Knowledge and innovation relationships in the shrimp industry in Thailand and Mexico

Louis Lebel[a,1], Po Garden[a,b], Amy Luers[c], David Manuel-Navarrete[d], and Dao Huy Giap[a,e]

[a]Unit for Social and Environmental Research, Chiang Mai University, Chiang Mai 50200, Thailand; [b]Internews, Chiang Mai 50202, Thailand; [c]Google.Org, San Francisco, CA 94105; [d]Department of Geography, King's College, London WC2R2L2, United Kingdom; and [e]Department of Aquaculture, Hanoi University of Agriculture, Hanoi, Vietnam

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Experts, government officials, and industry leaders concerned about the sustainability of shrimp aquaculture believe they know what farmers need to know and should be doing. They have framed sustainability as a technical problem that, at the farm level, is to be solved by better shrimp and management of ponds and businesses. Codes of conduct, standards, and regulations are expected to bring deviant practices into line. Shrimp farmers are often cornered in a challenging game of knowledge in which their livelihoods are at stake. In the commodity chain there are multiple relations with both suppliers and buyers, not all of which are trustworthy. The social networks shrimp farmers belong to are crucial for sifting out misinformation and multiplying insights from personal experience in learning by doing. Successful farmers become part of a learning culture through seminars, workshops, and clubs in which knowledge and practices are continually re-evaluated. The combination of vertical and horizontal relationships creates a set of alternative arenas that together are critical to bridging knowledge and action gaps for shrimp farmers. Government and industry initiatives for improving links between knowledge and practice for sustainability have largely succeeded when incentives are aligned: shrimp grow better in healthy environments, and using fewer resources means higher profits.

knowledge system | learning | shrimp aquaculture | social networks | sustainability

Shrimp aquaculture poses multiple, interlinked challenges to ecological, economic, and social sustainability. Ecological concerns include conversion and degradation of coastal ecosystems through physical disturbance of hydrological regimes, dumping of sediments or organic pollution (1–3), the risks posed from indiscriminate chemical use to wild populations and consumer safety (3, 4), and the pressure on ocean-caught fish populations harvested to make feed (5, 6). Economic concerns include the difficulty of sustaining a competitive national industry in a world in which there are a growing number of countries capable of growing and selling shrimp (7, 8). Social concerns include the fairness of distribution of profits and risks across the production–consumption system (9, 10), working conditions, and the impacts on access to land and other natural resources for poorer households not directly involved in the industry (11, 12).

Addressing these challenges often appears to require simply a good understanding of aquatic ecosystems and shrimp biology, aquaculture management techniques, incentives, and institutions (8, 9). However, practical experience, formal training, and basic research all may contribute to innovation and expansion of shrimp aquaculture. Furthermore, general beliefs about appropriate rural and coastal development also shape public policy and, in turn, may be modified by the emergence of the shrimp aquaculture industry. Understanding how these various forms of knowledge are combined, and how research and practices influence each other, is crucial for identifying opportunities for promoting sustainability (13, 14).

In this article, we explore the knowledge systems (15) relevant to the sustainability of the shrimp aquaculture industries in Thailand and Mexico, both major shrimp-exporting countries. We opted to study Mexico and Thailand for their contrasting histories of shrimp aquaculture industry development. Thailand's industry expanded much earlier than Mexico's (16). Thailand has been the world's largest exporter of shrimp in most recent years (16). Its industry grew out of a combination of government and private sector initiatives served by many small farms (10, 11). Mexico's shrimp industry started from early efforts to promote shrimp farming by government-centered support to peasant collectives known as ejidos. Mexico's rapid expansion, however, did not begin until the mid-1990s, when a series of privatization and liberalization of national policies reforms opened opportunities for transfer of ejido land to the private sector (17, 18).

We focus our analysis on shrimp farmers: their perspectives on knowledge and action problems and what other people, like scientists and policy makers, think they should know and do.

We present our analysis of research and policy initiatives in 4 parts. In the first section we show that disease has been a key driver of innovations, including inappropriate use of chemicals, as have breeding programs and switches in species cultured. In the second section we highlight the importance of expert advice, practice norms, and policy for improving the locations of shrimp farms, managing of water, and maintaining competitiveness. In the third and fourth sections we argue that successful engagement and learning in horizontal relationships with other shrimp farmers and vertical ones with participants in the commodity chain are key factors for farmers' business success and sustainability transitions in the industry. The article ends with a discussion of how the knowledge systems for shrimp aquaculture in Mexico and Thailand are organized and the implications for the pursuit of sustainability.

