

The Shrimp Commodity System

A Sustainability Institute Report

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*There's a basic fear between your world and mine. I don't know why.
What I came to say was,
teach the children about the cycles.
The life cycles. All the other cycles.
That's what it's all about, and it's all forgot."*

—Gary Snyder. "To/From Lew"



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Commodity Project Background

Sustainability Institute, a non-profit organization with a mission to encourage sustainable systems at all levels of society, has undertaken a project to understand the dynamics of commodity systems. Commodities (e.g. sugar, coffee, metals, beef, fish, lumber, paper) are products taken directly from the earth; they are the place where the economy most directly meets the ecosystem. All commodities exhibit similar patterns of behavior, some of which are persistently problematic. For example:

- Commodity prices are notable for their instability, sometimes cyclical, sometimes subject to extreme booms and busts.
- Commodity extraction and processing are major causes of unsustainable resource use and disruption of ecological systems.
- Though commodity flows can generate great wealth, people at the extractive end of the value chain (loggers, fishers, farmers, miners) often live in financial insecurity.

To understand the generic structure that produces the above behaviors, the Institute is applying system dynamics computer modeling to three very different commodities: shrimp, corn, and forest products. These commodities have different regeneration times (shrimp regenerate in a few months, trees only in decades), and are also at very different stages of industrial maturity (corn has been organized as a globally traded commodity for at least 100 years, while shrimp, specifically commercial aquacultured shrimp, is a relatively new commodity).

The purpose of the commodity project is to understand why commodity systems behave as they do; to find leverage points where relatively simple changes could lead to more stability, sustainability, and financial security in these systems; and to build shared, comprehensive, mental models among their participants—so there can be concerted efforts to make those changes.

The remainder of this paper will focus on the shrimp commodity system.

The Shrimp System

World shrimp consumption has been on the increase since the 1970s, especially in Japan, Western Europe, and the United States. Until the 1980s, almost all of the world supply came from wild fisheries. But by the mid-80s, the ancient practice of aquaculture began to take an increasing share of the global market, through use of new methods that concentrated production, increased yield, and developed procedures for long-distance shipment and standardization of product. Most of the world's traded shrimp are caught or cultured in tropical or subtropical waters, especially in China, Thailand, Ecuador, Indonesia, India, Bangladesh, and the Gulf of Mexico. Most consumption of commercially trade shrimp takes place in North America, Europe, and Japan.

Wild Shrimp Fisheries

Shrimp fisheries have steadily increased their catch through the last three decades, mainly by opening up new fishing areas. World catch has gone from an estimated 770,000 metric tons (MT) in 1970 to over 2 million MT in the 1990s. There is some evidence that the shrimp catch has leveled off and even begun to decline in some regions, though wild shrimp population levels are largely unknown, so it is difficult to determine whether the populations are steady or in decline. Shrimp reproduce so prolifically that any population declines may be due as much to habitat disruption as to overfishing.

The increase in catch over the past 30 years has not occurred without cost. Many proponents of environmental responsibility believe the bottom-trawling techniques employed by the industry are destroying marine ecosystems. Shrimp fishing also results in large numbers of other species being caught in the nets—estimates are that for each pound of shrimp, 4.5 to 7.5 pounds of other species are caught as well. This by-catch is generally killed in the process of harvesting and thrown overboard, since it has no value to the shrimp fisheries.

Another cost of growth is that the trawler fleet is typically overcapitalized. Experts on the Gulf Coast shrimp fishery, for example, say that the fleet could be cut by 30% of its present capacity without reducing the catch at all. Some of the consequences of overcapitalization are vanishing profits, extreme competition that often results in squeezing out smaller boats, and increasing regulations that idle the fleet for parts of the fishing season or in parts of the fishing area, in order to prevent inappropriate harvest of immature shrimp.

Shrimp Aquaculture

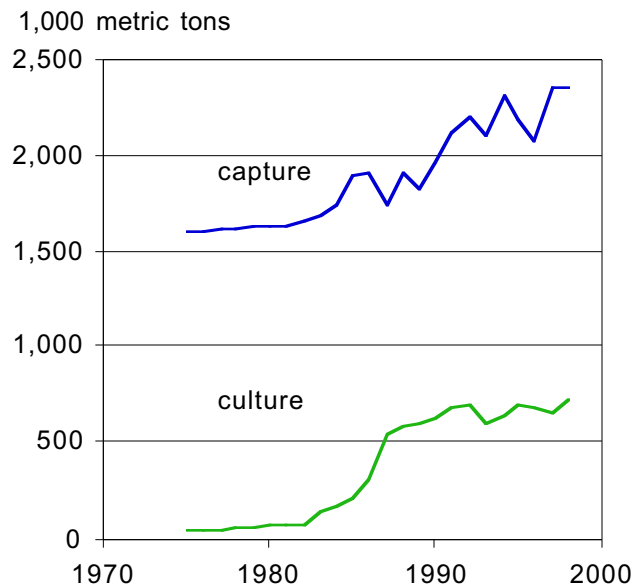
Aquaculture has been practiced, especially in Asia, for centuries, using simple techniques involving simple coastal ponds and low shrimp densities. Its relatively small output was usually consumed locally, and the practice had little impact on the environment. Starting in the 1980s, with the spread of innovations in aquaculture technology and practices, shrimp aquaculture became a popular investment. Coastal land for ponds was readily available and inexpensive, costs of inputs were low, and demand for the product was soaring. This combination of factors generated sizable returns on investment, which fueled further investment. By 1989 aquaculture was meeting over 25% of the world's shrimp demand. Since 1989 aquaculture has increased its market share more slowly, as the outbreak of disease in some countries slowed the growth of the industry.

The majority of shrimp farmers still rely on wild-caught seedstock. The process of capturing the seedstock has an associated by-catch that is estimated to be even higher than that of the wild fishery. The sites chosen for ponds, especially during the 1980s and early 1990s, were often in mangrove-forested coastal areas, causing large scale clearing and destruction of natural shrimp nursery habitat—thus the spreading aquaculture threatened not only the wild fishery, but its own seedstock replenishment (and marine biodiversity in general). Mangrove-cutting has now been stopped by many governments.

