consumption may also be responsible for some spread of the disease.[65]

[64] Lightner and Redman et al.

[65] Lightner, D.V. 1995. Taura syndrome: an economically important viral disease impacting the shrimp farming industries of the Americas including the United States. In: Proceedings of the niney-ninth annual meeting USAHA, Reno, Nevada. Pat Campbell & Associates, Richmond, Viginia, USA. pp. 36-52.

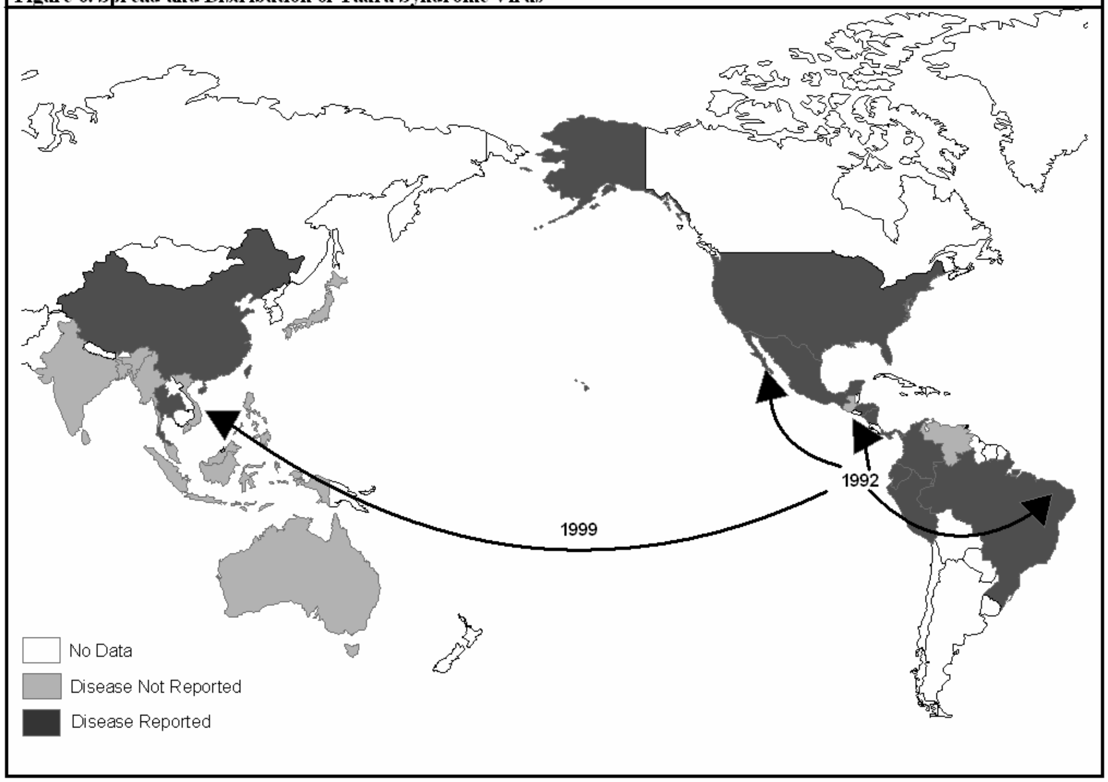
In 1992, the disease was detected in the coastal town of Taura, Ecuador that led to massive mortalities within days of any visual symptoms. Ecuadorian shrimp farming in the early 1990s was booming and generating hundreds of millions of dollars, mostly in the Gulf of Guayaquil estuary. Incidentally, this was also a region that had developed a very prosperous banana farming industry inland and upstream of the shrimp farmers' domain. When heavy mortality markedly cut profits in 1993 by nearly $100 million, the blame was instantaneously cast towards the runoff of toxic pesticides used by the banana farmers. Soon it was established that the syndrome was in fact a transmittable virus, though in many ways it was too late. The virus spread quickly throughout the various *P. vannamei* populations of Latin America within a few years, mostly by transported Post-Larvae for seed stock. However, possible use of frozen shrimp as bait, discharge of wastewater from packing plants and ballast water dumping from tankers may all also be drivers of the dissemination of the disease. From the discovery of the syndrome in 1992, the disease quickly spread in 1993 to Colombia and Peru, in 1994 to Brazil, El Salvador, Guatemala, Honduras, Hawaii and the continental United States, in 1995 to Belize, Mexico, Nicaragua and Panama, and finally in 1996 to Costa Rica.[66]

Until 1995 the virus was confined to the Americas, but with increasing disease pressures on Indo-Pacific shrimp producing species, *P. vannemei* was introduced as a supposed pathogen-free solution. From 1995, *P. vannamei* was first introduced in Taiwan, then two years later in Philippines, the Thailand, China, Vietnam, Indonesia, India, and Malaysia by 2001. However, the introduced species also introduced the Taura virus and

[66] Hasson, K. W., Lightner, D.V., Mari, J., Bonami, J., Poulos, B.T., Mohney, L.L., Redman, R.M., Brock, J.A. 1999. "The geographic distribution of Taura Syndrome Virus (TSV) in the Americas: determination by histopathology and in situ hybridization using TSV-specific cDNA probes." *Aquaculture* 171 (1999) 13-26.

is now prevalent throughout Asia, though so far it has not spread to *P. monodon,* the primary species of farmed shrimp in the region.[67] (Figure 6)

Figure 6. Spread and Distribution of Taura Syndrome Virus



Shrimp production in Ecuador from 1992 to 1993 dropped over 25% due to the Tuara virus and cost the industry nearly $100 million dollars. Not until 1997 would production again be back up at its 1992 levels, in total costing the industry nearly a half billion dollars in potential revenue. Considering the growth in the Ecuadorian industry that had previously been at over 20%, the actual cost to the industry is much greater than this figure reveals. In Colombia, production dropped 45% in four years from 1992 to 1996 resulting in losses of over $100 million. Not until 2000 was production in Colombia again the same. In Peru, production dropped nearly 40% in two year from 1992 to 1994,

[67] NACA. 2003. *Impact of Penaeus vannamei introduction to Asia-Pacific*. http://www.enaca.org/Health/News.htm

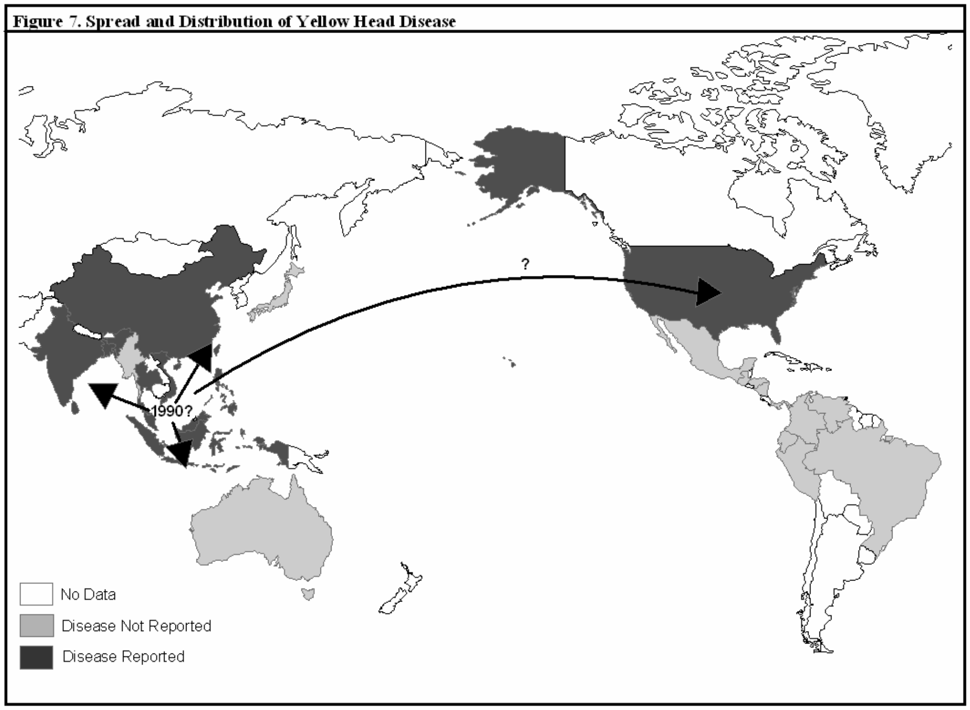
recovering by 1996, resulting in losses of over $25 million. In the Central American countries, economic losses are more convoluted due to multiple natural disasters including El Nino events and hurricanes. In Asia, there is little record of any economic losses due the TSV, such that it never spread to local populations, and was present within the *P. vannamei* introduced.

Yellow Head Disease

YHD is a single stranded RNA type virus that is primarily prevalent in cultured *P. monodon.* The disease is also prevalent in wild populations throughout Indo-Pacific waters. It has also been proven to infect *Penaeus vannamei*, *P. stylirostris*, *P. setiferus*, *P. aztecus*, and *P. duorarum*. Symptoms first appear in Juvenile shrimp between 5 and 15 grams in the form of a high feed consumption for a few days prior to an abrupt halt feeding. Within a day, shrimp will have a pale white discoloration of their bodies and a yellowing of their head as high mortality ensues. Transmission of YHD is primarily horizontal through many of the same mechanisms that have been previously mentioned for other diseases including sea birds and discharged pond water. It is postulated that YHD can also be transmitted vertically by infected individual survivors. The disease can also be carried by several wild shrimp populations and other crustaceans. Most likely the disease was introduced by seed post-larvae.

First detected in Thailand in 1990 and labeled as responsible for massive mortality, YHD has coupled with WSSV in Asia to hinder growth in the region throughout the 1990s. In Thailand, YHD has been widely prevalent, but only estimated to account for $30 to $40 million or 3% worth of losses in Thailand in the early 1990s, leveling off production slightly, but not significantly hindering production.[68] YHD may have been partially responsible for earlier mortalities in China, Taiwan, Indonesia, Malaysia and the Philippines since 1986.[69] Some have credited the decline in Chinese production in the late 1980s to YHD.[70] In 1989 and 1990, Chinese production was down 10% each year resulting in a calculated loss in overall revenue of the industry of $200 million that has been attributed to YHV. In 1995 the disease was first detected in Texas, but has had little overall economic impact in the Americas. There are also scattered but unconfirmed reports that YHV may have recently made it to Latin American shrimp farms. (Figure 7)

Figure 7. Spread and Distribution of Yellow Head Disease



[68] Lightner and Redman, et al.
[69] *Walker, Peter J. and Cowley, Jeff A. "Viral Genetic Variation: Implications for Disease Diagnosis and Detection of Shrimp Pathogens." FAO Technical Series Paper 395: DNA-based Molecular Diagnostic Techniques: Research Needs for Standardization and Validation of the Detection of Aquatic Animal Pathogens and Diseases. 2000. Accessed from : http://www.fao.org/DOCREP/005/X4946E/x4946e00.htm#Contents*
[70] CSIRO. 2002. Impact of Infectious Agents on Farming and Food Production: *Global Impact of Newly Emergent Pathogens on Shrimp Farm Production.* Accessed From http://ftp.cdc.gov/pub/infectious_diseases/iceid/2002/pdf/walker.pdf

White Spot Syndrome Virus

WSSV is a DNA type virus that is able to pass from non-shrimp to shrimp by horizontal transmission by shrimp as well as other crustaceans and aquatic insect larvae. The WSSV manifests itself quickly and deaths occur with days of symptoms. It has been known to prove fatal in *P.chinensis*, *P. indicus*, *P. merguiensis*, *P. monodon, P. setiferus, P. stylirostris, and P. vannamei.* After the first day, the tanks of shrimp begin to stop eating and come to the surface more than normal. On the second or third day, white spots begin to appear on the carapace, and gills. Within a week of the detection a heavy mortality begins on the entire infected population. Survival rates can be anywhere from 30% to zero, but in many cases the entire pond is wiped out. However, because of similar symptoms of the unrelated Bacterial White Sport Syndrome (BWSS), PCR tests have been developed to ensure that it is in fact the virus.[71] The rapid expanse of this disease can be due to various causes. In the United States, it is thought that the import of frozen shrimp and resulting waste-water first spread the disease from Asia to the Gulf States. This would explain the earlier appearance of this disease in the States, even though their production is much smaller. In South America, it is more likely that the disease was introduced by transported infected larvae from Asian ponds. Once present in a region, means of transmission vary, including: infected wild broodstock, infected post-larvae, contaminated humans or farm machinery, other infected crustaceans, contaminated estuary water and birds.