Disease

The pursuit of better shrimp farm management practices has been, from the farmers' perspective, driven primarily by concerns over disease epidemics that have had recurrent and large impacts on production, profits, and practices in both Thailand and Mexico. Secondary drivers are criticism of unsustainable practices and socio-ecological impacts of shrimp farming (1, 9, 11, 19).

Detection and Resistance. Antibiotic drugs used to treat bacterial disease (e.g., *Vibrio* spp.) have no effect on viruses afflicting

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[1]To whom correspondence should be addressed. E-mail: louis@sea-user.org.

shrimp. Nevertheless, shrimp farmers widely believe that antibiotics help prevent and treat viral disease outbreaks, for example, by making shrimp healthier (3, 4). Viral disease outbreaks often result in escalating antibiotic use even as many farmers have little understanding about safety and how to use and combine chemical products (3, 4). The discovery of drug residues in exports from Thailand led to shrimp import bans as part of more stringent quality-control policies in Europe and elsewhere. Eventually, farmers were required to adhere to good agricultural practice guidelines and have aquatic animal movement documents (9, 20). In Mexico, new standards were introduced as emergency norms on the use of antibiotics in disease management with information about human and ecosystem health. Probiotics that compete with pathogenic bacteria for nutrients are increasingly recommended as an alternative to prophylactic use of antibiotics (21). Researchers and farmers also have sought ways to secure specific pathogen-free (SPF) brood stock and develop more disease-resistant strains and species.

When disease threatened black tiger shrimp, a general consensus emerged that the sustainability of the industry in Thailand depended on producing better shrimp seeds from the wild or through genetic research to produce disease-resistant stock. The state favored a genetic solution as they envisioned a shrimp industry shielded from nature's "wild cards." Farmers, however, have said they felt that more effort will have to be focused on understanding natural processes that enable the shrimp to survive and to better understand weather conditions and shrimp ecology well enough to improve management practices and capture stronger brood stocks from the wild. They were not optimistic that researchers could produce better shrimp than what they could find in nature.

Government has made significant investment in research, both through universities and quasi-public institutions like the Thai National Center for Genetic Engineering and Biotechnology (BIOTEC). In 2000 BIOTEC set up the Shrimp Biotechnology Business Unit to commercialize findings from research, like the virus test kits in the "Ezee Gene" series. Revenues from the business unit are reinvested in research. Centex Shrimp at Mahidol University in Thailand was established with support from BIOTEC building on an earlier private–public consortium that had developed DNA probes for shrimp viruses (22). Several other private–public collaborations were also supported to raise SPF and genetically improved tiger shrimp (23).

In Mexico government efforts have concentrated on controlling the spread of disease, whereas corporate efforts focused on biotechnologies for increasing productivity. Since 2002, total production of shrimp has been increasing at high rates despite significant disease outbreaks in 2002 and 2004. For instance, the area under cultivation in 2004 increased 28%, while production rose >35% regardless of sanitary problems. In 2005 the Aquaculture Sanitary Committee of the State of Sonora (founded in 2002 as a partnership between shrimp producers and the regional and federal governments) established a program in collaboration with 2 national research centers and a local university for sanitary verification. The kernel of this program is the establishment of a "sowing permit" through which the Sanitary Committee would ensure the absence of infections and guarantee that producers would carry out preventive sanitary operations. Inspections are also carried out in the postlarvae hatcheries and labs. The program also included training activities implemented through the establishment of Aquatic Sanitary Local Boards across the state formed by a group of producers.

Species Switches. Starting in 2002 producers in Thailand began switching more strongly away from the native black tiger shrimp (*Penaeus monodon*) to the Pacific white shrimp (*Penaeus vannamei*) (9). The reasons for the switch are complex but include easier disease management, faster and less variable growth, higher possible stocking densities, and lower overall food costs for white versus black shrimp. Currently, Thai farmers rely on importing SPF brood stock from Hawaii. The relevance of the large body of past research aimed at improving black tiger shrimp yields remains uncertain.