The extensive practices of the past allowed shrimp farmers to cycle water from coastal ponds into estuaries with little effect. But as pond area increases, and as technology allows for higher density within the ponds, higher levels of nutrients, drugs (including antibiotics), and chemicals are released into coastal waters. Where aquaculture pond water is gathered from polluted waterways, the incidence of shrimp disease has increased considerably. Furthermore, as the shrimp trade becomes global, diseases are appearing where they have never been seen before; Asian diseases appearing in South America, South American diseases in North America, etc.¹ It is not known what effect these pollutants or diseases are having on wild populations. Wild shrimp seek coastal waters for maturation from the postlarval state until they are ready to return to the open sea to reproduce. Any effects on the wild population will be felt not only on the wild catch, but on the supply of seedstock for shrimp farmers—and any effects of disease or pollution or genetic impoverishment (due to escapes from coastal ponds) on aquacultured shrimp are almost certain to spread into the wild.

Throughout the 1990s, standards for “Best Practice” for aquaculture have been under development by people associated with the industry and by environmental organizations. There is still disagreement about the nature of best practice, as well as how it is to be applied and enforced. Clarification of these issues is one of the things to be considered in the next phase of this project.

Global Shrimp Production
1975-1998



Model Purpose and Development

The world is full of computer models, most of them extremely hard for anyone other than their developers to understand. Our models are different. First, they are designed to be very transparent, so that people familiar with the system being modeled (in this case people in all parts of the shrimp commodity system) can see quickly how our model is put together, what the key assumptions are, how it works. Second, the model can be altered and rerun in seconds, so that a criticism, change, or test can be incorporated and its effect understood almost immediately. Third, we construct our models in the presence of and with the help of people who work in or are expert about the system we are representing. Not only does that help us get the numbers and relationships right; it also builds up a core of system stakeholders who understand the model and increasingly trust it, because it is in effect theirs, not ours.

So we have built a preliminary computer model to examine the shrimp system in its broad interconnections. We have done so with the participation and help of national governments, NGOs, and industry. We have also attended conferences on the shrimp industry, shrimp biology, shrimp economics, and have familiarized ourselves with the data and literature.

Because the rapidly changing shrimp industry is unusually widespread globally, turbulent economically, and fractious politically, up to this point we have met with system stakeholders on an individual basis or in very small groups. Typically we have met with environmental groups separately from industry groups separately from government regulatory groups. We think the model represents inclusively the knowledge and concerns of all these groups; that it in fact offers a neutral vehicle for them to explore their differing assumptions. In the next phase of our project we plan to spend more time with cross-stakeholder groups, both to improve on our current model and to build shared understanding of the interactions in and possibilities for the shrimp system.

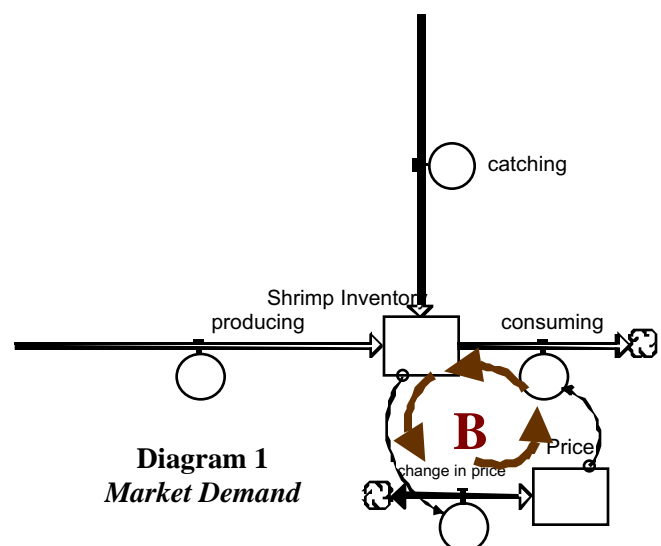
As you will see later in this paper, we run the model in 50-year scenarios, beginning in 1985. Models are always preliminary; they are never the real system; ideally they develop toward greater and greater credibility, but all models—including the ones in our heads—must always be taken provisionally, subject to testing and learning. Therefore the outputs from the model presented here should not be taken as “the truth” about the future of the shrimp system, especially since the model indicates that there could be several widely differing futures. The runs we show here are, we believe, some possible outcomes dependent upon choices and policies yet to be made.

Model Structure

The current model is divided into five sectors: Market Demand, Wild Shrimp Fishery, Aquaculture, Financials, and Environment. The following diagrams contain simplified maps of the most important interrelationships that appear in the model. Much of the system’s behavior, we believe, arises out of these interrelationships.

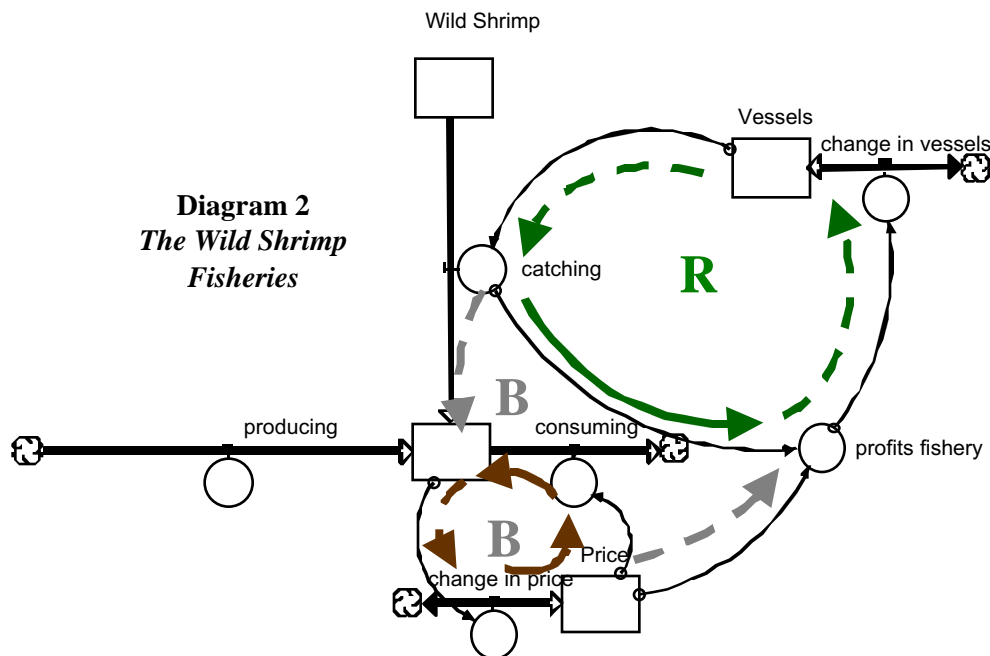
The diagrams show, first of all, the physical flows of shrimp, fishing vessels, aquaculture ponds, money, and pollutants through the system. Flows are represented as straight double arrows; accumulations of those flows, or stocks, are shown as boxes. Also shown are the feedback relationships; the flows of information that link stocks and flows to each other—for example, the fact that as the inventory of shrimp goes up, the price will tend to go down. As the price goes down, consumer demand will go up. And so on. Such relationships are represented by single curved arrows.