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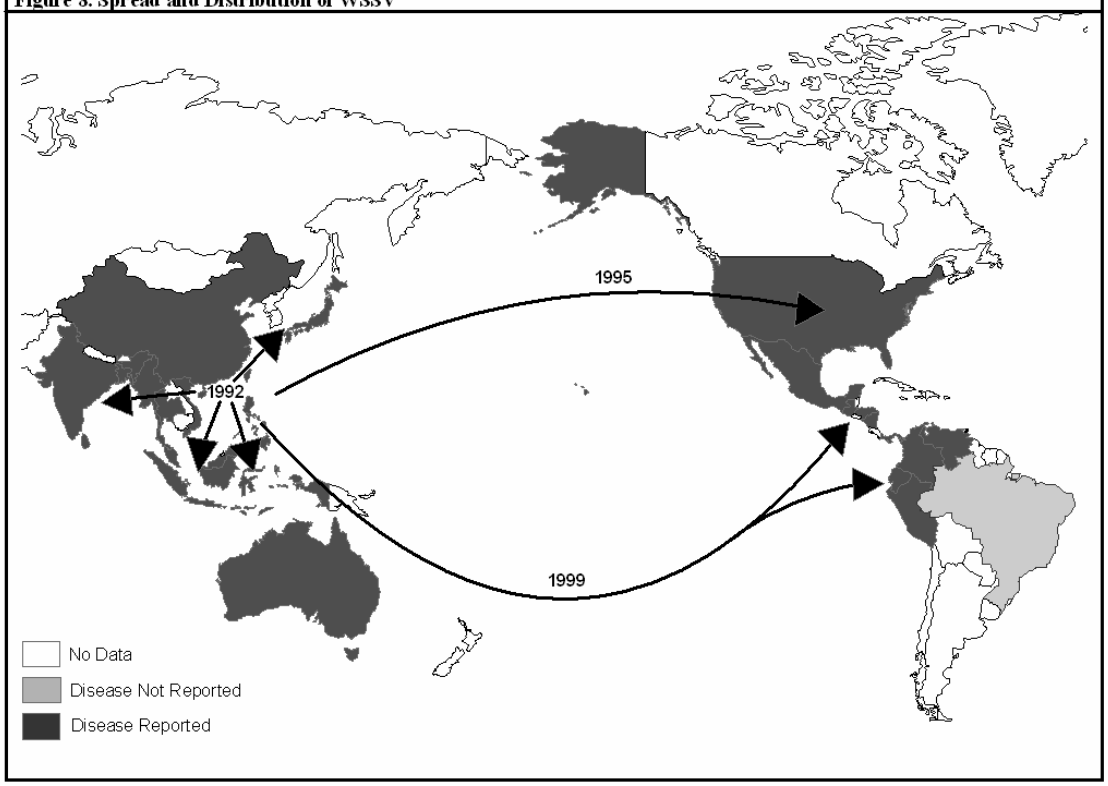
[71] FAO, NACA. 2003. *Quarterly Aquatic Animal Disease Report(Asia and Pacific Region)* January-March 2003) Accessed from: http://www.enaca.org/NACA-Publications/QAAD/QAAD-2003-1.pdf

Prior to 1991, global shrimp production had been increasing consistently year after year since data were first recorded in 1970. For the first time, in that year, a disease known as White Spot Syndrome began to cause devastating fatalities in the T'aipei Taiwanese province shrimp farms and subsequently in the Fuzhon and Quangzhou provinces in China. By 1994 the syndrome had spread by imported shrimp to southern Japan, through Thailand, into Indonesia and as far west as the coast of India. A year later, the disease leapt over the Pacific Ocean and spent the following three years spreading throughout small scale farms in North America. Not until late 1998 or 1999 did the disease begin to ravage South America, first in Ecuador, then Peru and the rest of the Pacific shrimp farming countries.[72] In less than ten years this disease appeared and spread to global extent (Figure 8), creating by far the greatest economic damage of any of the

Figure 8. Spread and Distribution of WSSV



[72] CSIRO et al.

aforementioned diseases. The reasons for this rapid spread are a combination of the strength of the disease, lack of awareness and prevention, internationalization of the industry and increasingly intensive farming practices.

It has been estimated that WSSV in the past ten years has cost the industry as a whole between $20 – 30 billion.[73] As has been previously mentioned, the WSSV epizootic has left the industry in many countries in shambles for the past ten years. However, certain countries have been hit harder than others. Upon detection in China in 1992, the disease dropped production over 70%, from a 1991 high of nearly 220,000 MT to under 64,000 MT three years later. The crash resulted in an industry-wide production loss in China of over $2 billion in three years, not considering a growth rate in the industry of 28,000 MT per year in the 7 years previous to the crash. Not until nine years later, in 2001 did China again produce over 200,000 MT. An estimate of potential losses through those years, considering previous growth rates, is roughly $15 billion, placing China as the country by far most affected by WSSV to date. In Thailand, production was growing at an annual rate of roughly 34,000 MT per year, until the white spot hit in 1994 and stagnated production at 265,000 MT, or $1.6 billion in value. Production for the following five years declined slightly, resulting in estimated losses of $1.5 billion through five years, considering lost potential growth. Indonesia exhibited a similar trend, as production until the WSSV outbreak was steadily increasing at a rate of 17,000 MT per year from 1985 until 1991. Production since has stagnated resulting in potential production losses of roughly $1 billion through ten years. India and then the Philippines combined suffered declining production following their outbreaks, but of lesser economic importance than

[73] Ibid.

other Asian countries. The rest of the Asian countries continue to deal with the WSSV, but in their aggregate production figures there was little macroeconomic shock.

Asian efforts to deal with the WSSV outbreak have been made difficult by a failure to develop a disease free line of tiger shrimp. The industry has responded to disease outbreaks through many of the same methods later addressed in this paper. Farms in many of the first shrimp farming countries such as Taiwan, China and Thailand are showing increasing trends towards rapid industrialization and intensification, partially because of falling prices and the necessities presented by disease parameters.[74] However, without a closed generation supply of larvae, the Asian industry will remain significantly behind Latin American shrimp farmers on the path towards sustainability.

In Latin America, as has previously been mentioned, WSSV did not have significant economic impact until 1999. The disease first hit Nicaragua, but only slightly affected the small producers with a decrease in production of 13%, or a few million dollars. However, neighboring countries were not so lucky. In Ecuador, production decreased over 60% percent in two years, resulting in losses of over $1 billion from 1998 – 2001. In Panama, production dropped by 90% due to the epizootic resulting in losses of over $100 million over three years. The same occurred in Peru, as production through two years fell nearly 90%, with resulting losses of $70 million over the same period. The following case studies and analysis focus specifically on the various Latin American responses to the WSSV outbreak.

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[74] Lebel "Industrial Transformation and Shrimp Aquaculture ion Thailand and Vietnam: Pathways to Ecological, Social, and Economic Sustainability?" *Ambio* 21(4) (2002):311-323

METHODOLOGY

To answer the question proposed in this thesis, three research trips were taken from March through August of 2003. First, ten days were spent in Tumbes, Peru, in March. Then in May, three weeks were spent collaborating with the International Marine Shrimp Genomics Initiative while traveling up the coast of Ecuador from the Peru border as far north as the city of Machala, Manabi. Ten weeks were then spent in Mexico working with Conservation International on the development of sustainable shrimp farming and marine conservation, while undertaking research for this thesis. Research in Mexico was based out of the state of Sinaloa, between the cities of Culiacan and Mazatlan, and primarily around Bahia Santa Maria.

Figure 9. Mexico Reference Map

Figure 10. Ecuador/Peru Reference Map

Economic data has been gathered from a variety of sources, including official government publications, independent assessments, and farmer accounts. Technical data came primarily from first hand witnessing of the various techniques as a participant observer. Additionally, interviews with farmers, developers, academics and government officials were of great help to build the technical data. Finally, a great wealth of information regarding the technical changes occurring in the various shrimp farming economies were available in trade journals and reports made available by the various interviewees. Environmental observations came again from interviews with the same group of people that were previously mentioned, as well as fisherman and environmentalists.

CASE I. ECUADOR

Industry Development

Shrimp Farming in Latin America began primarily in the mangrove swamps of the El Oro region of Ecuador in 1968. As a result Ecuador has been, until the recent WSSV outbreak, the lead producer of farmed shrimp in Latin America. Ecuadorian shrimp exports have consistently been the third largest export from the country, behind only small margin from bananas and petroleum exports. In 1998, the final year of elevated shrimp exports prior to the WSSV outbreak, shrimp exports totaled $872 million, ahead of petroleum exports and $200 million behind banana exports.[75] These shrimp exports of the late 1990s accounted for over 3.5% of the total GDP of Ecuador. In 1999 it was estimated that direct employment related to the shrimp farming industry was over 200,000 individuals, or just under 2% of the population, including 76,000 larvae collectors, 2,300 laboratory workers, 103,000 farm employees, 20,000 packaging plant workers and 17,000 involved in other forms of peripheral support, ie. food, transport, ice-making etc.[76] Other estimates have estimated that total employment at the industry's peak in 1998 totaled over 1 million people, over 7% of the population.[77]

Internationally, in 1998 Ecuador was the second largest producer of farmed shrimp in gross tonnage at 144,000 metric tons, second only the Thailand. According to some sources[78] Ecuador was the world's second largest producer of farmed shrimp from 1993

[75] Banco Central de Ecuador. *Infomacion Estadistica Mensual No. 1.803*. May 2002
[76] Camara Nacional del Acuacultura. 2002. *Libro Blanco del Camaron Ecuatoriano.*
[77] Schwaegler, Dan. "Ecuador: State of Emergency declared over lost shrimp revenue Funds will be directed toward battling white spot virus." *Worldcatch News Network*, Sept. 26, 2000. Accessed from: http://www.shrimpaction.com/News/Ecuador5.html
[78] Rosenburry. 1999. *World Shrimp Farming.*

until 1999. At its peak, Ecuadorian farmed shrimp controlled nearly 15% of the international market.

The development of shrimp farming grew at an incredible pace from the early 1970s until the late 1990s. Only three times did production recess, the first due to the 1982-83 El Niño event and twice due to disease outbreaks. Besides these contractions in production, in 20 years from 1978 to 1998 production grew from under 4,000 MT (metric tons) to over 140,000 MT. The first El Niño event, caused large scale destruction of property and farm infrastructure with heavy rains and flooding. The first significant disease was called the Gull Syndrome, primarily caused by Vibrio but named after the tendency for seabirds to flock around diseased ponds. The disease stunted growth in the industry by about 4,000 MT for a single year in 1989. Again, in 1992 the Taura Virus emerged, setting production back for five years.

Table 2 demonstrates the effects of shrimp farming on the Ecuadorian coastal landscape. In 1969, there were 200,000 hectares of mangroves and 50,000 hectares of salt flats in Ecuador. By 1995, over 55,000 hectares of mangroves had been lost, nearly 180,000 hectares of coastal land were covered with shrimp farms and salt flats had been reduced by 90%. Slight improvements were made in terms of mangrove cover in 1999 due to replanting and increased regulation efforts.

Table x. Evolution of Mangrove, Shrimp Farm and Salt Flat Areas from 1969 to 1999 (hecatares)

Zona	1969	1984	1987	1991	1995	1999
Mangroves	203,624.80	182,157.30	175,157.40	162,186.55	146,938.62	149,556.23
Shrimp	0.00	89.368.30	117,728.70	145.998.33	178,071.84	175,253.50
Salt Flats	51,752.00	20,022.10	12,273.70	6,320.87	5,109.47	4,531.08

The majority of shrimp farms in Ecuador are of the extensive type, roughly 60% according to figures from the mid-1990s. The remaining 40% has developed in a semi-intensive manner, while intensive farms had in the 1990s been slow to develop.[79]

Economic Impact of WSSV

By the end of 1999 it was obvious that this record was all about to charge. A state of emergency was declared by the then president as production plummeted by over 65% in 2 years.(Figure 11) Each year since 1998, exports have remained a half billion dollars less than they were prior to the outset of WSSV. It is estimated that over 130,000 jobs were lost in the first year alone that the virus struck, a reduction of nearly one half of those directly employed by the industry. Nearly 100,000 hectares of the total 175,000 in ponds were abandoned by early 2001. Of the 75 processing plants that operated in 1998, only 25 were still open by 2001. Of those that remained open, all were only working at 20% of capacity. 60% of the 300 laboratories were shut down. Ecuadorian shrimp feed factories were producing $150 million less in shrimp feed.[80]

Of the many farms that were forced to shut down, the majority were the smaller land-holding and those that were owned by poorer, less wealthy farmers. As the disease outbreak has continued, there has been a massive amount of consolidation in the industry. The larger farmers have been able to get the loans necessary to continue, but many smaller scale farmers have had to fold.