Mexico's aquaculture industry has largely developed as an extension of the capture fisheries industry with the aim of maintaining high exports of shrimp (24). In the 1970s the Center then later, Department, of Scientific and Technological Research at the University of Sonora (Sonora, Mexico) began experimental farms with the blue shrimp *Penaeus stylirostris* (25). Production has since switched between blue and white shrimp in different periods and locations depending on disease outbreaks (25).

Ponds

The pursuit of healthier and more profitable shrimp has not been restricted to chemicals and breeding but also at taking a much closer look at where and how shrimp are cultured.

Sustainability of the shrimp aquaculture industry is widely equated by government and industry officials as finding ways to technically improve the management of outgrowth ponds, including site selection, preparation, and operations. The international best-practice discourse now dominates policy and research discussions around the world (26) and has been fairly effective at countering criticisms of unsustainability (27).

Site Selection and Land Use. One of the most important business decisions for profitability and longer-term sustainability is location. Much of the initial environmental concerns with shrimp farming was with conversion of coastal lands and degradation of ecosystems, in particular mangroves (1, 2, 28). In recent years mangrove areas in Thailand have partially recovered through replantings and natural recruitment and enforcement of regulations so that new shrimp farms are not opened in mangrove areas (29). Farmers say they have moved out of mangroves because the costs of managing water and soils were too high; enforcement of mangrove conservation rules and policies undoubtedly also played a role (2).

Access to unpolluted water is a key factor in site choice (30). Conflicts with other land and water users, including other shrimp farmers, but also rice growers and coastal fishers, are related factors (11, 31). During the early expansion of the industry in Thailand, activities of shrimp farming fell between the responsibilities of fisheries and forestry agencies, and laws and zoning regulations were frequently ignored or reversed (2, 32). Later, enforcement became much more stringent.

In Mexico it was not until after changes were made to property rights that the shrimp industry could develop (24). The most pivotal policy reform was the amendment to Article 27 of the Mexican Constitution, which for the first time provided transferable titles to ejido lands and legalized the sale, rental, and mortgage of these previously inalienable lands (18). Until 1992, the ejido cooperatives held exclusive control over most of the coastal resources critical for shrimp farm development and the legal rights to capture and culture shrimp species (24). But with limited access to credit, these poor coastal communities lacked the resources to develop shrimp farms (18). Subsequent research shows that the transfers did not end up benefiting many poorer households and communities (18).

As the industry expanded, the Sonoran State government solicited several studies. For example, it funded a study by Monterrey Technical Institute in its city of Guaymas to assess shrimp farm potential in the region and the social and environmental factors. Much of the data collected in this study was put in a geographic information system database on the web for public access and regularly updated. The database included information on multiple threats and provided guidelines for

shrimp farm siting based on community participation and local technical assessment (25). Unfortunately, after the director changed in 2001, much of the conservation research program disappeared and the databases were no longer maintained.

Water Management. The nutrient-rich effluents from shrimp farms can cause salinization, reducing rice yields (33), creating conflicts with other water and land users (32), or impacting coastal ecosystems (30). Sediments dumped into waterways and coastal creeks affect the growth and survival of mangroves (34). Untreated effluent is also a cause of disease epidemics in shrimp (8). Expert advice to growers is usually to limit water exchanges and improve the quality of effluents (35). A study of alternative water management systems showed that farmers would voluntarily switch to closed systems with lower short-term profits because of the longer-term benefits of more stable and predictable production (36). Reduced water exchange assists in disease prevention (37). Some researchers in Mexico have promoted polyculture with bivalves and fish to reduce effluents from shrimp ponds (30), whereas others have emphasized the need for more closed systems to reduce disease risks (25).

In 2004, no shrimp farms in southern Sonora treated their effluent; however, there are 2 environmental laws that regulate the discharge of effluents from industries including aquaculture. These regulations establish maximum load of dissolved solids and other pollutants into natural water bodies. Many people we spoke to admitted that these laws are rarely enforced. Some research has been performed in Sonora on pesticide contamination of coastal lagoons and shrimp farms (38). They conclude that continental runoff carrying municipal and agricultural wastes contribute to decreasing shrimp production and may represent risks for consumer health. At the same time shrimp aquaculture in combination with other sources of pollution have combined to degrade water quality in the Gulf of California (39).