The sector shown in simplified form in Diagram 1 is Market Demand. A flow of producing (from Aquaculture) and a flow of catching (from Wild Shrimp Fisheries) feed the stock of Shrimp Inventory. Inventory is represented in this dia-



gram by a single stock, though in the real world there is a chain of stocks through processors, exporters, importers, and retailers. The outflow called *consuming* is determined by the current demand for shrimp in the market. Population, per capita consumption, and Price determine demand (which is represented in the model, but not in the figure). Price is determined by Shrimp Inventory; when inventories are low, prices tend to go up, and when inventories are high, prices tend to go down. This creates a demand-side negative (balancing) feedback loop, shown in heavy brown arrows, which works to balance supply and demand by regulating demand.

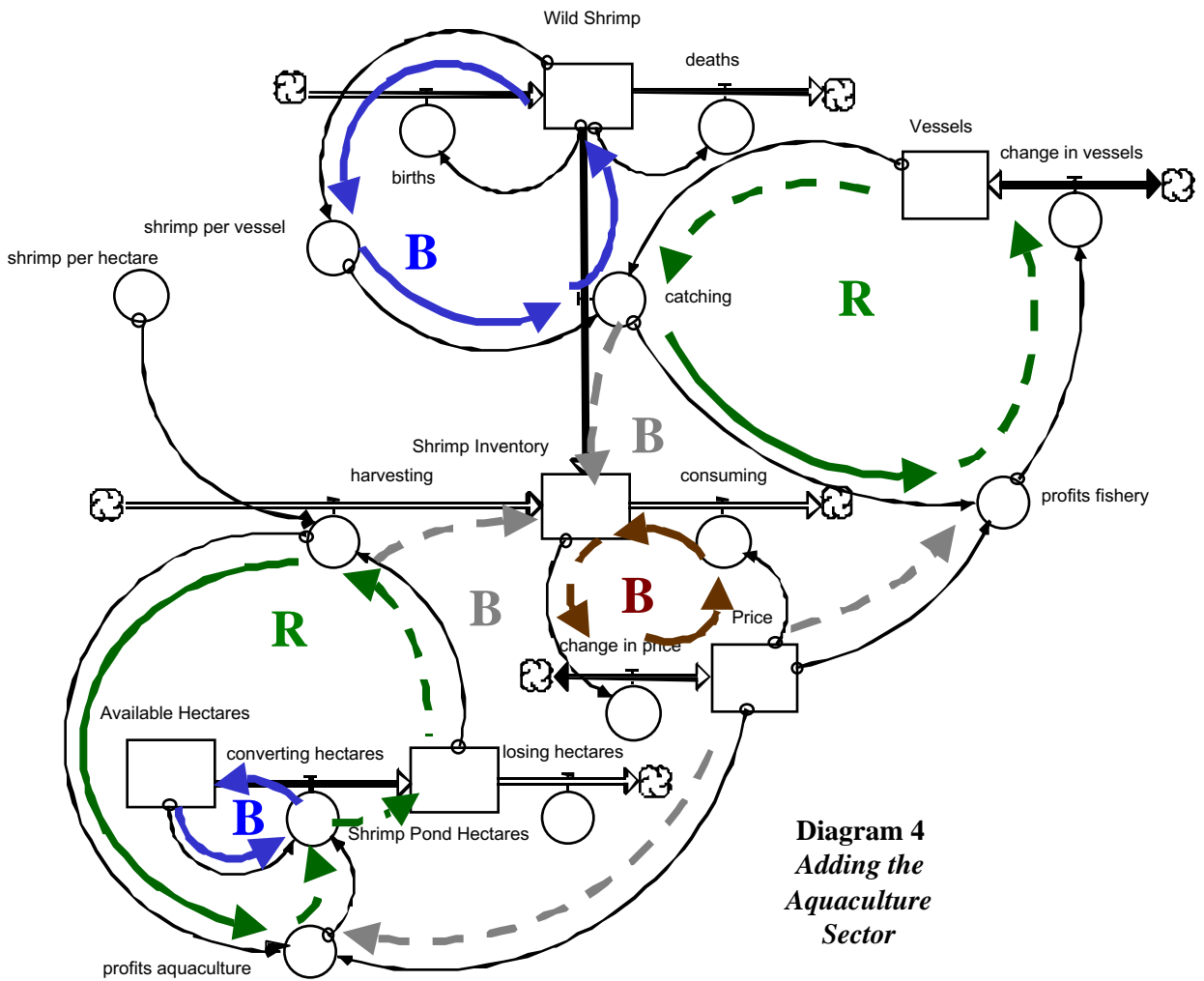
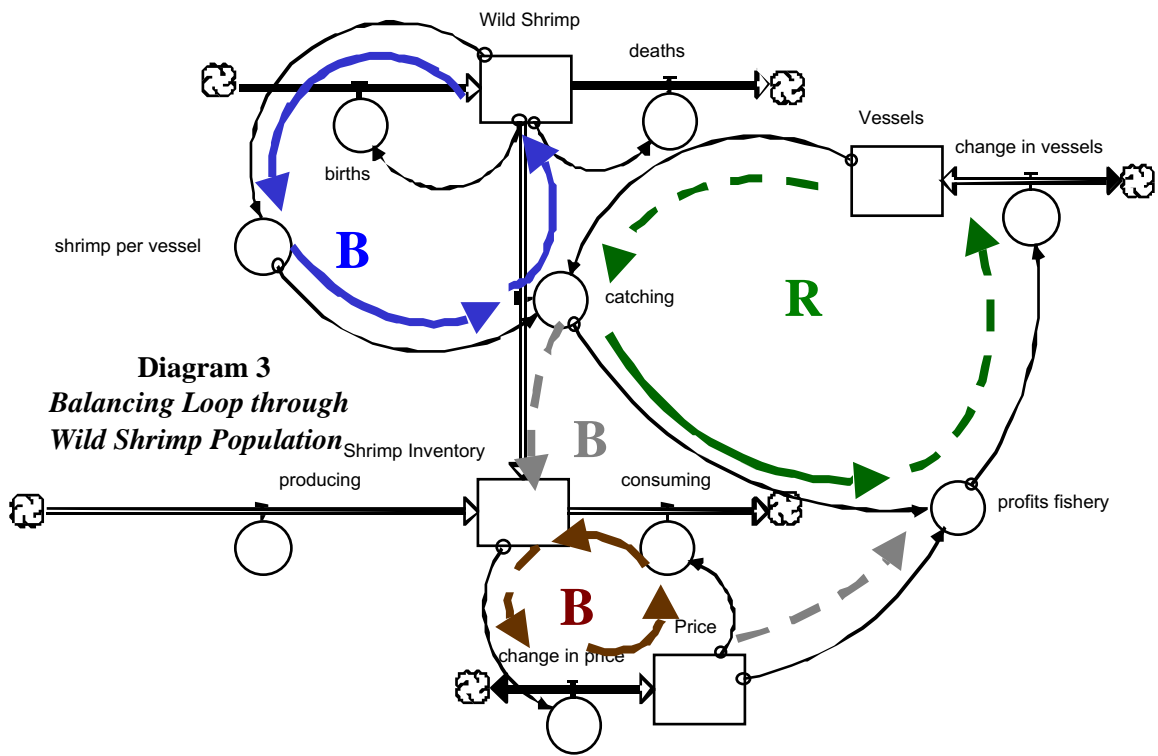
Diagram 2 contains elements from both the Wild Shrimp Fisheries and the Financials sectors and adds two more primary feedback loops to the one shown in Diagram 1. The first is a balancing loop (highlighted with dashed gray arrows), which demonstrates how an increase in Price will lead to an increase in fishery profits, which will increase investments in shrimp fishing Vessels. More Vessels means more catching, all else equal, which raises levels of Shrimp Inventory, which bring Price back down. (As with all balancing loops, the dynamics also work in reverse—a decrease in Price decreases Vessels, and thus catching, ultimately bringing Shrimp Inventory down and Price back up.) This loop balances supply and demand by regulating supply.