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[79] Coastal Resources Center, URI. 2000. *The Economic, Environmental and Social Impacts of Shrimp Farming in Latin America*. Accessed from: http://www.crc.uri.edu/comm/download/shrimp_report_all.pdf
[80] Acuacultura de Ecuador. *Las Cifras de la Crisis*. November – December 2000

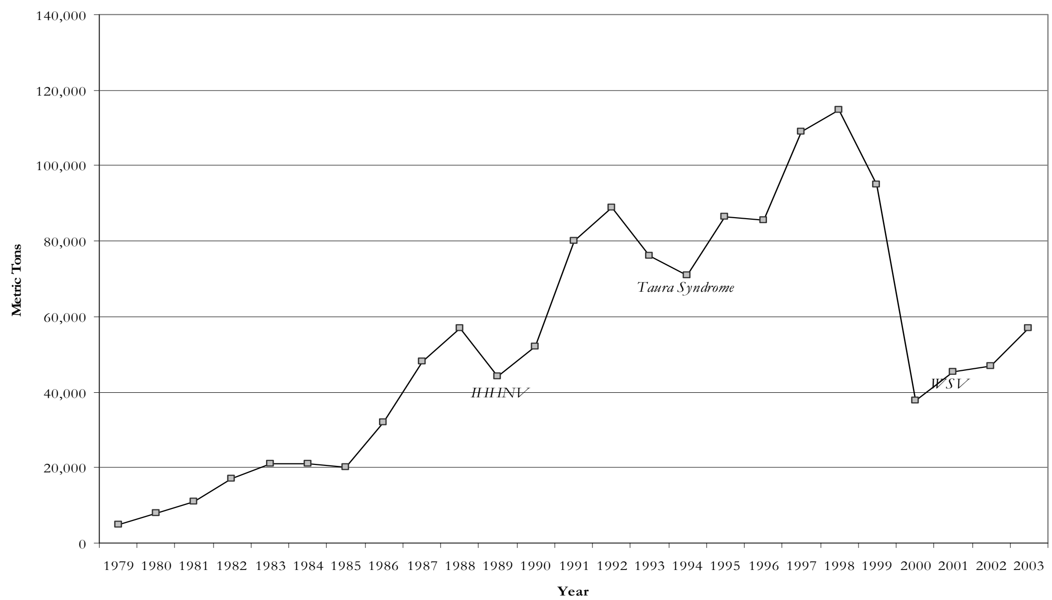

Fig. 11 Shrimp Production- Ecuador. ***Data Source: Camera Nacional de Acuacultura (2003)***

An Ecuadorian economist working at the Central Bank described the major hurdles left by the WSSV outbreak, and the financial barriers to Ecuador regaining competitiveness in international markets. He first commented on all of the positive steps that have been taken by the industry that have previously been described in this report, but dwelled mostly on the problems that are currently faced in regaining the foothold Ecuadorian farmers once had. The most important problem in Ecuador now from the Bank's perspective is the elevated cost or lack of financing for the sector. The most affordable loans have interest levels of 16% and must be paid back within 6 months. This prevents many of the smaller farm owners from investing in the green and more sustainable technology. Second, many of the exporters and producers still have to cope with the very high taxes that were in place when the industry was much more profitable. Third, low international prices have hurt shrimp farmers world-wide. Forth, barriers to trade in shrimp by growing producers such as China and Brazil that are able to produce at a lower cost with high levels of government support. The global recession that has hurt increases in demand, especially in Japan and Europe. This year, special customs preferences to Vietnam by the European Union will end, shifting Vietnamese exporters to US markets, Ecuador's number one importing state. Additionally, Ecuadorian exporters are extremely worried about the implication of the new Bioterrorism law of the United States that requires certification and inspection of all food shipped to the US prior to crossing the border. Finally, many farmers have little faith in the success of better production from new techniques without government intervention to lower interest rates.

Legal and Government Intervention

The Ecuadorian Government has yet to successfully regulate the shrimp farming industry in Ecuador. This is not to say they haven't tried. Starting in the 1980s a series of declarations banned the cutting of mangroves and other destructive aquacultural practices were implemented. Much criticism remained throughout the 1990s regarding the lax enforcement and cooperation with the increasing numbers of regulations, while the felling of mangroves and other environmental malpractices continued.[81] The powerful shrimp farmers were often able to find their way around the legal code through bribery or other means to maintain their farms.[82] Much of the coastal land in Ecuador is granted through 10 year government concessions to shrimp farmers through a convoluted and unaccountable application process.

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[81] Hemphill, A. H. *National Coastal Policy in Reference to Mangroves and Shrimp Aquaculture in the Republic of Ecuador Coastal Conservation Program*, Fundación Jatun Sacha. Accessed from: http://www.geocities.com/arosemenatola439/Coastal.htm

[82] Stephan Bohórquez, in interview.

Decree No 824, June 5, 1985 declared mangroves public property and prohibits their cutting without permission. Five years later an additional law declared that all mangroves on private and public land are property of the state and cannot be cut without permission. Then in 1994 a moratorium was declared on all mangrove cutting. Not until 1996, however was an actual ministry of the environment created to monitor the observance of such laws. Table 2 reveals that nearly 30,000 hectares of mangroves continued to be cut following the implementation of the previous laws. However, with the advent of serious disease problems and a strengthened regulatory framework, that has changed drastically. Again, in late December of 2000, another law was passed banning permanently the cutting of mangroves, this time it is presumed by actors on all sides that the law may finally be observed, this time due to the effects of WSSV.

One new law published in the governments official register No. 690 from October, 2002 prohibits damming of rivers or estuaries, destroying or mal-affecting mangroves, alteration of agricultural of forested land that is otherwise profitable, discharge of contaminated water. Another law specifically addresses the salinization and other types of contamination of inland shrimp farming onto lands. In February of 2002, the import, sale and use of the antibiotic Chloramphenicol was banned and a program established to check for the presence in exported shrimp product.

One of the most important and effective pieces of legislation in recent years was the banning of the artesenal extraction of shrimp post-larvae from estuarine ecosystems.

This law was very effective in ending post-larval fishing, mostly due to the concurrently declining demand for such larvae from shrimp farmers preoccupied by disease. However, the impact of the combine legislation and disease scare have been drastic on the populace as hundreds of thousands of jobs have been lost by small scale beneficiaries of the industry. On the other hand, the environmental gains are just as great for many coastal artesenal fishers hoping to enjoy greater levels of catch in shrimp and other marine life with estuarine larvae, and coastal ecosystems are given a chance to recover. The passage of this law in Ecuador, and the WSSV forced compliance, has markedly improved the chances of a long term sustainable future for shrimp farming in Ecuador. At the same time, there is still no permanent ban on the extraction of gravid females from the wild and transporting their eggs to laboratories, but this activity is more successfully regulated by the Fisheries Department through seasonal bans.

The Ecuadorian coastal zone management agency (PMRC) has set up a series of seven conservation and vigilance units (UCVs) for each coastal region to support and monitor the regulations. The primary job of these UCVs has been to enforce the zero cutting policy of mangroves. Interviews by local fisherman in the Machala region suggest that the UCVs have been increasingly effective at preventing mangrove destruction in the local regions. One fisherman described how a legal case successfully forced brought against one farmer so that he could be stopped. In the Esmeraldas region, however, there continue to be complaints that the UCVs, while positive, do not completely take care of the job. On the whole, the satellite data suggests that the regulations along with the new knowledge of disease management have prevented continuing large scale expansion into mangrove areas in coastal Ecuador. Disease has also left so many ponds abandoned, that it is now much cheaper to just use an old, abandoned plot of land than to bother with the costly process of reconstructing new pond infrastructure.

Thus, prior to the WSSV outbreak, the booming aquaculture industry in Ecuador took advantage of Ecuador's paper legal system. With a new series of increasingly specific laws, and an industry with a new focus, it appears this trend is on the reverse.

Public-Private Partnerships and NGO Intervention

The National Center for Aquaculture and Marine Research (CENAIM) has taken the lead in public research after shrimp farming in Ecuador. Unfortunately, most shrimp farmers introduced had only negative things to say about the research institute and its disconnectedness to the industry. They do continue to publish research on disease control and innovative technologies, but it is all shrimp farmers maintained that they work independent of the industry's immediate needs and concerns. Regardless, several technologies have resulted from their research that are worth noting. First they have found with empirical research that elevated temperatures can help ponds avoid WSSV outbreaks. Thus they have developed a "greenhouse" apparatus that serves to cover shrimp ponds and raise temperatures much higher than normal. Second they have developed the infrastructure for web/GIS based alert system that will warn farmers as to when the appropriate climatic conditions are arriving that may lead to increased disease numbers. Additionally, the alert system monitors production numbers and will notify users if production trends are indicating a disease outbreak, even if there is none being discussed. Much of the research in CENAIM appears to be high tech and relatively costly—thus the dissatisfaction of many of the shrimp farmers.

On the other side, the industry and government backed National Chamber of Aquaculture (CNA) serves to promote the industry internationally and also disseminate information amongst members. The chamber recommends a series of practices that were re-iterated throughout an interview with the executive director, Leonardo S. Maridueño. These actions include: destroying possible carrying vectors, careful analysis of larvae and its origin, double check with PCR for WSSV prevalence, management and reduction of water exchange, filtration and monitoring of water discharge and intake, avoiding sedimentation, proper nutritional intake, anti-viral use, stress reduction through water quality monitoring, abandon use of anti-biotics, biosecurity precautions, polyculture with Tilapia and genetic improvement. The priorities of the CNA now are to try and get the shrimp farming industry back on its feet, by promoting it around the world. Major difficulties are being experienced in acquiring investment, now that the profitability in the industry is severely reduced. On the other side of production, it is increasingly difficult, even though world demand is growing, to regain international markets for Ecuadorian shrimp. Two thirds of their global sales were quickly absorbed by Asian and other Latin American competitors. Mr. Maridueño stated that given the experiences of disease in other countries, as well as their own, the 'ecological cultivation' of shrimp is a major opportunity forward to avoid the disease and marketing problems. The use of 'ecological cultivation', while being a more sustainable and long term approach, also opens up the opportunity for new markets in organic shrimp sales to the European Union.

The CNA has also recently cooperated with Ecuador's largest environmental organization, FUNDECOL to battle the felling of mangroves. As the WSSV was first hitting Ecuador in 1999, the two organizations co-sponsored over 40 flights of aerial monitoring to determine illegal mangrove cutting. Of the 58 cases discovered, 88% were confirmed immediately by authorities on the ground. 95% of those violations were determined to be for the development of small scale and informal shrimp farming projects.[83] Hence, the actors that once, in the eighties and early nineties in Ecuador were adamantly opposing each other now stand on common ground in battling the practices of those that seek to continue in an unsustainable manner.

This is not to say that all concede that shrimp farming is not without its problems in Ecuador. In the northern Esmeraldas region, the industry is still in its infant phase, and ecosystem destruction is a real and evident threat. Stefan Bohórquez, the civil society coordinator for Comité Ecológico del Litoral works with fourteen local NGOs in the Esmeraldas region that have seen ample evidence of continuing illegal activity by shrimp farmers. He stressed throughout the interview that many of the shrimp farms that are currently in production sit on non-existent or expired concessions from the government; hence it is time for these farmers to give the land back. Additionally, in the southern El Oro province, Greenpeace along with local NGOs has recently won lawsuits forcing farmers to give their land back for reforestation.

[83] Camara Nacional de Acquicultura, 2000. *Libro Blanco de Camaron Ecuatoriano.*

With the large scale abandonment of shrimp farms due to WSSV and an increased pressure from fishers and environmentalists the conversion back to mangroves is beginning to happen. Mr. Bohórquez argued that the livelihoods of many coastal fishers rely on these mangroves for fishery production. He stated that he had evidence of fishing villages in Esmeraldas that now only caught 10% of what they used to, prior to shrimp farming. The villages have begun to experience much out-migration to the cities for alternative sources of income. In the southern of El Oro, an interview with Ronaldo Cruz, the President of the Costa Rican Association for the Protection of Mangroves also revealed that many abandoned shrimp farms were now being left for reforestation.

Mr. Bohórquez also discussed that he does see certain improvements in the industry partially, in his opinion, because they cannot afford some of the chemicals they used to use and dump into estuaries. Also discussed was the new 2002 law that banned post-larvae extraction by subsistence fishers. He claimed that the law was framed as a guise to protect ecosystems, but was only passed because of the WSSV outbreaks, and the flagging demand for the product. In the Esmeraldas region however, he knew of several communities that still support a *larvero* industry, for sale to the poorest of shrimp farms that can no longer afford the laboratory purchased larvae. Another result from WSSV his NGO is fighting has been the movement of shrimp farming capital to other countries, especially Brazil and Mozambique, as the fear is the same problems will occur in those countries as well.

Technical Change in the Industry

The recent regulations banning larvae extraction were only possible with the declining interest by the industry for wild caught larvae in Ecuador. By the time the law had been passed, over a hundred thousand *larveros* were already out of work. The transfer of the industry to laboratory purchased larvae in Ecuador, would seem to be a boon for the functioning laboratories, however the simultaneous crash in overall market demand for larvae led to a decrease in the price of laboratory produced larvae and the viability of the industry. At the same time the costs of producing laboratory raised larvae in a closed cycle were raised even higher due to the increased disease management necessities. The operator of the largest supplier of larvae and exporter of shrimp Ecuador—Expalsa—described specifically the problems his company faced even though they had first mover advantage. When WSSV hit in 1999 they already had six generations of closed cycle bred shrimp. This has led them to be the number one producer of shrimp larvae in Ecuador, but in a rough financial state due to the lower prices paid for larvae. According to this source, only the smaller facilities still use gravid females from the wild for their post-larvae to lower their costs, but they will soon be out of business. This was agreed to by several other laboratory owners and operators interviewed, both in the southern El Oro province, Guayas and the northern Manta province.