The Code of Conduct (CoC) of the Thai Department of Fisheries includes provisions requiring treatment of waste water through settlement basins or other methods. Awareness and understanding of codes was initially low (2). Certification under the CoC can be a difficult option for small farms, whereas larger farms with sufficient land are able to comply and do so because of expected benefits of certification for sales. Siri Tookwinas, a marine shrimp specialist who helped develop and adapt the CoC believes that researchers must work with farmers to be effective in addressing problems; some university professors, he felt, were disconnected from the real issues. Farmers treat researchers' advice with skepticism for at least 2 reasons: their advice has failed in particular with respect to disease prevention and treatment and they do not have as much experience or even data as many farmers.

But there are exceptions. Shrimp farmers in both Mexico and Thailand obtain useful information from articles written by scientists sharing their discoveries about water management and farming practices in leading industry magazines (2). In Thailand farmers widely use and contribute to *Sart Nam* (*Aquatic Animals*) magazine. Similarly, in Mexico many farmers mentioned the *Panorama de Acuicultura* magazine as an important source for stories of different management strategies being used throughout Latin America.

International Best Practice. Many elements in the international best practice discourse (26) are shared between Thailand and Mexico, in part because key documents and policies have origins in the same group of experts who have been active with international organizations.

Thailand has hosted the secretariat of the regional intergovernmental Network of Aquaculture Centres in Asia-Pacific (NACA) since 1988. The network now includes research centers in 17 countries. NACA was a founding member of the consortium on shrimp farming and environment that was formed in 1999. Initial partners were the World Bank, Food and Agriculture Organization, and World Wildlife Fund; the United Nations Environment Program joined later. The group supported case studies and consultations (40), the most significant of which was the set of guidelines on responsible shrimp farming in 2006 (27). Recent guides, handbooks, and spreadsheet tools cover things like health and disease management, diet formulation, and hatchery management practices. International assessments and dialogues have been an important research–action arena in the shrimp aquaculture industry. Participants from various parts of the commodity chain have gotten involved, in part, to defend the industry against critics by showing that better management is possible.

In Mexico, a new ecological consciousness emerged during the 1990s as a result of concerns over environmental impacts (41). Sustainability discourses are deeply embraced by research and government institutions, but also by the 3 main shrimp buyers (Ocean Garden, Diazteca, and Ojai Shrimp). In 2007 the Mexican Congress passed the Law for Sustainable Fishing and Aquaculture to regulate the relationships between different participants under the perspective of the sector's sustainability.

In the next two sections we turn to the relationships between shrimp farmers and other participants and identify key research–action arenas in each country at different times.

Horizontal Growers Associations

In Thailand the farmer-to-farmer network has frequently self-organized or been encouraged by state agencies to organize into associations for dissemination of information and ultimately to lobby the state at various levels. In Mexico a much greater role of the state is often apparent, but otherwise associations seem to have taken on similar functions.

Learning Organizations. According to close watchers of the industry, most of the innovations in aquaculture techniques in the past 10 years came from farmer groups getting together to form small learning organizations such as clubs and associations (9). Most of what are considered significant innovations in the industry are farming practices that reduce risks and cut costs. Many of these innovations are in line with sustainability objectives simply because of the low tolerance of shrimp to poor environmental conditions.

By far the most sophisticated grower's association that has arisen in Thailand is the Surat Thani Shrimp Farmers' Club (SSFC) or Growers' Association that was established in 1990, in part as a response to the collapse in the late 1980s of intensive shrimp farms in the Upper Gulf area of Thailand. The organization has had an evolving agenda, initially focused on reducing costs for shrimp farming inputs, but later including conservation and social responsibility activities (42). The organization runs a successful annual "Shrimp Day." The SSFC differs from several other organizations that have emerged in that it was very much driven by a group of concerned farmers rather than led by the state, a large corporation, or academic interventions.

The national Thai Marine Shrimp Farmers Association (TSA) was established in 1996 along similar lines. The two organizations continue to collaborate closely, with the national association working more at larger national international levels. The TSA, for example, is a member of the Global Aquaculture Alliance and has also engaged substantially with associations representing interests at other parts of the chain (food processing, feed mills). The SSFC and TSA are largely funded by donations from successful members, although income from laboratory consulting services, membership fees, and joint activities are also important (42).