The second loop is a reinforcing loop (green arrows). It says that an increase in Vessels will increase catching and thus profits. The additional profits allow the fishery to invest in more Vessels. Clearly these two new loops oppose each other, and they operate in different time frames. The interplay between them is the primary determinant of behavior in the Wild Shrimp Fisheries sector.

Diagram 3 adds one more loop, this time a balancing loop, which limits the catching of shrimp due to a decrease in Wild Shrimp population. This loop is colored blue. The formulation of shrimp reproduction in the Wild Fisheries sector is based on the Schaefer model of fish population growth².

Diagram 4 adds the Aquaculture sector (and corresponding elements from Financials), which includes the use of land for ponds (Shrimp Pond Hectares) and the population of cultured shrimp in the ponds. The feedback loop relationships are similar to those of the Wild Shrimp Fisheries. The balanc-



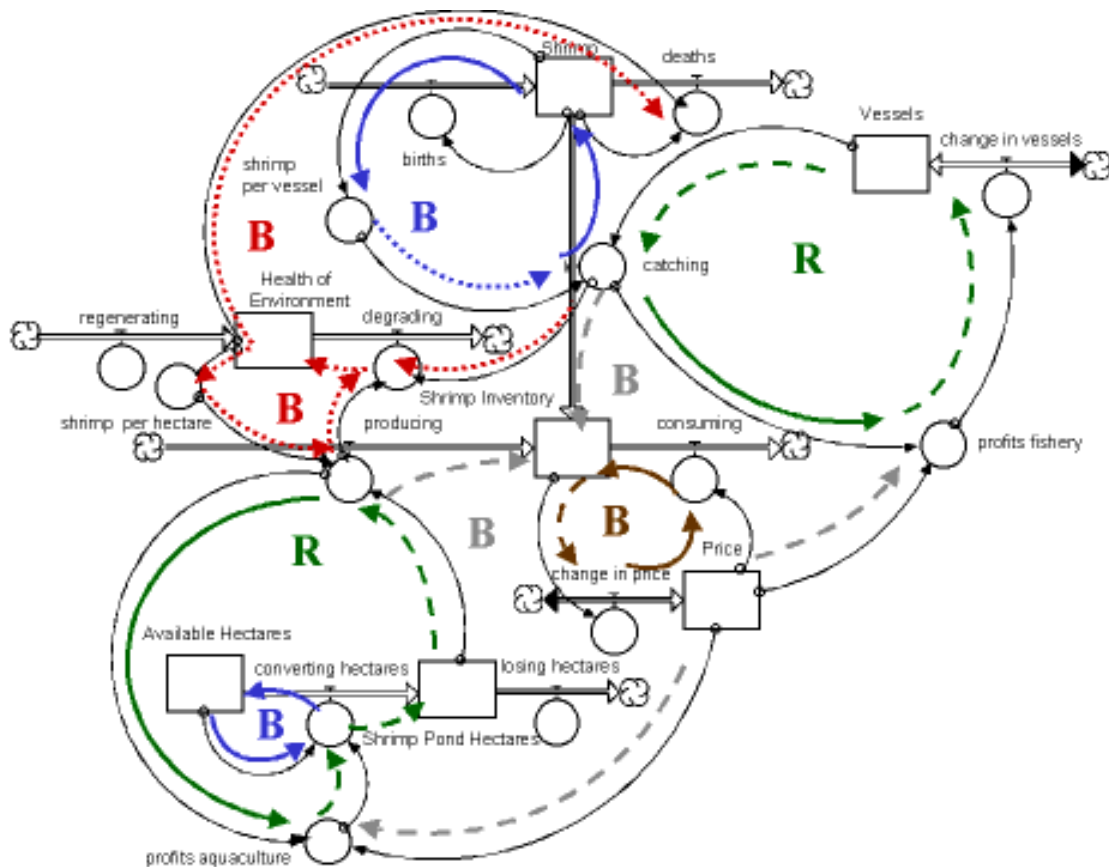
ing loop (shown with dashed gray arrows) allows an increase in Price to cause more profits for aquaculture, more investments in ponds, increases in the Shrimp Inventory, and reductions in the Price. The reinforcing loop (shown in green) causes an increase in harvesting to increase aquaculture profits, and thus increase investment in Shrimp Pond Hectares. The increase in land results in more shrimp being stocked and harvested, therefore still more profits and more investment in ponds. This is the capital growth loop driving growth in any industry, as long as that industry is profitable.