At the farm level, there are a variety of changes taking place, such that this thesis only can describe some of the changes observed, but cannot fully document all that is happening in Ecuador to try to address the issue of WSSV and other disease problems. All shrimp farmers and technicians interviewed in Ecuador recognized the importance of caring for their local environment in order to protect their production. This was especially true in the Southern provinces where shrimp farms were built, legally or illegally into mangrove swamps. Shrimp farmers throughout the country were certainly not in the expansion mode of the business cycle, but those with the financial resources to do so were moving towards less water exchange, or recirculating intensive production.

One shrimp farm in El Oro, owned by Fernando Granda, of over 200 hectares had entirely switched over to "organic production" following guidelines set forth by a German marketing agency in efforts to fill a niche market and raise the price of their product. As WSSV hit in 1999, production on his farm was lowered 70%, but they were able to continue while many other farms folded or were bought up by larger players. The guidelines prevent intensive farming, mandate less than 20% fishmeal content in shrimp feed, disallows anti-biotic and other chemical use, demands no additional clearing of mangroves and mandates replanting among other stipulations. He discussed the various changes that WSSV has meant for his and other nearby farms. Construction of new ponds is no longer viable due to the fact that it costs about $5,000 to prepare a hectare of used farmland vs. $9,000 to clear fresh land. Additionally, pro-biotics, or bacterial cleaning agents, have been used more and more to keep ponds clean. All of his larvae are produced in closed cycle laboratories and tested with PCR prior to use. Other farms around him have invested in raceway technology that allows for closed cycle recirculation of water, at high and intensive levels of production in a very small area.

Effects on Fisheries

Various interviews with fisherman along the coast of Ecuador revealed several distinct responses concerning their relation to the shrimp farming industry. In mangrove areas, such as Guayas, el Oro and reports from Esmeraldas, there were universal complaints of the mangrove destruction caused by the industry and its effect on their fisheries. Additionally, the displacement of local subsistence, or small scale fishers from their common property resource base was a major theme. Both of these complaints however were eased by statements regarding the halting of mangrove destruction and new reforestation plans for ponds abandoned due to WSSV. Another universal response by local fishers was the loss of jobs for *larveros* induced by legislation and the WSSV outbreak. In the southern El Oro region, there were many complaints about the various chemicals used by the industry in efforts to control disease. In Salinas, Manabi, an area famous for its pure water and breeding laboratories, fishers complained that the number one effect the disease outbreak had on their industry was that the price of gravid females went so low and the demand lessened to such a degree that it is now extremely difficult to find buyers. Further north in Manta, fishers have similar accounts explaining that gravid females and reproducers used to be able to bring in hundreds of dollars. Currently, they are worth only as much as they weigh. On the contrary, WSSV had little effect on their local fishing industries, as most employees of the shrimp farms were not fishers themselves, but migrant workers. Prior to WSSV catch had been declining markedly. One fisher said that in the past he used to catch on average up to seventy pounds a night, whereas now the catches are down to about ten pounds per evening. There have been a number of reasons to explain this though, including increased trawler pressure, mangrove clearing, decreased water quality etc. Most fishers agree that the WSSV disease outbreak has had little effect on the actual productivity of their industry. In short, coastal fishers closer to the mangrove clearing shrimp farms of Esmeraldas, Guayas and El Oro previously benefited little from the farming industry, and now are experiencing a recovery in their ecosystems. At the same time those tens of thousands of *larveros* undeniably have been hurt by the WSSV outbreak. Finally, the fishers near Salinas and Manta that fished the open ocean previously had little effects on their industry, and now lack a market to purchase gravid females.

Conclusions

Ecuador pioneered shrimp farming in Latin America, to great financial gain, and great environmental detriment. The original profitability in the industry led to a largely unregulated growth period in the industry. Only after production had peaked, disease presented a formidable obstacle, and farmers began to require government assistance for progress has the industry finally allowed it to fall under some regulation. The efforts of the mid 1990s that followed the Taura outbreak, began a process that was then repeated on a more successful level after WSSV. One of the central reasons for the effectiveness of these regulations is that the industry no longer has demand for spatial expansion at this point. With more ponds in abandonment than in use, the issue of cutting mangroves, Ecuador's number one environmental problem, is severely reduced. Increasing effectiveness of government regulation, technical change and economic pressures have forced aquaculture towards a more sustainable path in Ecuador. Closed cycle of larval production, water quality monitoring, increased organic farming, recirculating raceway systems among other changes have significantly decreased environmental impacts of the farming system. As Ecuador's shrimp farming economy slowly regains its strength around the world, farmers are impatient to reach past levels of production. However, the slow growth that is now being witnessed can only be positive for the industry as it takes time to expand in the sustainable direction.

CASE II. PERU

Industry Development

Shrimp farming in Peru began in the latter half of the 1970s, first with experimental ponds funded by the Ministry of Fisheries and the *Instituto del Mar del Perú* (IMARPE). Shortly thereafter the private sector was able to obtain sixty land concessions from the government totaling 6,000 hectares. By 1982, the industry included 20 businesses generating $5.3 million dollars a year. Throughout the 1980s there was a large scale expansion of the industry to use all of the land granted by the original government concessions, and more. In the boom years of shrimp farming in Peru, from 1976 to 1992, it is estimated that roughly 40% of the original 8,000 hectares of mangrove cover was lost specifically due to shrimp aquaculture development.[84] Peru, like Ecuador is able to nearly continuous production throughout the year, with three growing cycles. Additionally, because Peru's industry developed slightly later, nearly 90% of the industry is based on the semi-intensive type model.[85]

Unlike Ecuador, shrimp farming in Peru is only one very small component of a large fishery sector, and hence not extremely important for the national economy. The only department of Peru in which shrimp farming is conducted with any significance is Tumbes. Tumbes, the only place in Peru in which mangroves exist, is the smallest department of Peru with a population of just around 200,000 people and a gross income of roughly $170 million in the past few years. The economy is balanced between many

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[84] Lacerda, L.D. 1993. *Conservacion y Aprovechamiento Sostenible de Bosques de Manglar en Las Regiones America Latina y Africa.* International Society for Mangrove Ecosystems.
[85] Coastal Resources Center et al.

different industries including 10% agriculture, 10% fishing, 8% industry, 35% hotel and restaurant business, and 25% services.[86] The department sits right on the border with Ecuador, so has a large informal economic sector in smuggling and black market cross-border trade, mostly cheap gasoline and oil. Until the outbreak of WSSV, shrimp production was steadily increasing to around 3,500 hectares of production, producing 4,620 MT of product for an export value of over $30 million in 1998. Nearly 80 separate shrimp farmers were in business, big a small prior to the virus.

Economic Impact of WSSV

In August of 1999, WSSV hit and production plummeted in 2000 to nearly a tenth of what it had been in 1998 (Fig 4.) 85% of shrimp ponds were abandoned such that only roughly 500 hectares were left in production with significantly reduced production and survival rates. Only 10 shrimp farming businesses remained, the ones with other sources of capital to invest in pond improvements. At Alicorp, Luis Miguel Zapata Vargas described his losses, from 1350 tons of shrimp-feed a month sold in 1997 to only 15 tons per month sold in 2000. This represents a loss in revenues of over $9 million for the company each year since the outbreak of WSSV.

The data suggests that while shrimp exports were valued at nearly 20% of regional gross income, a near complete collapse had no effect on the economy. Through interviews it is apparent that feed and ice companies as well as processing plant did require fewer inputs, but obviously were not significant enough to alter the economy. In terms of labor, interviews reveal that most of the labor for the Tumbes shrimp farming industry is low

[86] Instituto Nacional de Estadistica e Informatica et al.

skill seasonal migratory labor that only comes if the industry needs it. So, when the industry crashed, effected workers either found other jobs or migrated elsewhere. This suggests that the Peruvian shrimp industry can best be described as an enclave industry, with little repercussions for the local economy. This is to be expected as the industry in Tumbes is considered as more intensive and technologically based than the rest of Latin America, requiring more foreign inputs and expertise to run the industry. The one shrimp farm that was visited, INYSE, the largest in Tumbes, had a Spanish owner and operator, who lived in Lima, and a few experts from Lima that ran production. This effect is amplified by the border location of Tumbes and the ample opportunities in trade along the frontier.

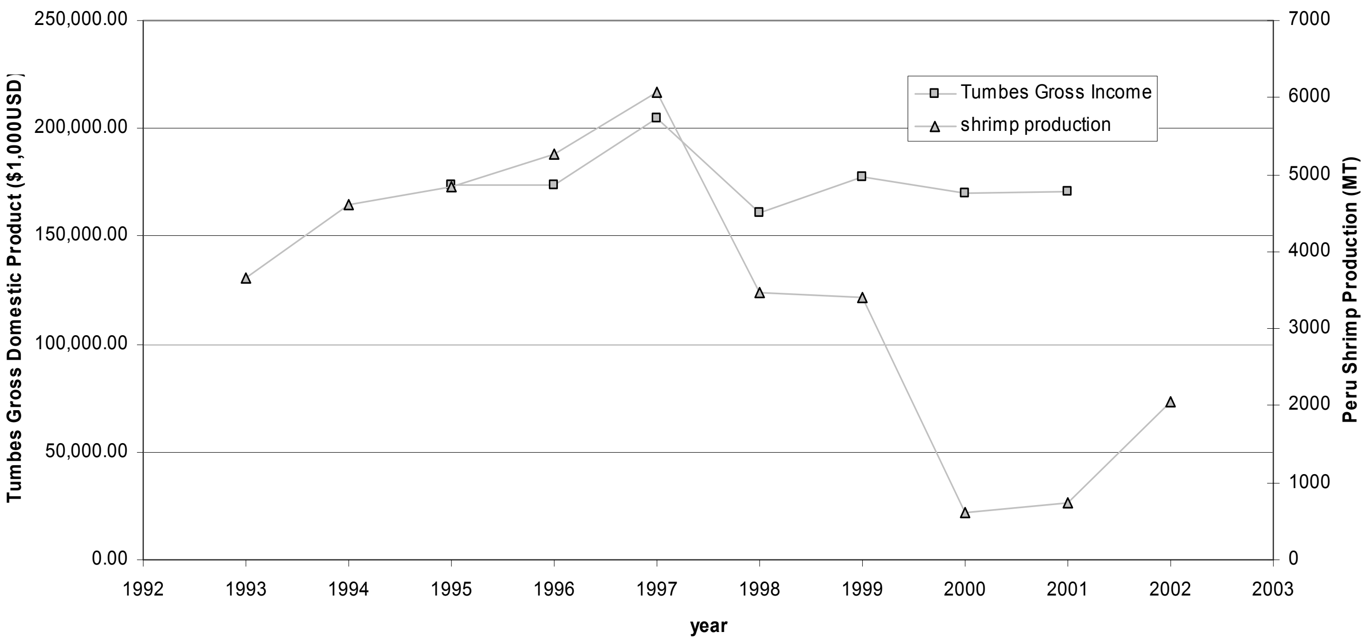

Fig 12. Peru - Shrimp Production *(Data:Instituto Nacional de Estadistica e Informatica*[87] *& Prompex)*[88]

[87] Ibid.

[88] Prompex, 2003 *Informe Annual Desenvolvimiento de las Exportacions Pesqueros,* Accessed from: http://www.red-arpe.cl/document/Informe%20Sectorial%202003.pdf

Legal and Government Intervention

The single most important environmental regulation of the industry in Peru was a government backed program to reforest and conserve mangroves. Most of this originated from a natural mangrove sanctuary and RAMSAR site located within Tumbes' small mangrove resource. Otherwise, there were several shrimp farmers who stated that with regard to laws regulating water quality discharge, there was no enforcement or monitoring mechanism. Government in Peru has served a minor role in regulating in the industry, partially due to its small size, and partially due to the cozy relationship between the government and the fishing industry as a whole.

Public-Private Partnerships and NGO Intervention

Due to the relative small size of the industry, there are no national networks of organizations working on a large scale, but several Public and NGO groups have become involved in the industry. Pro-Naturaleza has been working for years on the preservation of mangroves both in and around the Tumbes National Mangrove Sanctuary. They have also worked to start the mangrove replanting process, now that many shrimp farms have been abandoned. Their central focus has been on the positive side, trying to encourage many of the farmers that have abandoned their ponds to allow for replanting efforts.

Recently, a plan for the development of the Peruvian-Ecuadorian border[89] has focused towards promoting other industries besides shrimp farming in the region. The drastic losses associated with the WSSV outbreak and the relatively small benefits received by

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[89] Lucich, Luisa Galarza and Testino, Manual G. 2002. *Tumbes: Una propuesta para el desarollo.* Plan Binacional de DEsarollo de la Region fronteriza Perú – Ecuador. Capitulo Perú

the community have placed the development of aquaculture as only a small component of a larger development picture. Specifically, the plan mentions the benefits for the development of the region that the intensification of the industry will bring, as less land is required for production and more can be converted back to mangrove cover. In a chance encounter with the regional president of Tumbes, Rosa Yris Medina Feijoo, she discussed shrimp farming as a non-factor for the future of the Department. Instead, the president and the binational plan call for restoration of previously harmed eco-systems and an increased investment in tourism as a more sustainable future.