An important function of the associations has been the creation of a "seminar culture" run largely by and for shrimp

farmers and hatchery operators. At these meetings invited speakers, often successful farmers, talk about their experiences. Farmers in both places discussed how successful management requires close monitoring of pond conditions, fine-scale experimentation, and tracking market conditions to place and time investments. As more countries have brought larger areas into active production, issues of competitiveness have risen strongly to the foreground, forcing farmers to look for ways to reduce input costs and make their operations more efficient (43). Surasak Dilokiet, secretary of the Thai Shrimp Farmers Association, said that their research interests focus on shrimp farmers not shrimp; they want to know what people with experience and expertise in aquaculture could be doing in 3–5 years time.

In Mexico, there are both private and ejido farmer's associations. In most cases, the administration of ejido farms is assisted by unions that also provide help to secure loans. In addition, the unions send ejido farmers to aquaculture conferences around the world. These trips appear to be a sort of reward (or incentive) to maintain the working spirit for those who both own farms and work in the offices. The conferences do not appear to be specific training sessions, but a time to share experiences with other farmers.

Shrimp farmers in Thailand said they valued guidance from scientists to solve specific problems and improve their farming practices. Farmers also find researchers useful for describing and communicating their experiences to others. Activities organized by associations and clubs are important research–action arenas in the shrimp industry.

Aquaculture Parks. In Mexico there are examples of strong cooperative arrangements around ejido lands. The ejido "aquaculture parks" consist of groups of ejido plots developed as separate shrimp farms but with shared infrastructure like canals. These farms coordinate their management decisions yet maintain independent administrative centers. Most of these farms currently work under the umbrella of 2 national ejido unions, the Union General Obrero Campesina y Popular and the Union General Obrero Campesina de Mexico. The unions provide administrative support and contract skilled personnel to operate farms, while members of the ejido contribute the less-skilled labor on the farms. The experiences in cooperative aquaculture parks were an important foundation for the subsequent expansion by private investors (25).

Vertical Business Relations

Being able to negotiate and maintain good relationships with processors, exporters, and overseas buyers has become crucial to successful shrimp farming. Shrimp farmers are involved in a network of horizontal and vertical relations as part of the production–consumption system. Trustworthy knowledge is an important transaction, paralleling flows of material and money, in many of these relationships.

Suppliers. An important source of scientific knowledge from grow-out pond managers are from suppliers of feed, chemicals for soil and water treatment, and other disease-related products. They are important because of their outreach effort, either through media or sales channels. They offer technical explanation of how a particular problem occurs and why their product is a good solution. Most of the literature, which could be a product advertisement, information sheet, or stylized as a news piece, is written in an accessible form and contains sophisticated scientific explanations written strategically. Farmers meet scientifically-literate salespeople much more often than they meet scientists from government or a university. The bigger the farms, the more salespeople who visit.

Several advances in aquaculture techniques resulted from the close economic relationship between farmers and hatcheries. One example is the refinement and spread of acclimatization to freshwater that allowed shrimp to be grown much further inland than before. The incentives are two way. When their crops fail farmers want to know which supplier to blame. Hatcheries survival, however, depends on the success rate of their customers because much of their business involves repeated interactions with farmers. Farmers said they do business with hatcheries they trust.

Buyers. In contrast, the relationships between frozen-food producers and farmers in Thailand are often much more strained. Many farmers believe that information about market uncertainties, food safety standards, and certification schemes is used strategically by frozen-food producers to bargain for lower prices. Farmers frequently complain about failures to honor promises and contracts. They believe food processors and their purchasing agents need to be more closely and independently regulated.

In Mexico critical sources of information about inputs and selling come from workshops provided by marketing groups. For example, Ocean Garden, the major shrimp distributor in Mexico, leads workshops on management practices. Similarly, Purina, a major shrimp feed seller, provides specialty training on feed and disease management. These training sessions are often led by local researchers from the university or private institutions.

Integration. Charoen Pokphand Group (CP), the largest individual producer and trader, with its market share dominance in feed production and significant interests in hatcheries (10), continues to frame the boundaries within which innovations take place. The business success of CP in shrimp is attributed to its ability to combine technological capabilities in agribusiness, established first in poultry, with networking skills (44). More controversially, many people also argue CP has too much control in business relationships with farmers, for example, requiring them to buy their feed if they purchase their brood stock, and accuse the company of influencing prices of feed inputs and shrimp to pressure competitors. Regardless, it is clear that the Thai industry is in part vertically integrated, which has undoubtedly been important for the way it has developed (10).