The dynamics of the Aquaculture structure are similar to that of the Wild Shrimp Fisheries, except that vessels have a longer effective lifetime than do shrimp ponds, the wild shrimp population is not (yet, anyway) subject to diseases as is the cultured population, the cultured population is not subject to overall depletion from overfishing (though depletion through disease is possible), and the costs and risks of the two production streams are quite different. All these differences are captured in the model.

Price levels and harvesting rates determine the dynamics of profit in the Financials sector. Returns on investment are calculated for the two producing industries; new investment flows preferentially to the sector where returns are higher. Since both sectors receive basically the same Price (over a range that accounts for size and quality differences), the relative costs between the two producers determine who gets the edge on profits and thus new investment and growth.

The final sector is the Environment, which produces barometers of environmental health that respond to both aquaculture and fishery practices. The model contains relatively simple indicators for impacts of the fishery (by-catch), and aquaculture (by-catch, effluents). (We have not modeled all ecosystem effects in detail—which would be an interesting and complicated research project beyond the scope of this endeavor.)

In Diagram 5 we have simplified the environmental indicators to a single stock labeled Health of



Environment. The addition of this stock shows a feedback connection that could eventually limit both aquaculture and fishery harvest. Looking first at aquaculture, as harvesting increases there is a coincident degradation of Health of Environment (a loop that will be greatly slowed by implementing Best Practice). This degradation in turn results in an increase in Wild Shrimp deaths, which causes a decrease in Wild Shrimp population, finally decreasing catching. Another loop from Health of Environment affects harvesting from ponds. Poor quality of coastal waters will increase the incidence of disease in ponds and decrease the available seedstock. Since many aquaculture businesses rely upon this wild population to stock their ponds, the pressure will be on industry to use hatcheries, and costs will rise. Currently the model does not show any feedback from the wild fishery's by-catch, because there is none in the real system (none back to the shrimp industry, that is—by-catch affects other fisheries). One way such feedback could appear would be to have news of by-catch erode public opinion, which could bring down consumption. Another would be the imposition of regulatory measures that increase the cost of fishing (such as the turtle excluders already required in American shrimp fisheries).

Scenarios from the Model

A model like this is not intended to predict the future—to say what *will* happen. It is designed to test various scenarios of what *could* happen, given inherent uncertainties (such as the weather), policy choices (such as by-catch restrictions or “best practice” aquaculture regulations), constraints (such as shrimp carrying capacity), or impacts from outside the system (such as shifting prices of competitive seafoods). We run the model many times, under many different conditions. The goal is to see not only what happens, but *why* it happens. As that understanding builds, so does a dynamic sense of where the system is sensitive and easily changeable, and where it is resistant to change. Whole categories of possible interventions can get ruled out as producing only small effects after great effort. Other kinds of interventions—at leverage points—may do the opposite.

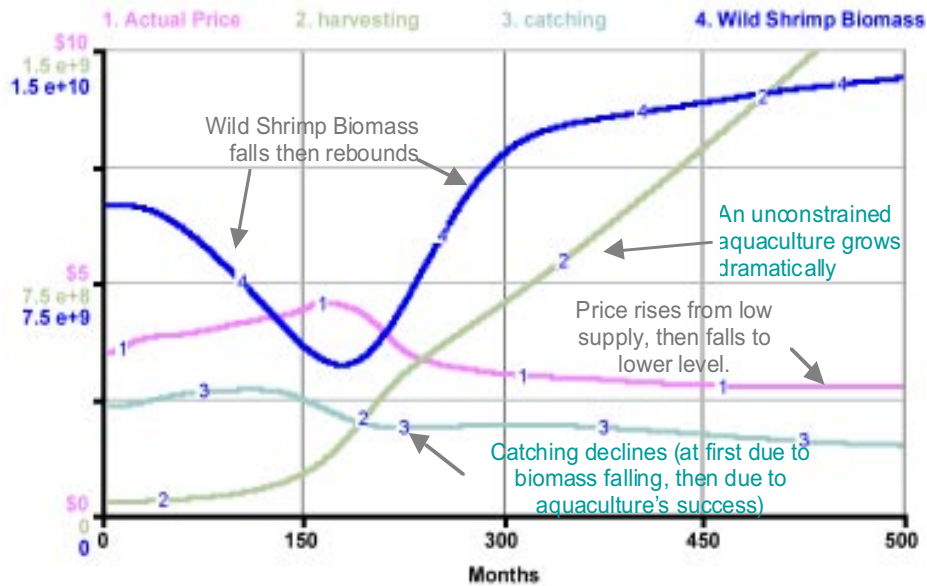
We can show here only a few of many possible runs, with a model that is not yet detailed enough, nor reviewed enough by the system stakeholders, to be entirely credible. These runs are to be taken as indicative of what sorts of things the model can reveal; not as prescriptions for policy.

Scenario 1: Unbounded Aquaculture

The model begins by approximating the years from 1985 to the present (to test the model's capability of reproducing general historical trends) and then continues on for a total of 50 years. This scenario (and all those to follow) assumes that population and per capita consumption will continue to grow in a pattern consistent with current growth patterns. We do not consider this the most likely scenario; it is only a baseline for comparison.

Initially, demand for shrimp grows faster than production, so price goes up. Eventually increasing profits bring in more production capacity, especially in aquaculture, so supply catches up with demand, and the price begins to fall. In this scenario, the fisheries, pushed on by the favorable price, eventually hit the limit of the ability of the wild population to reproduce. Catching goes down slightly because of lower shrimp populations, fishing costs rise, and aquaculture is able to take over market share. The natural limit on fisheries allows aquaculture to grow rapidly to close the demand gap.