Not all government programs are acting together however, IMARPE the government sponsored fisheries institute, in currently building a production site for laboratory raised generations of genetically selected SPF shrimp to serve the local market. The research center is also in charge of the careful monitoring of ecosystem quality surrounding the aquaculture ponds, thus is very aware of the changes that need to be addresses to make the industry more sustainable. While the vast majority of the IMARPE national program is focused on other types of aquaculture and fisheries research and development, the Tumbes office is trying to works towards a more sustainable future.

Technical Change in the Industry

Due to the fact that Peru's industry was overcome so quickly, only the few with alternative sources of capital were able to continue to produce shrimp. These few have begun to take a series of measures that have led to the removal of their industry from dependency on the local ecosystem. Of the farms that remained in Tumbes, all were going through serious investments to remain in business. Many farms were switching over to more intensive production, with complete recirculation of water, lined tanks and regular water quality and shrimp health analysis. Additionally, all major farms had switched over to laboratory produced larvae.

There were many stories shared by farmers and fisherman alike regarding the various remedies pursued by the farmers that were caught unprepared for the disease outbreaks. These ranged from placing garlic and lemon juice or diesel fuel in the ponds, to more scientifically sound methods like those mentioned below.

One shrimp farm in particular owner by the largest seafood packing plant in Peru, INYSE initiated a very detailed shrimp disease management plan as soon as WSSV was discovered in Ecuador. First, they began coordination with the Ministry of Fisheries to prohibit the import of marine species from countries that carry the WSSV disease. Second, they began PCR analysis of samples of all larvae before it enters their ponds. Additionally, only certified laboratory produced larvae are now accepted at the farm. Prior to WSSV, the majority of their ponds were supplied with wild caught larvae. Third, All vehicles, machinery, personnel etc. that may be transporting the WSSV from outside sources are sanitized and decontaminated prior to entrance to the farm. Lastly, laboratory technicians have begun regular sampling and maintenance regimes for water quality, and shrimp health to limit chances of stress or disease.

Their efforts were too late however, because three months after starting this plan, WSSV was noticed in their ponds. Thus, further actions were then taken including a change from a 1mm mesh filter for intake water to a 120 µm mesh filter to prevent the entrance of estuarine organisms. Also, probiotics are now used to clean water and allow for fewer amounts of water intake and discharge. Additionally, as capital is made available, they are lining tanks with plastic, to avoid contact with the soil. By August of this year, their first zero water exchange ponds were in production.

Shifting demand away from laboratory purchase larvae has turned the town of Bendito, on the Ecuadorian border into a virtual ghost town. Previously, tens of truckloads of larvae would leave the Bendito estuary daily to cross the border into Ecuador for sale to shrimp farmers. Since the WSSV outbreak though, the demand for wild caught larvae is so low that only a single truck passes through Bendito each day and many of the houses are left abandoned. When the shrimp farms were originally developed they did take away marine resources by occupying otherwise open access resource, but provided jobs, namely for the *larveros*. Now, with that gone and the shrimp farms abandoned or otherwise occupying the estuary, there are few sources of income.

Effects on Fisheries

With the exception of the fishers that worked the northern Zarumilla estuary, none of those interviewed had experienced any decline in their fisheries that they attributed to the shrimp farms, nor any change as a result of the WSSV. Without exception, every fisher complained of the large factory trawlers that plied their shores once a year and took all of the shrimp and destroyed their resource for the rest of the year. It was explained that these trawlers had all the political power in Peru as they were mostly owned by government officials. Hence, there was a relative lack of concern about the small problem of shrimp farms. Additionally, there were no fishers that reported having depleted resources due to wild epizootics. Although some fishers outside the mangrove estuary were affected by the end to a demand on fishing for post-larvae, this income was described by most as supplemental income.

On the other hand, the opinion of fishers with the Zurumilla estuary occupied by the shrimp farms had a great deal to say about the deleterious side effects of the farms. The complaints ran the whole gamut, including mangrove destruction or occupation, decreasing estuarine catch due to the consumption of other larvae by the farmed shrimp, loss of larvae for seed stocks to ponds, and the poor quality of effluents from the ponds.

Conclusions

The Peruvian industry in most ways was affected just the same as Ecuador, but for one simple reason—its geographic situation. Otherwise, the Peruvian industry was in many ways unique from its northern neighbor. The real difference now remains to be seen if the Tumbes region will be able to recover its shrimp farming economy. Relative to total production, the losses in Peru were much greater than in Ecuador, but the production numbers have rebounded quickly in 2002 and the past year. A greater focus on intensification of production and a consolidation in the industry to only those farmers that could afford the improvements bodes well for the industry's environmental sustainability.

In sum, scale effects have severely down-sized the industry as a whole, while composition and technique effects have intensified and reduced its environmental impacts.

Case III. Mexico

Industry Development

Shrimp farming in Mexico for many years was hindered by governmental policies that remained from the agrarian reform of the revolution. Due to laws not changed until the early 1990s, Mexico's coasts were owned by thousands of small fishing cooperatives and *ejidos*, that were not allowed to sell their lands, or allow private enterprise into the fishery trade. As a result, there were few dollars invested in the development of the industry on until economic reform in the 1990s allowed for the sale of coastal property by the cooperatives and *ejidos*, and market entry for private corporations.[90] This change had a stunning effect on the increase of Mexican production, from under $50 million in 1992 to over $300 million 10 years later.

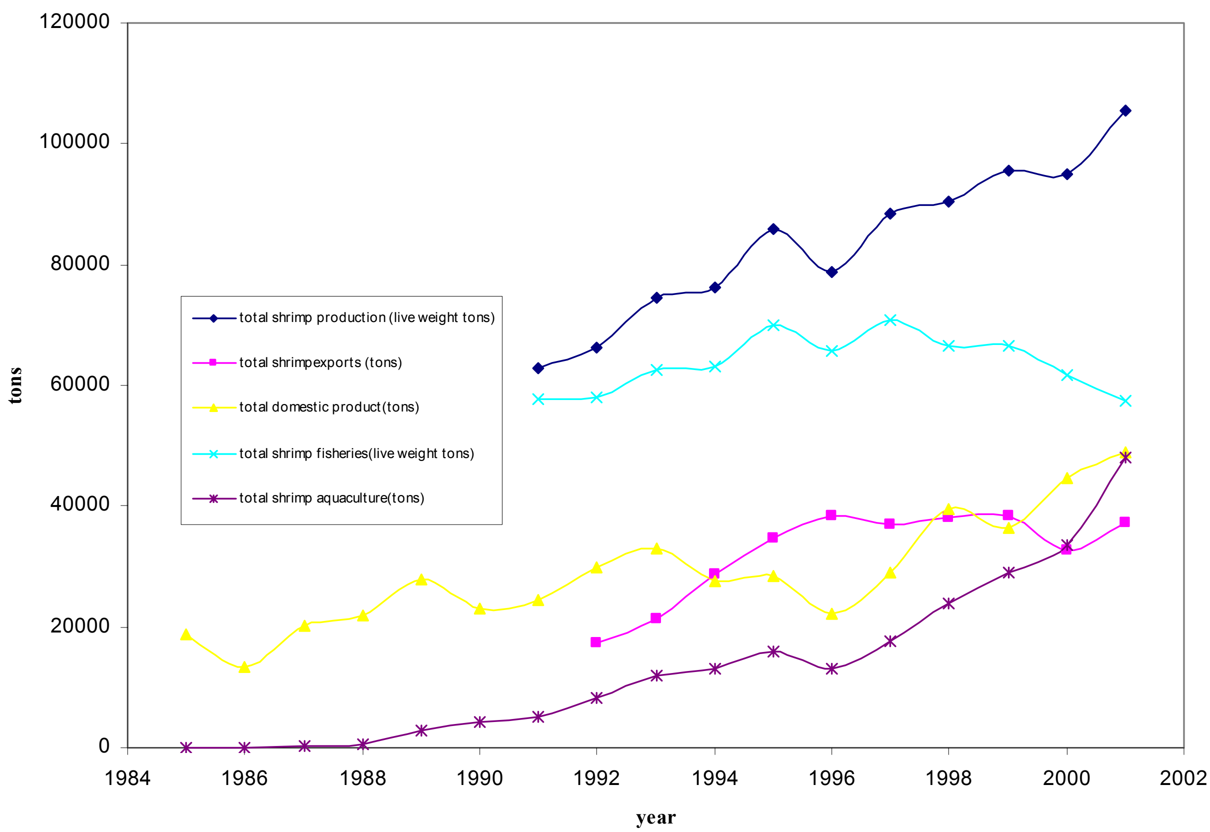

Fig 13. Mexican Shrimp Production Figures(1985 - 2001) *Source: SAGARPA Subdelegación de Pesca.*

[90] DeWalt, et. al. 2000.

For various reasons, the Mexican experience with WSSV is very different than that observed in Peru and Ecuador. The response of the Mexican industry is well worth noting for farmers and policy makers alike as they bring to light some very important mechanisms for prevention of future disasters such as the continuing WSSV, and other environmental problems both within and separate from the shrimp industry. Some important circumstantial differences must be discussed: The shrimp production system in Mexico is diversified by a substantial wild-catch fishery that begins in September and lasts through the New Year. Additionally, the larger and wealthier Mexican populace is more capable of affording the relatively expensive shrimp product than in Ecuador and Peru. Hence, a substantial local market for shrimp has developed and served as a cushion for the declines in production that would otherwise have been experienced by the occurrence of the WSSV. Perhaps most significantly, because there is not one continuous growing season, due to colder winters, the virus is less capable of spreading from one season into the next generation. It cannot be ignored that cooperation between the industry and government, public-private partnerships and NGO presence in Mexico have had a strong effect preventing serious outbreaks such as those that crippled the Ecuadorian and Peruvian production systems. All of these factors have contributed to a much smaller and delayed over-all effect to the shrimp economy in Mexico in comparison to the previous two case studies.

Economic Impact of WSSV

Mexican shrimp production on the aggregate has appeared to be unaffected by the outbreak of WSV in 1999 – 2000. Aquaculture production has increased steadily from a mere 35 tons in 1985 to over 48,000 tons in 2001. Though official production figures are not yet out for the 2002 and 2003 growing seasons, data from some several sources indicate flagging production numbers,[91] mostly due to an increased prevalence of WSSV and financial problems caused by the reduced productivity and profitability incurred while dealing with WSSV contaminated ponds. The only other decline in shrimp production indicated in the data was in the 1996 growing season, when production declined 2,750 tons from the previous year, or 17% of total aquaculture product. This was due to an outbreak of the Taura Syndrome Virus (TSV). In the leading shrimp producing state of Sinaloa, the production in 1996 was reduced by nearly 30%.

Aquaculture production in 2001 was mainly distributed between 3 coastal provinces on the west coast of Mexico, Sonora, Sinaloa and Nyarit. The highest levels of production were in Sinaloa, with nearly 20,000 tons, followed by 15,000 in Sonora and 2,700 in Nyarit. However, due to the complexity of the shrimp supply chain and the relative immaturity of the industry, the regional statistics are not so reliable and vary on the order of thousands from one source to the next. Sources agree that in 2002 and 2003 production began to finally feel the effects of WSSV, three years after its first detection. In 2002, production in Sonora was down roughly 2,000 tons, or about 10% from the previous year.[92] While production in Sinaloa continued to grow by 3,000 tons in 2002, initial production figures show that production in Sinaloa was down by 1,300 tons in the first three months of 2003, on pace to produce roughly 5,000 tons or 25% less product for

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[91] Ocean Garden Products, Inc. *Comportamiento del merecado del camaron.* January – March 2003 20:105 and Fisheries Information Services

[92] *Fisheries Information Services.* 2002 "Mexican Shrimp Production Down from Last Year." November 26, 2002 www.fis.com

the year. These declines are only being noted in the areas of Mexico where the industry has been around the longest. Nyarit and other smaller producing states are showing no signs of diminishing production and contribute significantly to over all growth figures in recent years.

Mexico is unique compared to other shrimp farming Latin American economies in that it supports a strong domestic demand for shrimp sold in local markets around the country, along the roads, and in nearly every restaurant. As a result of this, as the world markets became saturated with shrimp and prices began to drop in 1998-99, Mexico's export earnings from shrimp began to level off at around 450 million dollars. There are two notable declines in export earnings in 1995 and 1999, these can be explained partially by the problems created by first Taura then WSSV. When these viruses hit, the crop will perish as soon as three days following detection. Hence, the shrimp are harvested rapidly and often not suitable for international export. Thus, in Sinaloa, while production of shrimp continued to grow, crops were being increasingly harvested at less than ideal production sizes. From 1998 to 2000 exports from shrimp farms in Sinaloa halved in value from roughly $60 million to $30 million.[93] These declining foreign revenues in the first years Mexico was exposed to WSSV contributed to the financial problems that now are being experienced by many farmers.