In Mexico, despite a well-developed institutional framework and government support, a powerful regional system of aquaculture innovation has not yet been consolidated (41). The private sector has grown considerably and has achieved a certain degree of internal integration through the establishment of influential organizations such as the National Association of Shrimp Larvae Producers. There are mechanisms of coordination between the private sector and public institutions for addressing specific problems such as shrimp disease. In addition, there is collaboration between private actors and ejidatarios (farmers working on ejidos or communally farmed lands). However, because in part of the seasonality of most jobs, many farmers remain unskilled and are poorly paid (45). As a result, the profits tend to be accumulated by agricultural companies and the local wealthy elite, who are not interested in enabling a solid and integrated class of skilled farmers.

Discussion

Learning. Shrimp farming is an uncertain, high-risk investment. Many of the challenges come not just from technical issues of managing pond conditions and health of a crop, but also shifts in market prices and regulations. Shrimp farmers must sift through misinformation pushed by vested commercial interests before making decisions. Economic gains from sharing information with other farmers generally outweigh gains from keeping secrets. Having an extensive social network of trustworthy sources of information, not just with other farmers, but with other parts of the commodity chain, appears to be a key to

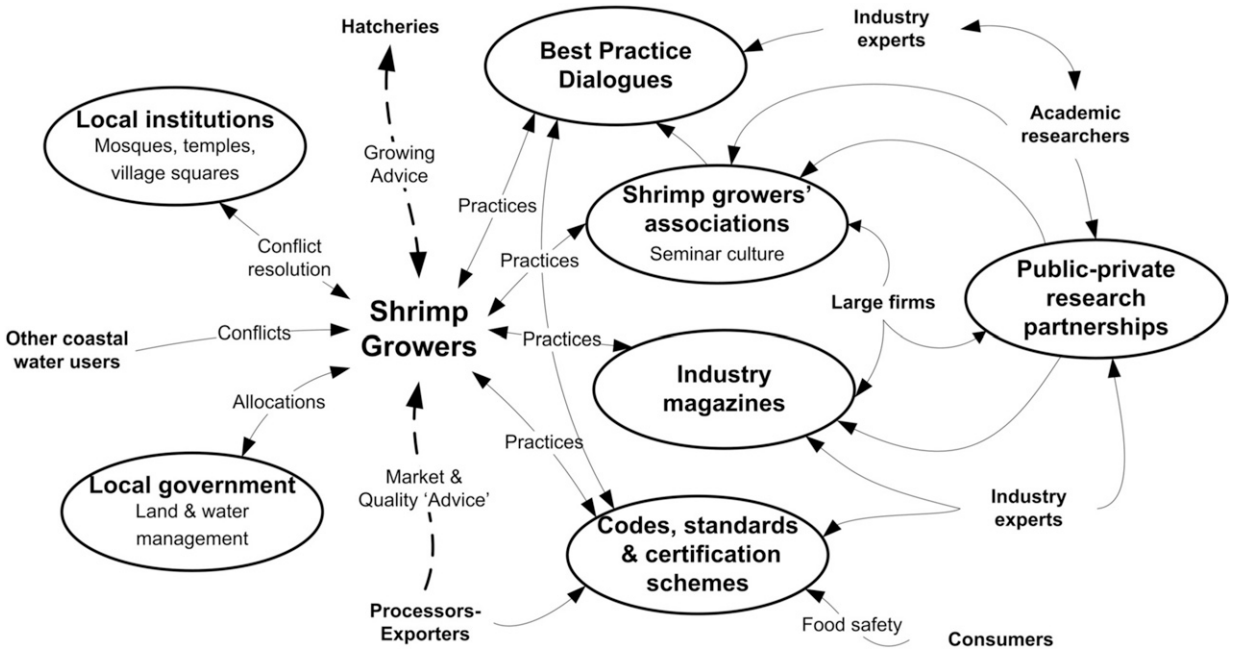

Fig. 1. Some of the research–action arenas important for shrimp growers in Thailand are shown.

success, especially in the Thai industry. In Mexico links are also important but reflect a history of ejido organization and government control. Both social and individual learning are important to success in this knowledge game.