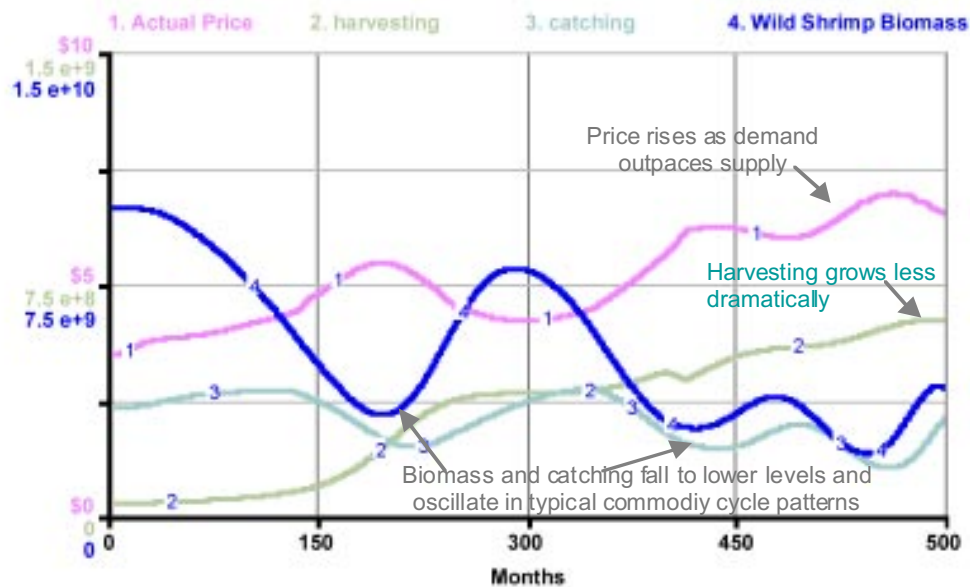
Virtually no natural limit is assumed for aquaculture, and diseases are assumed to stay under



control. (There is a land limit, but it is assumed that essentially all suitable coastal land is available, so the industry doesn't come close to hitting this limit.) The fisheries continue to produce at near-historic levels, but only with higher operating costs, which reflect in the fishing communities as loss of income and jobs. Once the fishery is economically marginalized, the wild shrimp population rises toward its natural carrying capacity (pre-1985 levels). Because aquaculture keeps growing to meet demand, price stays low—too low to give the fishery enough profit to grow.

Scenario 2: The Environment Strikes Back

The problem with the scenario above is that aquaculture is not subject to any natural constraints as the fisheries are. An obvious way to close this feedback loop is to recognize the effects of environmental degradation caused by rapid expansion. In this profitable market, investment money floods in and ponds are built without concern for good management practice or appropriate siting, but in Scenario 1 we assumed no feedback from the expansion of aquaculture back to the productivity of aquaculture.



When we close this loop by connecting the coastal effluents to the shrimp stock loss fraction (representing the rise of disease caused by polluted waters used in ponds), aquaculture is not able to produce as effortlessly or grow as quickly as it did in the first run.

With both producing sectors running into limits, demand runs ahead of supply, and price rises higher, making the fisheries more profitable than they were in Scenario 1. (Note, however, the appearance of typical commodity price cycles in this run). More boats are acquired, and gradually, with ups and downs, the wild shrimp population is fished to lower levels. Aquaculture is struggling with disease. Price reaches new highs (and therefore reduces demand, as consumers switch to other seafoods). Since aquaculture is not able to take over market share, investment in fishing boats rebounds whenever the shrimp populations rebound. That is the source of oscillations in the system, as the fleet overbuilds, reduces the shrimp population, which raises costs and cuts profits, which reduces boat investment, which allows the shrimp population to grow again—and so forth.

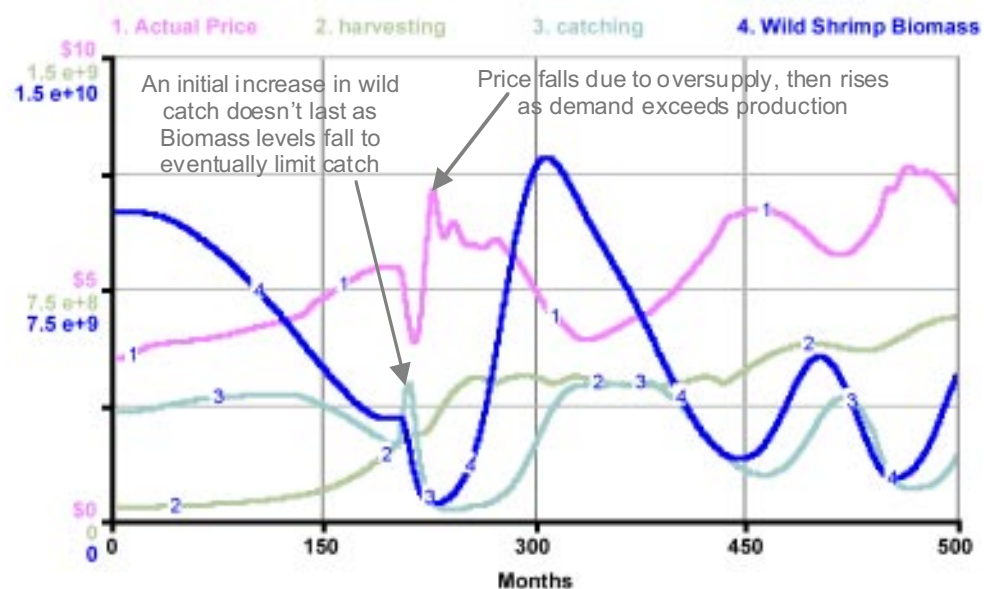
This is obviously not a desirable scenario. If growth is limited by nothing but environmental constraints, the system is cyclical, unprofitable, expensive to consumers, and flirting with environmental disaster. There are several ways to intervene to produce other outcomes. Interventions can be government-driven or market-driven. We will look at two of these interventions next.

Scenario 3: Help for the Fisheries

Probably the most common government response to troubled fisheries is to subsidize them. Estimates of government subsidies range from a world total of 20% of annual fishing revenues up to 75%³.

Here we add in the simulated month 200 a subsidy to the fishery to help it along when things start to look bad. The subsidy is modeled by artificially increasing investment in vessels without any cost to the industry. (As with an investment tax credit. Many other possible forms of subsidy can be modeled—this one is typical.) As a result fishery capacity and harvest go up for just a blip and then continue on their downward path, though the subsidy is still in place.