An interview with Jose Luis Gitierrez Venegas, the Coordinator of Acuaculture Projects for Ocean Garden, the leading exporter of Mexican shrimp to the United States, helped express the reality of the problems created by disease in Mexican Shrimp Farming. The

[93] SAGARPA and CONAPESCA. 2001 *Anuario Estadistico de Pesca*

Taura Virus outbreak in 1995, was the first wake up call for Mexico as to how serious an impact disease could have on the industry. It was at this point that the government began moving to protect the industry. Laws were passed to regulate effluents and the biosecurity of shrimp larvae that would be used to seed ponds. Although it is clear, not until the WSSV outbreak in 1999 and increasingly in 2000 did the government began to take strong action. Mr. Venegas discussed the main financial effects when a virus hits a farm hard. Because of the relative boom experienced in the industry, individual farms were easily able to get loans for facilities improvement and investment. When the WSSV or Tuara hits, it doesn't tend to give too much warning and instantaneously potential profits are lost, as it is necessary to harvest right away. As a result, returns are not made back at the expected rate such that those with long term loans, especially with high interest rates, cannot be paid back, and farmers begin to experience financial crises. In Sonora, when the virus first hit, there was large scale abandonment of farms and relocation at first. This strategy was possible because of the massive profits returned in the earlier years, but not sustainable in the long run. Over half of the farmers in Sinaloa are in serious debt trouble and some are beginning to be called into court to pay their defaulted debts. According to an Ocean Garden report, in early 2003, 8,000 hectares of farms, or about 20% of the total shrimp farm area in Sinaloa, could not be planted due to lack of capital.[94] On top of it all, because the industry has such strong backwards linkages, Mr. Venegas said that the laboratories and food producers have begun to lose there ability to pay their debts. Lack of governmental support for these projects makes it difficult for them to operate at high cost, low product levels. In the mean time those from the social sector are even more affected as they live on nearly 100% social credit from the

[94] Ocean Garden Products et al.

government. As profits fall, so dues their ability to pay back loans and ask for assistance though difficult times. Mr. Venegas also blames the corrupt politics for maintaining this problem, by requiring further bribes in order for the social sector to receive benefits and continued.

At a conference on Best Management Practices(BMPs), five shrimp farmers that were living through this experience discussed their problem along the same line. They owned their own farms, but because of WSSV were not able to pay their debts and now were forced to work off farm to raise the money. The farmers did not have the start up capital to begin a season of shrimp farming, thus their ponds lay untouched.

Legal and Governmental Intervention

On July 19, 2002, the *NORMA Oficial Mexicana de Emergencia NOM-EM-05-PESC-2002,* was signed to create public-private partnerships and a regulatory framework to control and protect the growing shrimp farming industry from various diseases, specifically WSSV, Taura and IHHN. In the introductory segment, the new law recognizes that these pathogens can be introduced from any number of vectors, including water, unwanted organisms, humans, machinery, and post-larval stock. Additionally the law recognizes that the virus tends to break out in clusters, because one farm's wastewater can then be immediately used as the input water for another tank. Then, the law goes on to list a number of problems that must be addressed in order to control and prevent the spread of these diseases: water quality, source of post-larval stock and anti-biotic use and accumulation. The object and purpose of the law translates as follows, “This Official Emergency Law of Mexico has as an objective the establishment of requirements and methods to prevent the spread of high impact diseases and for the use and application of antibiotics in this country’s shrimp aquaculture.” The law then requires that in order to initiate a growing season, basic information must be submitted to a local aquaculture specialist regarding condition of the farm, and what laboratory the post-larvae stock came from. In the case of Sinaloa, that organ of the government is called CESASIN, or Sinaloa Center for Aquaculture Sanitation. If a disease is detected during a growing season, it must be immediately harvested and reported. The law also prohibits the use of *chloramphenicol* or *furazolidona* anti-biotics for the treatment of ponds with shrimp. To this end, if a crop is to be harvested for export, first a sample must be sent to the lab sponsored by SAGARPA. If the sample tests negative for the aforementioned prohibited anti-biotics, then the crop may be harvest and processed for export.

Beyond these, the law then follows with several specific mandates. First, shrimp farmers are told they should place a 500 micron net on the water intake pumps if the shrimp farm’s intake is located in an estuary or lagoon. This is to avoid the taking of that which is not considered the shrimp farmers’ property, estuarine organism and larvae. Shrimp farmers are told that they should especially be concerned during reproductive cycles. Local aquaculture sanitation councils are to be in charge of informing farmers as to when these cycles approach. Second, mentioning the risk that is posed by the introduction of wild harvest post-larvae, it is mandated that only laboratory produced shrimp are to be used to seed ponds. Post-larvae may only be purchased from government certified laboratoeis that meet the standards mandated by Official Mexican Law NOM-030-PESC-2000. The law also reminds shrimp farmers of the effluent standards set for wastewater discharge set by Official Mexican Law NOM-001-ECOL-1996. Several divisions of the government are placed in charge of regulating the aforementioned provisions, including, SAGARPA[95], CONAPESCA[96] and SENASICA[97] According to the director of CIAD[98] as of July 2003 about 27% of the farms' production and catch had been certified by the SAGARPA appointed agency.

Public-Private Partnerships and NGO efforts

In response to the new laws, several key institutions were put into place by a combination of private and public support in Sinaloa. The Sinaloan Institute of Acuaculture (ISA) has just completed its first year of activity. The membership organization serves to support the industry through exchange of information, promotion of Sinaloan aquaculture interests, communication network of producers and evaluation of production. The second institution that has most relevance for this study is the Sinaloan State Committee for Aquaculture Sanitation (CESASIN). This research, extension and regulation service, also in its first full year of service, gathers information on farm production, disease prevalence, methods of production. The Committee has local extension officers, mostly shrimp farmers themselves, that serve the farming community in the case of an outbreak. The regional officers are also in charge of certifying that ponds are following the appropriate laws and regulations, though are not charge with enforcing in the case of a

[95] El Servicio Nacional de Sanidad Inocuidad y Calidad Agroalimentaria
[96] National Commission of Aquaculture and Fisheries
[97] National Service of Sanitation, Health and Agrofeeds
[98] Centro de Investigaciones Acuicolas y Desorollo

violation. Finally the Food and Development Investigation Center (CIAD) in Mazatlan serves Sinaloa as a research institute providing analysis and research solutions to the various disease problems. As with any other bureaucracy, there are numerous other agencies involved in the gathering and dissemination of information and regulation of the aquaculture industry, but these three are the most relevant to this study.

Perhaps more important than what the law actually says, is what the expert s are saying, and the farmers are doing. An interview with the state manager of CESASIN[99], Ricardo Urías Sotomayor provided a great amount of insight into what is being done on farms in Sinaloa to prevent WSSV and other viruses. While he said that there is no officially mandated position of the local offices, there were some well accepted practices in the region. He cited a paper by Lucio Galaviz Silva entitled, *Contingency Methods to Prevent the Introduction and Dispersement of viruses(WSSV, TSV & YHV) in Shrimp Culture.*[100] The recommendations therein used by CESASIN extension agents in the field can be abbreviated as follows: (1) Identify precisely the virus (2) harvest the crop without draining water, treat with chlorine, drain tanks and then let thoroughly dry (3) clean, bleach and put calcium on the bottom of the tanks (4) thoroughly disinfect all equipment (5) advise all other neighboring farmers and relevant authorities (6) Establish a monitoring system of the wild populations surrounding the pumping stations (7) Periodically disinfect the entire farm, equipment etc.(8) restrict entry to only sanitized vehicles (9) maintain and analyze data on the farm for trends. After Harvesting the report

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[99] Comite Estatal de Sanidad Acuicola de Sinaloa. A.C,

[100] Silva, Lucio Galaviz. 2002. Medidas de Contingencia para Prevenir la Introduccion y Dispersion de enfermidades Virales(WSSV, TSV & YHV) a los Cultivos de Cameron. Centro Nacional de Sanidad Acuicol, Facultad de Ciencias Biologias, Universidad Autonoma de Nuevo Leon.

says to: (1) completely clean pond bottoms with chlorine and calcium carbonate (2) Let dry for 20 – 30 days (3) clean and disinfect the pump intake nets (500um) and entrance canal nets (1 cm). (4) take physical and chemical analysis of the soil bottom for organic material, Ph, ammonia, color, smell etc.(5) re-flatten and level the pond bottoms.(6) only refill tanks when input water quality is good, no dredging, no neighbor draining ponds. (7) Only ever use laboratory certifier pot-Larvae, and be sure to have them independently tested. (8) Be sure water quality is stable and normal. (9) During growing season, be sure to exchange water as infrequently to add as little new organisms as possible. (10) be sure not to add too much fertilizer or feed to the system. (11) Avoid the use of anti-biotics. (12) maintain consistent temperature, dissolved oxygen and ammonia.

There are numerous NGOs involved in Mexican Shrimp Aquaculture, but the two most prominent and active are Conservation International(CI) and the World Wildlife Fund(WWF). Both organizations are working to support the growing industry through extension, conferences and sustainable development programs. In Bahia Santa Maria, Conservation International has been working to implement BMPs with existing and proposed farms. Workshops on water quality, disease prevention, and sustainable aquaculture have been coordinated by both NGOs. It is worth noting that there is a markedly different perception of CI in the aquaculture circles, where the organization is making efforts to further develop the industry, versus the wild-catch fisheries where CI has a less positive name, due to its efforts to decrease industrial fish catch.

Technical Change in the Industry

The recommendations of all the various actors, as well as the mandated legal text, are received sporadically by individual farmers. Their involvement in the regulation, conservation and development of the industry has led to a high acceptance rate. Farmers interviewed in the region of Bahia Santa Maria verbally confirmed their compliance with the new laws and the suggested Best Management Practices. The three most common solutions to for the initial prevention of the disease according to the farmers interviewed were (1) Maintenance of consistent water quality (2) Purchase and testing of certified laboratory produced Post-Larvae (3) Prevention of introduced foreign organisms (through preventative filtration techniques, such as 500 um nets). As of yet, there have been no significant studies to measure if these techniques significantly prevent or resist disease, but the theory is enough to convince the farmers who are looking for any solution.

At a conference supported by Conservation International on Best Management Practices in Mazatlan, 25 – 30 shrimp farmers gathered to discuss their problems and learn from experts. Dr. Claude Boyde, a pre-eminent aquaculture scientist discussed water and soil quality issues and led field exercises to enforce the methods. Most importantly, in individual interviews, farmers discussed the recognized importance of preventing WSSV and other diseases through water quality control. It was understood that by maintaining constant temperature, salinity, Ph and primary productivity, shrimp would be less stressed and able to fight off many existing threats. High levels of dissolved oxygen were recognized as crucial to shrimp production, day and night. The recognition of water quality importance are of great environmental significance, because too often in the waste water expelled from shrimp farms is highly unbalanced and thus contaminates the surrounding estuary when discharged. Additionally several farmers discussed their usage of nets to filter incoming water from possible introduction of infected organisms. Lastly, and significantly different than Ecuador and Peru, a universal recognition existed at this conference that cutting of mangroves for construction of new ponds was not only strictly prohibited, but also would increase the likelihood of disease prevalence in the future. Wet, estuarine soils would never be able to dry out and pathogens could remain indefinitely from cycle to cycle. Finally, the importance of a limited usage of fertilizer, calcium carbonate and feed was stressed by farmers, so as to not push the pond ecosystem into imbalance of anyone ingredient. All of the following techniques are discussed in detail in the research of the aquaculture scientist, Claude E. Boyd at Auburn University in Alabama. Dr. Boyde has for years published extensively on water and soil quality management as a necessity for healthy and productive ponds.[101,102] All farmers publicly stated that they did not use any type of anti-biotics. A report supported by Conservation International – Mexico shows significantly consistent results.

The CI report[103], still in its final stages of production, is being generated from data gathered from 23 shrimp farms in the Province of Sinaloa, Mexico, representing slightly over 5% of the total number of farms, over 10% of the hectares and over 25% the tonnage and value of production in the State. The majority of the farms investigated were semi-

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[101] Boyd, C.E. 1990. *Water Quality in Ponds for Aquaculture.* Alabama Agricultural Experiment Station, Auburn University, Alabama.
[102] Boyd, C.E. 1995. *Bottom Soils, Sediment, and Pond Aquaculture.* Chapman and Hall, New York, NY, USA.
[103] Fritch, Lourdes Patrica Lyle and Beltrán. 2003. *Informe Final de las Encuestas Sobre Practicas de Manejo en el Cultivo de Cameron en Sinaloa.* Conservation International

intensive, with the exception of two extensive and one intensive. Over 80% of the farms dried and applied calcium carbonate to the pond bottoms. Nearly 2/3 actively took soil samples for laboratory analysis. All but one farm measured dissolved oxygen regularly. Nearly all farms also measured Ph and used a sechi disk regularly to measure turbidity. All but two farms obtained their post-larval stock from certified laboratories. The two which did not were both extensive farms, using wild larvae from adjacent estuaries. Again, 22 out of 23 farms used fertilizer to support primary productivity. Nearly all the farms used feed combined with medicine when the shrimp populations began to show signs of a disease outbreak including: Oxitetracycline, Enrofloxazine and Elancovine, mostly for bacterial outbreaks. One farm reporting using onion and garlic mixed with feed to combat bacterial and viral outbreaks. While 22 farms had some form of disease present throughout the year, about 50% had positively identified WSSV as the specific cause. Upon disease outbreaks, 87% of the farms reported harvesting their stocks immediately, while the rest incinerate the product. Over half of the farms have available PCR testing to verify the presence of viruses.