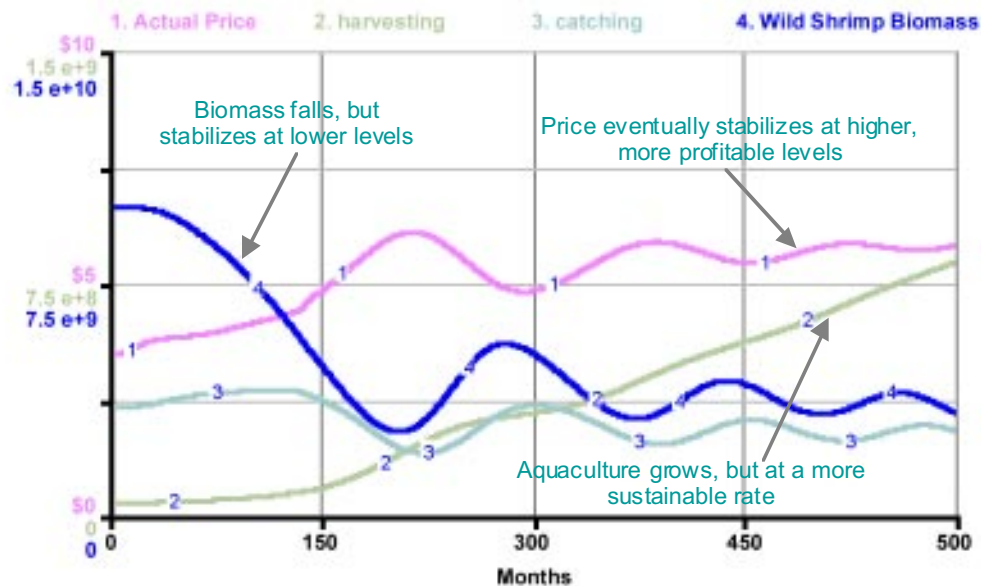
The influx of boats produces a short-term increase in production and profitability in the fisheries. However overfishing occurs even more rapidly than in previous scenarios, which raises costs in the fishery and once again leads to aquaculture becoming the dominant production method. Note that



when more ships begin to bring in shrimp, there is a corresponding decrease in the price of shrimp. That causes financial problems for both the fisheries and the aquaculturists, so the help to the fishery substantially delays the growth of aquaculture.

Scenario 4: Best Practice for the Shrimp Farmers

In this exercise, we assume that shrimp farmers do not continue bad practices that lead to environmental degradation. They learn from their mistakes. In the model we make a connection between the rate of stock loss and the farmers' willingness to bear the cost of best practices in the industry.



Though aquaculture growth is still considerably slower than it was in Scenario 1 (with no environmental feedback), it is faster and more steady than in Scenario 2 (environmental feedback from which no one learns.) The best practices increase the cost of shrimp produced by aquaculture, and that helps to keep the fishery profitable. Price increases and fluctuates, but becomes more stable over time, giving both producing industries more operating certainty.

Of course many further experiments can be run to see, for example, how subsidies might be applied to speed up the adoption of best practices and slow the negative impacts on the environment—to see how the two industries would balance if environmentally conscious best practices were applied to both of them—to test the resilience of any set of changes against weather or market or disease fluctuations—to explore the emergence of a slightly more expensive “green certified” product line.

Summary of Dynamic Lessons

Though the model is still in a preliminary state, it is already suggesting some important lessons and leverage points:

- Left to its own devices, the market balances production capacity (boats and ponds) with both consumer demand and environmental constraints very inefficiently. This

occurs because of delays in the response of price to production, production to price, and cost to environmental limits. The consequence is that capacity overshoots and undershoots its balance points, causing unnecessary investment losses, financial insecurity and (in the overshoots) environmental damage.

- Possible leverage points to correct this instability include strong internalization of externalities, and/or regulatory constraints on environmental damage—such as best practice regulations for the aquaculture industry or bycatch reduction devices in the fishing industry (by implicitly limiting production). It's important to note that these interventions, usually justified on environmental grounds only, actually stabilize the industry economically as well.
- Subsidizing a failing industry, especially when the cause of failure is an environmental constraint, is likely to have small short-term effect at great cost, and ultimately to drive the industry even faster into decline.
- Subsidy or regulation of just one of the two shrimp-supplying sectors is likely to tip the market toward or away from the other in ways that can be unpredictable and surprising.

So far these are extremely general lessons. Much more detail and many more lessons will emerge, as the model is developed together with participants in the fishing and aquaculture industries.

Notes on Process to Date

During the process of developing this prototype model, we have been acquainting ourselves with the players and experts in various parts of the shrimp industry. We have, for example:

- Attended the Boston Seafood Show, the Aquaculture America Conference (Tampa Bay, FL), and American Fisheries Society Conference (Charlotte, SC).
- Co-moderated and presented at the American Fisheries Society Conference's "System Dynamics for Fishery Management" Symposium.
- Presented at a shrimp symposium sponsored by Tufts Veterinary School.
- Met and interviewed system stakeholders, including representatives from NOAA, Sea Grant, World Wildlife Fund, National Resources Defense Council, World Bank, academic institutions.
- Assembled a first modeling advisory team from the Gulf fisheries.
- Conducted a workshop at the National Marine Fisheries Service, bringing together shrimp biologists, economists, consultants, and modelers to assemble a more detailed fishery model.

In the process we have reached some conclusions, not about the structural shrimp system as modeled, but about the system as we encountered it as researchers.

1. The shrimp commodity system is polarized even more than other commodity industries (most of which have their differences between producers, processors, environmentalists, regulators, etc.). Often stakeholder groups are unwilling to meet together. There appears to be an underlying "war" mentality between industry and environmentalists.

At the Aquaculture America Conference a keynote speaker made some of the following statements:

“Environmentalists just need a cause.”

“Just because someone says they’re an environmentalist, doesn’t mean they know anything about ecology.”

“Environmentalists selectively choose data.”

“Environmentalists don’t cooperate with either industry or government.”

“We (aquaculturists) shouldn’t be worried about what environmentalists think. Environmentalists are not going to listen anyway.”

These statements were met with laughter and applause. Other speakers believed that the public wasn’t getting the facts about environmental concerns. For example, one speaker believed the *pfiesteria* scare in the Chesapeake Bay was blown out of proportion. If the public and government really had the facts, regulations would be much less severe, if they happened at all (in his opinion). The common industry perception is that if the public knew how responsible the industry is and how it is working to become better, environmentalists would be seen as alarmists.

A researcher on sustainable aquaculture who communicated with over one hundred experts in the aquaculture field found that most industry representatives are tired of the sustainability issue and environmentalists “and want nothing to do with them.” In our own contacts with industry representatives, we have found their response rates (to emails, phone calls, and letters) to be very low.

Things aren’t any more collaborative on the environmental side. The anti-environmental behavior of industry at the WAS conference in Seattle was in direct response to an anti-shrimp marketing campaign by NGOs during the conference. One source suggested that industry had made a good faith effort to set up dialogue with environmental groups, only to feel attacked by the negative campaign.