Effects on Fisheries

Interviews with shrimp fishers in Bahia Sata Maria, Sinaloa revealed that although shrimp catches were down in recent years in the bay, the shrimp farmers were not specifically to blame. Over-all, while Mexican aquaculture supplies are booming, wild-harvested shrimp have in the last seven years declined in productity. Estuarine shrimp catch declined over 5,000 tons or 20% from 1999 to 2001[104] and have continued to slip since. Significant tropical storms this year have further exacerbated the problem.

[104] SAGARPA et al.

Estuarine shrimp fishers are strictly regulated to fish, without the aid of combustion engines, and only after the government has officially called the start of the season, usually in early September. There are a variety of shrimp, white (*vannamei)*, brown, (*californiensis),* and blue (*stilirostrus)* that are all caught by the fishers, while only *P. vannamei* is currently farmed extensively. When asked about the effects of WSSV, not a single fisher claimed to have witnessed the disease in the wild, or claim that he had experienced any effect with the advent of the disease. A few fishers were able to postulate that if the bay (60 kilometers long) were to become over-developed with shrimp farms they may notice a difference, due to the poor fishing right outside pond discharge pipes. Contrarily, some fishers said any farm virus would help their industry, because current shrimp farms production is so lowering domestic prices that they are less able to realize gains from their harvests. That said, it can safely be concluded that the WSSV has not affected local poor fishers in Mexico the way it was able to in Ecuador and Peru.

Conclusions

Thus, the Mexican experience with WSSV has been entirely different than the first two cases. Not only has the industry remained strong throughout the outbreak of the virus, but it has continued to grow. Legal reforms, with strong requirements, focused on sound marine environmental science, and supported by both the industry, government and academics has helped to formalize a process of sanitation in the ponds that it appears pre-existed much of the regulation. Contrary to Ecuador and Peru, it appears much was learned from the Taura outbreak in 1995 and several laws were enacted to deal with the environmental drivers to the virus. In Mexico, ownership was taken over the causes of the virus, contrasted to the legal suits that resulted in Ecuador towards the banana industry, trying to pin the blame for the Taura outbreak on their pesticides. Farmers appear to be choosing the environmental solution, not just to appease consumers, but for true benefits to their production. Many farmers interviewed expressed excitement in their new innovations to increase their "biosecurity" and at the same time help protect the environment. Importantly, farmers are very careful to control water quality in recognition of the implications resulting from drastically changing environments. Billie R. DeWalt's thesis that the late start of shrimp farming in Mexico, due to reform in property rights, cannot be ignored as an important driver to the sustainability and resilience evidenced in Mexico.[105] On the down side, WSSV does now appear to be creeping through the cracks of the Mexican regulatory system and perhaps regulations have only served to delay the inevitability of a crash. Second, there has been abandonment of farms and new construction that has significant environmental impact with little net gain. Increasing capital constraint also do not bode well for the environmentally positive trends thus witnessed, if the disease were to strengthen.

In conclusion, substantial technical changes and cooperation in Mexico have resulted from the combination of Taura and WSSV outbreaks, including most significantly, nearly universal acceptance of laboratory certified larvae, water quality control, monitoring of effluent into local ecosystems, reduced water exchange, recognition of the need for dry, higher soil without conflict with mangroves, and beginning of filtration of input waters. These technical changes have benefited both the economic return and environmental impact of the relatively nascent Mexican Industry.

[105] DeWalt, 2000 et al.

ANALYSIS I : IMPLICATIONS FOR SUSTAINABILITY

WSSV has obviously had a negative impact on the short term sustainability of the shrimp farming industry world-wide. On the other hand, due to this and other diseases, the industry has been forced to count their losses, fully evaluate what were once considered to be unfortunate but unaccountable externalities, and begin to practice a more environmentally sustainable business. Though it is difficult to determine on which side the sustainability spectrum the industry currently resides, it clear in which direction it is moving. As the massive profits of the 1980s and early 1990s have passed away, shrimp farmers are now forced to fully evaluate their practices, cut cost to what extent possible and preserve their local marine environment. WSSV has forced the issue in Latin America to the extreme—no other disease has so dismantled a regions industry. Even the earlier diseases were fully recovered from without much change as losses in one country were made up for gains in another. This is especially true in Asia, as poor practices bounced diseases around the region, then around the world. It is evident that WSSV in Latin America is somewhat different, the widespread ramifications and the severity of the economic losses have shaken a previously stoic and stubborn industry.

Negative Environmental Impacts

There are four important negative impacts that WSSV outbreaks have had on the environment in general. First, shrimp ponds with diseases have served as incubation areas for the spread of these otherwise sporadically occurring diseases to natural populations. The potential, as in the Mexican experience with IHHNV, for diseases to spread to wild populations and cause significant mortality presents significant concern for fishers world-wide. Although little reliable data is available, due to the much less densely populated wild populations, introduced diseases so far have an exponentially smaller impact on natural populations. Second, antibiotic and other chemical use were on the rise, due to lack of knowledge about how to deal with disease. Currently, due in part to international pressure and an increased dissemination of BMPs, it is surmised that the use of these chemicals is on the decline. Third, and perhaps the greatest long term impact of disease outbreaks, is the resulting introduction of non-endemic species around the world. There is a litany of examples in environmental literature of the dangers of introduced species, and shrimp are no exception. The dangers are increased by the coupling of introduced shrimp species with companion pathogens into foreign waters, such as the Taura and WSSV introductions. In Brazil, Colombia and other Latin American countries on the Atlantic Ocean *P. vannamei* is being introduced as the prawn of choice for shrimp farmers. Finally, though this may be a disguised blessing for the environment, abandonment of diseased ponds for newly better constructed ponds leads to greater land conversion and degradation. This has been especially apparent in countries that were once prominent in production, but have since experienced great declines, such as Ecuador and Taiwan. The upside of abandonment is that in some cases, deserted ponds have been replanted with mangroves and restored to their previous natural setting. Additionally, newly constructed ponds tend to follow the newer BMPs and regulations for pond construction, which are much more sustainable for the environment in the long run. Thus, abandonment, while in the short term negative for the environment, may in the long term be a boon.

Positive Environmental Impacts

The shrimp farming industry has been oft criticized by environmental organizations for four major divisions of environmental harm: damage to mangrove ecosystems, effluent water quality and resulting contamination of neighboring ecosystems, pressure on wild shrimp for post-larvae seed and the fishmeal content of processed feed. In all four of these categories, disease outbreaks have forced the industry to lessen its impact on the environment and pay more attention the quality of its surroundings. First, the revelation by scientific data that mangroves are an unsuitable location for the construction of shrimp ponds, due to their wet soils, has been of utmost importance. Thus in all countries investigated it is currently illegal to construct ponds in reclaimed mangroves, and replanting efforts have begun. As well, shrimp farmers have begun to faithfully frown on this activity for sound scientific reasons. The impacts of this major shift cannot be overstated. However, there still remains a significant population of farmers world-wide that cannot afford the luxury of proper site selection, thus the importance of strong regulatory regimes.

Second, the BMP emphasis on water quality within the pond has unintended benefits for the ecosystems surrounding the pond. Additionally, governments have increasingly begun to regulate discharge water quality to prevent to spreading of diseases from one pond to the next via the supporting ecosystem. Moreover, the screening of intake canals to prevent the entry of local organisms, while protecting the ponds, also reduces pressure on those supporting ecosystems by creating further barriers for the harms wrought by the pond. In Latin American estuaries, these changes have already and will continue to increasingly benefit those fishers and subsistence level poor that rely on the open-access mangrove fishery. As the damaged ecosystems begin to recover, a cycle which takes many years, local fisheries production will increase.

Third, a huge change that has taken place in Latin America with *P. vannamei*, but not yet in Indo-Pacific waters, is the development of closed cycle laboratories, removed by generations from wild caught populations. This has tremendously reduced the impact of fishers on wild post-larvae and broodstock. Additionally, the thousands of tropical aquatic organisms that rely on the mangrove estuaries for the protection of their young are now on the road to more productive populations, for the benefit of all. However, the social ramifications of this change are not as positive for subsistence level fishers many of which relied on the partial income the larval fishery supplied. Unfortunately in the Indo-Pacific, *P. monodon* has not yet been bred in a generation after generation closed cycle breeding process, and pressure still exists on wild caught populations for seed stock. This is partially due to the tremendous power of the hatchery industry in Asia that has a lot to lose should the shift be made.

Finally, although with less obvious benefits for the environment, the reduced profitability of the industry must be discussed. Increased global demand has been more than met by increased supply, even with disease outbreaks, resulting in falling world prices. This reduced profitability have made it more important for farmers to cut costs, take more care in the long term viability and investment in their ponds and compete for the least amount of input for a certain output. One such example is shrimp feed, which is extremely costly throughout the production cycle. Currently, intensive shrimp farmers around the world are aiming to lower their Food Conversion Ratios (FCRs) to below the average of 2:1, for their own economic benefit. Claude Boyd, in interview, stated that it is the inevitability of the industry as profitability is reduced to begin to cut fishmeal protein content and food costs. He had observed similar changes in the catfish and other earlier aquaculture industries. Additionally, researchers are trying to develop less costly feed with reduced quantities of fishmeal and fish-oil, by replacing it with more soymeal and oil. The implications, if the trends in feed management continue, are an even further removal of the shrimp industry from the pressures it was previously exerting on the global marine environment.

ANALYTICS II: COMPARATIVE ANALYSIS

The first order of analysis for this investigation was to determine the direct affect of the WSSV outbreak on various Latin American countries. A second order of analysis is necessary to gain understanding of why there were such drastically different experiences with the virus. The Mexican industry, while feeling the impacts of the disease to some degree, shows little sign of a resulting aquaculture economic slowdown in the aggregate, while Ecuador and Peru have been devastated. For the most part, the differences between Mexico and Ecuador will be discussed, because Peru's situation is mainly a reflection of the poor practices to their immediate north. The following discusses four categories of causation differentiating the case studies: (1) geographical determinants, (2) economic determinants, (3) governmental determinants and (4) international NGO participation. The experiences of these three case studies and why this may be important for future aquaculture development and more generally sustainable growth in resource based industry throughout the developing world.

Geographic Determinants

Vulnerability and Value of Natural Ecosystems

Geographically, the case studies take place in two separate latitudinal regions of the world—the equatorial Peruvian and Ecuadorian industries versus the extra-tropical Mexican industry. This has many implications, one of which is the natural ecosystems that must be displaced in order to develop shrimp farming areas. In Mexico there are significant mangrove swamps but there is also significant amount of barren dessert coastal plain. Especially in the Sonoran and Sinaloan province, the industry has built itself on otherwise unproductive and abundant dessert plain. This is not to say that the dry lands on which it has been developed do not have other environmental uses, but, their natural productivity is much less than the diversity and abundance of the mangrove ecosystem in the tropics. Due to the lack of development in Mexico of its mangrove swamps, these nurseries have remained preserved and shrimp farms have been built on more stable higher ground.

On the contrary, in Ecuador, there was little option in most areas but to clear mangrove forest to create ponds.[106] The rest of the land near the coasts was already in productive agriculture or covered with dense terrestrial forest. This difference has strong implications for the connectivity of the shrimp farms to their natural ecosystems. Those built in mangroves are more difficult to dry out, avoid unwanted vectors, and maintain sturdy construction. On the other hand, the more removed farms in Mexico are on higher ground, easier to dry out, less connected to their marine environment and more able to be bio-secure.

Frequency of Growing Cycles

Shrimp are very responsive to temperature changes and require a specific temperature for breeding and larval growth. In the Mexican extra-tropical waters temperature range from over 30°C in the summer months to 18°C in the winter months. This drastic change in temperature prohibits growth of shrimp during the winter months, thus limiting farmers to only 1 – 2 cycles of growth per year, with a substantial dry out period. Incidentally,

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[106] In Salinas there was significant development of shrimp farms outside of the mangrove swamps. This region is an exception , as most of the productivity in Ecuador is in the Gulf of Guayaquil, a large estuarine system.

these cycles provide a consistent supply of shrimp to the market in the shrimp fishing moratorium summer months. Along the equator consistently high temperatures are present year round. Additionally, due to increased temperature, growth rates for *P. vannamei* tend to be slightly higher in the equatorial region as compared to the extratropical zone. This provide for three complete cycles of growth annually, without any time for the ponds to recover between seasons. This has been partially responsible for Ecuador's rapid growth in production. However, the climatic variation of the two regions must be recognized as a significant impact on the farming systems. Disease may have a more difficult time surviving in the soil for four months without water, or other organisms to serve as host.