This “war” mentality makes it difficult to gather stakeholders into a collaborative discussion. On the other hand, we believe it makes a neutral discussion tool like our model especially useful, because it can incorporate contradictory data, assumptions, and experience of various players in the system, and test them all. Our forest model, for example, which was first suspected by industry as being environmentally biased, is now showing that some of the environmentalists’ favorite policies will be both environmentally and economically disastrous, and that some industry assurances that overharvesting can’t happen are dubious. Each side is beginning to see that it is partly right, partly wrong—and so is the other side.

2. The shrimp system is disorganized and decentralized. It is still in its infancy as an organized system.

Although the fishing industry is perhaps more organized than aquaculture, it is still the case that most shrimp fishing vessels are small and independently owned. Aquaculture has been practiced for millennia, yet only in an organized way during the last half of the 20th century. Both fishing and aquaculture industries are consolidating and “commodifying” before our eyes. This is a system in rapid evolution.

There are no organizations with regulatory oversight for the global shrimp industry, either aquaculture or fisheries. Countries have different policies (when they have them) concerning farming or fishery practices, and their ability to enforce policies may be severely limited by insufficient budgets or government corruption. The idea of “green certification” of marine products is just getting underway through the Marine Stewardship Council.

These attributes make it difficult to determine where to focus and whom to involve in modeling the shrimp commodity system. Many small players are working to optimize their piece of the system, often with results that create unintended consequences detrimental to the larger system. This is, however, an ideal setting to apply system dynamics modeling. The process of building a model will provide opportunities to uncover and explore potential system problems before they happen, and the end product will provide a method of disseminating insights to others in the system.

3. There are few sources of good data. What data there are tend to be sketchy, based on conjecture, and often contradictory.

Because no one is responsible for the system as a whole, data appear in a variety of places. Two interviewees suggested that our modeling project might facilitate the generation of data.

Even the industry's accepted expert in aquaculture statistics estimates his numbers are only accurate within 25% for the Western Hemisphere and are "best guesses" for Southeast Asia. Standards for reporting data are inconsistent among countries (e.g., head-on vs. head-off weight) and many available numbers are based on international trade data, not production data.

However, system dynamics modeling is focused less on quantities in the system than on physical stocks and flows, and the interconnections that cause patterns of behavior over time. The interconnections (how are the shrimp produced, what inputs change decisions, how is the system organized, when one part changes, what effect does that have elsewhere in the system?) are easier to determine and slower to change than specific numbers, and—as long as the numbers are in the right ballpark—they are sufficient for discovering leverage points. We can use estimates of quantities in the model building process, test them for uncertainty, and identify which data are absolutely essential to know precisely, and which can be approximated.

4. Because of the uniqueness of each country, it appears difficult to devise potential policies that can positively influence the system.

Two environmental advocates mentioned how difficult it was for them to figure out where to target their efforts, because of the decentralized nature of the system. Because it is difficult to find regulators, many environmental advocates have focused their efforts on marketing, in a hope to influence consumers' purchasing choices and thus change industry practice. To date, such efforts have not been effective. For example, many purchasers we spoke to didn't know whether their shrimp supply comes from ocean catch or aquaculture, or even that those were the two possibilities.

Again, if anything can help here, a system dynamics model can, as an educational tool helping to build shared mental models. It is out of shared mental models that system structure actually arises—only when there is enough common understanding to show the need for a regulatory system will a regulatory system evolve—only when many people in industry see the benefits of best practice will best practice be taken seriously.

In short, our work in the system so far has convinced us to try to persevere with this model and this process—though it is by far the most difficult of the three commodity models we are working on—because a system in evolution, conflict, and disorganization needs it.

Future Plans

We see two new phases of work ahead. The goal of Phase II is to go more deeply into the system structures of both the fishery and aquaculture segments of the industry. We think this will best be achieved by studying each segment separately. Phase III will integrate this understanding of the two production sectors into a global model that can explore global policy recommendations.

Phase II will consist of two parallel projects. Each project will:

- Build a model of a particular production method (fishery, aquaculture) that can be used to inform a global model during Phase III.
- Choose a distinct region (Gulf of Mexico fishery, Ecuadorian or Thai aquaculture).
- Come to understand different “best practice” for each production method.
- Provide system stakeholders with insights on their system(s). An advisory team will be assembled for each project.
- Demonstrate the value of the process to influential stakeholders, thus building credibility for Phase III.

These regions were chosen based on places where the industry is relatively well organized, where we have connections that will give us access to stakeholder groups, and where consistent and verifiable data are available. The choice between Ecuador and Thailand (both large producers of aquaculture shrimp) will depend largely on political developments in those two places.

We expect this phase to take roughly one year to complete.

The goal of Phase III is to develop a combined model to bring together the dynamics of the entire global shrimp commodity system. Specifically, Phase III will:

1. Expand the regional models developed in Phase II to include global dynamics in each of the areas of study, i.e. aquaculture and fisheries.
2. Build a global shrimp commodity model that combines the structures of the two models in number one above.
3. Include more of the system stakeholders who are downstream from the producers such as processors, exporters and retailers.
4. Provide an opportunity to explore how “best practice” for each production method will impact the other source of production, as well as other segments of the global shrimp commodity system.⁴
5. Determine the most effective policies for influencing system stakeholders to create a more effective system for all.
6. Provide system stakeholders with insights on the system.
7. Publish a final project report, including recommendations on policies and strategy for disseminating system insights, including outreach products and activities to influence the use of these policies.

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NOTES

- 1 Acacia Alcivar-Warren, Tufts University, private communication.
- 2 Schaefer, M. B. 1954. *Some aspects of the dynamics of populations important to the management of commercial marine fisheries*. Bull. Inter-Am. Trop. Tuna Comm. 1:27-56.
- 3 Milazzo, M., *Subsidies in world fisheries: a reexamination*, World Bank Technical Paper No. 406 (World Bank, April 1998).

FAO, *The State of Food and Agriculture 1992*, special chapter, FAO Fisheries Circular No. 853 (FAO: Rome, 1993).
- 4 One of the promising areas that we would like to better understand and incorporate into our model is best practices. Aquaculture has sponsored a great deal of research on best practice in recent years. People representing both industry and environmental concerns have focused on the best practice, and have recently begun releasing their findings. The shrimp fisheries and governments have also been exploring best practice, including the reduction of by-catch, better trawling techniques, and no-fishing zones. There is still debate over the effectiveness of these practices, who determines which ones are critical, and who insures that the industry will adhere to them once they are established.