Geographic Endowments

There is a simple observation regarding the massive disparity between the geographic endowments of the two comparative regions. Ecuador, while producing much more shrimp than Mexico, has a coastline of 2,237 km versus 9,330km in Mexico. Additionally, much of the Ecuadorian coastline is in the extremely concave Gulf of Guayaquil. Thus Mexican shrimp farming has obviously developed to be much more scattered in distribution than that in Ecuador. For disease transmittance, this must be a fey factor to explain the different results.

Economic Determinants

First Mover vs. Late Mover

Ecuador has the distinction of being the first country to truly exploit shrimp aquaculture at any significant level in all of Latin America. However, due to its earlier development, there was less of a scientific base on which to decide which externalities was indeed important and warranted regulation. Mexico's industry did not truly take off until the reform of the *ejido* system in the early 1990s. This difference cannot be ignored as one of the root causes of the economic disparity in experience with WSSV. It is recognized in the business world that although the first mover has many advantages, there are also many disadvantages, especially with regard to long term sustainability. In Ecuador, quick profits and little knowledge of the negative externalities involved in those profits led to the explosive growth of what is now known to have been an unsustainable production system. With high global shrimp prices, reflecting the higher cost of fishing for shrimp and increasing global demand, the profit margins in early Ecuadorian ponds were so high that there was little need to consider sustainability. Every year shrimp farmers earned well beyond their fixed and variable costs such that even if the industry did collapse, returns to investment were still economically viable.

Quite the reverse, Mexico's late start in the industry has allowed for the industry to learn from the environmental, management and economic mistakes of the countries before it and incorporate twenty years of international experience in pond construction and management. World-wide, profits in the 1990s were not as high as earlier and attention had to be focused on sustainability over a longer time of investment. Perhaps more important, the presence of WSSV and other diseases, from around the world was widely understood at the time of Mexican aquaculture expansion. The industry could not expand without built in precautions planned into pond construction, management and industry regulation. A test to see if this variable is true will be more obvious in the years to come as Brazil's industry develops. In many ways, the geographic situation of equatorial Brazil is very similar to Ecuador and Peru. As both Brazil and Mexico begin to surpass Ecuador in total production figures, the benefits of the late mover become more and more evident. In an industry plagued by disease and other previously unaccounted for environmental externalities, those economies that are able to consider these problems in their accounting from the beginning are in an increasingly advantageous position.

Vertical vs. Horizontal Integration

In Ecuador and to a lesser degree Peru, due to the longer lifetime of their industries, shrimp farming companies tend to be very large, sometimes thousands of hectares, and vertically integrated. Through time, larger companies with various farms, and associated distribution chains, packing plants and export companies have come to dominate the industry. In Mexico, the businesses are much smaller, all purchased and run locally through the remnants of the *ejido* system. Due to the relatively large shrimp fishing industry, there are national packaging and export companies, such as Ocean Garden that buy shrimp from local farmers and sell nationally or internationally. The difference is that the farmers in Mexico are more small-scale, more local and connected to their respective ecosystem and social community. In Ecuador and Peru, many of the big owners are distant and removed from the surroundings. This problem is evident on the short term scale, but also in the long term. As a result of the conglomerate shrimp farms, that are just one piece of an investment portfolio in Ecuador, farmers can easily decide to quickly pull their investment out and transplant in other parts of the country, or even overseas. In Ecuador, there are claims made by Stefan Bohórquez that this is exactly what has happened to the Ecuadorian industry—the businessman abandoned their farms and left for Brazil, other parts of South America or even Mozambique. Farmers in Mexico are less able to mobilize their smaller resources, and are tied to their land in many ways.

Development: Environmental Kuznets Curve

There are two possible dimensions to the Environmental Kuznets Curve (EKC) that these three case studies can fit into—the cross-sectional and the temporal. A cross sectional analysis of economic development puts Mexico at a significantly higher level of economic and human development—$9,000 PPP versus $4,800 and $3,000 in Peru and Ecuador respectively.[107] Thus, according to the EKC hypothesis, environmental degradation would tend to get worse as GDP rises to a certain point, but at some certain point, begin to improve due to changes in scale composition and technique. The main factor changing in this circumstance is technological, including managerial, developments. Though three case studies are certainly not significant enough to establish an EKC relationship regarding shrimp farming, the EKC hypothesis may explain partially the trend of improving sustainability between Peru and Ecuador on one side of the curve and Mexico on the other. Regardless, the three data points we have do fit into this cross-sectional model.

[107] http://www.indexmundi.com/

Temporally, the picture is perhaps even more distinct. According to the World Bank[108], average annual growth rates in Ecuador and Mexico were 5.2% and 1.9% respectively from 1982 – 1992 and 1.8% and 3.2% respectively since. Thus, both countries have been moving for the past 20 years in the path of development. It is also apparent looking at estimates of environmental damages caused by the industry in Ecuador that during the boom years, the damage was much higher than it is now. As the country has developed, along with the industry, the externalities have decreased. On the other hand, over ten years of Mexican production, it is difficult to argue that the net impact of the industry is any less than it was earlier on. Pond development and production are increasingly consuming land area and even though it is not covered by mangroves, it is still a valuable environmental asset. Perhaps in the case of Mexico, the ten year temporal time horizon is too narrow of a view to witness any true change in rate of overall degradation. Finally, within countries, the evidence suggests that the poorer sections are getting the worst environmental problems in Ecuador, ie. Esmeraldas region, and in Mexico, new environmental problems are beginning to arise with shrimp farming in Chiapas—the poorest part of Mexico. Thus, for the vast majority of the evidence in this paper, supports the EKC model, though not proving the theory, the data surely agree with the concept of development brings about sustainability.

[108] http://www.worldbank.org/data/countrydata

Governmental Determinants

Presence of Successful Regulation in Industry Growth Phase

Government behavior during the initial growth phase of industry development is a crucial indicator that differentiates between these case studies. Although the government was a key player of Peruvian shrimp farming development, it was more as a promoter, not a regulator. As Ecuador acquired significant global market share, the profits generated were too much for a developing regulatory system to handle. Reasonable measures were taken on the legal national level to monitor and account for the negative externalities, but compliance was tremendously weak. As a result, by the time the most important problem with the industry, mangrove destruction, was recognized and addressed in Ecuador, there was a lag time, apparently 10 years or so from 1985 to 1995 before affective regulation was in place. Currently, it appears the chilling effect of WSSV has empowered the government to successfully regulate the second phase of expansion.

Mexico, on the other hand, is clearly in its initial growth phase of aquacultural development. Stronger environmental regulations and a more sound legal system have allowed the Mexican government to intervene sooner. Not only is it apparent in their unflagging productivity increases, but also in their quickly developed and specific regulatory response to the WSSV outbreak. The industry in Mexico appears to be working with the government for their mutual gain, as opposed to avoiding regulation to generate profits. This situation is analogous to the difference between the New England vs. the Alaskan fisheries in the United States. The New England Fisheries have existed for hundreds of years, and have historically been unregulated and controlled by industry based on fisher knowledge rather than science. On the other hand, significant Alaskan fisheries have existed for just over a century, and have been developed along with regulation. One conclusion that can be drawn from this is that resource exploitation based industries must grow within a proactive and effective environmental regulatory framework, rather than reactive. Reactive legislation on environmental regulations, such as was done in Ecuador can only hope to lessen the future impacts of poor industry development. Alternatively, this paper suggests that more proactive legislation can avoid the environmental and specifically economic damage before it happens. The issue of compliance is increasingly important in the developing world, where legal systems are weaker and more subject to corruption. Compliance, this paper demonstrates is much easier to achieve in a nascent and weak industry, as opposed to one more mature and strong.

Market versus Controlled Fishery Economy

The contrast between Mexico's socially controlled fishery economy and the market economies of Peru and Ecuador is another central difference between the two shrimp farming ecountries. Billie DeWalt has pointed out in his previously cited work, that this is perhaps the largest contributing factor to the difference between Mexican and other Latin American shrimp farming economies.[109] Because only small social sector fisheries cooperatives were granted the right to exploit local marine resources, and the private sector was disallowed from involvement, little development in aquaculture was able to occur prior to the change of the legal code in the early 1990s. The reason for this was primarily because there was little capital available to invest in aquaculture development.

[109] DeWalt 2000 et. al.

The government was supposed to set up investment mechanisms for the small fishing cooperatives, but the system often broke down, so development was slow. Additionally, small fishing cooperatives had to act in the best interest of the entire fishing community, so the free market was not able to operate. Thus, the tragedy of the commons principle was controlled by sufficient horizontal pressure. Private industry had no chance to enter the market and exploit the industry for the gain of only a few. The case of sustainability of shrimp farming provides evidence that the social sector developed by the Mexican socialist revolutionary thinking was certainly more sustainable at developing its resources than the free market comparisons of Ecuador and Peru.

Property Rights: Concessions versus Land Ownership

An additional side effect of the Mexican Revolution is that coastal property until the early 1990s was not able to be sold to Private industry for development. Thus, as a result, the land upon which aquaculture would later develop in Mexico was clearly owned by some group or individual, and provided many with their livelihoods. On the other hand, in Ecuador the coastal lands were given by concession to the shrimp farmers from the government. There were no prior owners, and after ten years the shrimp farmers had no responsibility for the land. Thus in Mexico, stewardship was necessary to care for an ecosystem to which you have invested to purchase or develop. Additional complications arose in the 1970s when the Mexican government created new *ejidos* in barren coastal areas unsuitable for farming. This *ejidos* could do little but fish, but further complicated issues of land ownership. Put simply, in Mexico the common property resource of coastal estuaries, both the water and surrounding land remained under the control of the local population for which the coastal lands were their lifeline. On the other hand, in Ecuador, massive coastal concessions led to a denial of common property rights and a lack of true ownership for the land. The implications for sustainability and epizootics are very clear. True owners of land when threatened with disease or other problems will seek to find the best solution, but keep in mind the long-term sustainability of their investment. On the other hand, those with concessions have little responsibility or economic rationale to invest in the long term sustainability of their projects. This answers partially the argument between policy makers and economist concerning regulation and privatization—equitable privatization is clearly more sustainable than ineffective regulation.

International Environmental Organizations

International environmental organizations were present in all three case studies. However, only there were sharp differences between the relations of the industry to these organizations. In Mexico, the prominent organizations were the WWF and Conservation International, who were present in an effort to promote the sustainable development of the industry. While there is recognition that shrimp farming has not entirely been positive for the environment, and in many cases negative, these two organizations have taken the stance that if it is going to happen anyway, best to promote its sustainable development as opposed to fighting it. Additionally, there is widespread recognition among environmentalists that if done correctly, aquaculture can provide a more sustainable alternative to wild capture fisheries, and contribute significantly to development of otherwise poor coastal settlements. Mexican aquaculturalists, perhaps due to their smaller size and ability to fund research, have responded relatively well to this, and agreed in many parts to work with the environmental organizations.

On the other hand, in Ecuador, for a long time the reverse has been true. It has been international environmental organizations, such as Greenpeace and the Mangrove Action Network, that have been responsible for helping support large scale protests and lawsuits against aquaculturalists with poor environmental records. The dialogue was less about how to make shrimp farming better, and more about how to eliminate or ban shrimp farming entirely. Thus, the industry and environmentalists developed in opposition in Ecuador, until recent disease pressures forced their hands into cooperation. Whether this is a driver or a symptom of the respective countries industries is debatable.

CONCLUSIONS

Overall, the future sustainability in shrimp farming depends on the future of disease management. Epizootics have devastated the industry from the pond level to the entire country and beyond. The billions of dollars a year that are lost to diseases world-wide threaten every cycle to plunge farmers into debt. WSSV has forced entire Latin American economies to rethink their entire approach to shrimp farming and begin anew with regulations and more sustainable practices in the twenty-first century. The first twenty years of shrimp farming in both Asian and Latin America can be characterized as the gold rush period, where profits were high, growth was astounding and there was little care for any long term considerations. Now that profits are less assured both at the national and local level, those that have survived are engaged in a transformation forced by international, national, and local levels, to an environment more sustainable, scientifically sound and risk averse industry. Of course there are many who are not changing their ways, but history shows that those who are environmentally irresponsible will not be sustainable in any sense of the word. Shrimp farming is beginning to change in the right direction, but it has a long way to go before being once again economically assured, disease-free and environmentally sustainable.

Perhaps even more important is the insight this research provides towards a slower, well regulated, planned and equitable exploitation of natural resources over the boom and bust that a true unregulated free market all too often allows. It takes time to fully evaluate an industry's potential environmental impact for the benefit of all those involved and all those uninvolved, but affected. The prudent pro-active method to proceed is to apply the precautionary principle in uncertainty, for the sake of the future sustainability of that industry, and all those that may experience declining utility because of it. As shrimp farming and aquaculture expand into new developing regions of the world such as Africa and the Middle East these conclusions are significant for all actors invloved. While the investors may be thinking short-term, it is the local actors that have a stake in the creation of a long term sustainable and fully accountable industry. *Give a man a fish he'll eat for a day. Teach a man to fish he will eat for a lifetime.* Teach a man to sustainably raise fish without negative externalities, in a functioning regulatory system, and the world will be able to eat forever.

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