Arenas. Research–action arenas have emerged as foci within the web of horizontal and vertical networks important to shrimp growers (Fig. 1). Apart from those already discussed in detail above we have found examples where social and political institutions support arenas. For instance, in one location in southern Thailand, regular meetings at the local mosque were important in sorting out disputes and shaping new water sharing and local land-use arrangements (9). Local government councils can also play a significant role in linking policy and expertise in shrimp-growing areas (9, 31, 42); in both Thailand and Mexico local leaders were often also shrimp entrepreneurs.

In Thailand the shrimp industry is comparatively well connected by large trade associations organized along the supply chain, from frozen-food associations and farmers to hatcheries. The substructure of these associations comprises of interlinking groups and small clubs known locally as "Chum Rom." Government and supply businesses (feed, chemicals, and related industries) that see a marketing opportunity provide support for activities within these groups both to push policy and products (Fig. 1). A workshop organized by a club to discuss how to produce organic shrimp, for example, would be attended by scientists and speakers from the Department of Fisheries and supported by companies selling organic additives.

A similar importance of a rural seminar culture was noted in the shrimp industry in Mexico and a study of innovations in the Argentine Pampas (sackler.nasmediaonline.org/2008/sd/Gilberto_Gallopin/Gilberto_Gallopin.html). These arenas seem to be important because they foster vertical and horizontal relationships important to farmers. Further research on these sorts of arenas in dynamic rural industries would be worthwhile for sustainability transitions, in particular to explore how they are maintained, for example, through the mutual value they create for participants. Are some arenas better at handling vested interests or fostering engagement among stakeholder groups than others, and how?

Social networks among farmers vary in the level to which they are institutionalized, for example, ranging across clubs and formal organizations to the collective arrangement still common in Mexico. Trust appears to be an important element in more loosely bound networks. Many farmers complain about lack of trustworthiness in others. More systematic analysis of trustworthiness in verbal and written contracts, and with respect to sharing of information about disease and market, is needed to better understand the editing, translation, mediation, and other boundary functions that networks seem to perform.

Assessment exercise and dialogues around codes, standards, and certification schemes have also been important arenas (Fig. 1) for the industry as a whole for learning to do business in new ways with farmers. Farmers find these important because, like seminars, they often bring together stakeholders from different parts of the production–consumption system (9).

Sustainability. The sustainability of the shrimp aquaculture production–consumption system has usually been framed as a technical problem solvable with the adoption of best practices. At the farm level it is assumed to be solvable by better management of shrimp and ponds. At the national level the objective is to maintain industry's competitiveness in export markets by adhering to standards.

Formal systems of research and development in both public and private spheres in Thailand and Mexico largely accepted this depoliticized view of shrimp aquaculture development. Economic and, increasingly, ecological concerns are being addressed, but social and political issues continue to be neglected, which poses difficulties for completing a sustainability transition for at least two reasons. First, issues of fairness in the allocation of burdens, benefits, and risks have been sidestepped. Second, it ignores the increasingly important role played by negotiations in making sustainability work in practice. Researchers, with some important exceptions, have not engaged broadly enough with the sustainability problems facing the industry despite the growing number of opportunities to do so.

In both Mexico and Thailand, research–action arenas have emerged that are crucial to business success and look promising for sustainability transitions. A common feature of many of these arenas is that they engage multiple stakeholders, encourage

deliberation, and are driven by concerns with practices. Social and individual learning opportunities have expanded: from initial concerns with practices that directly affect profits and food safety the range of issues being dealt with that can affect market access now includes ecosystem impacts, worker conditions, and affected communities. Many of these arenas appear to be flexible, a necessary precondition, to dealing with the dynamic challenges faced by shrimp farmers and the industry.

Despite their contrasting trajectories, in both Thailand and Mexico government policy has been crucial to the initial expansion of the shrimp industry. The need now is for support and incentives for diverse researchers to engage with the practical livelihood challenges faced by farmers and affected communities of making the shrimp aquaculture truly sustainable. So far the knowledge system is yet to come to terms with the multiple and dynamic dimensions of sustainability.

Methods

Field work in Mexico was carried out over two main periods. The first was between January and November 2001 when 131 interviews were collected from 41 coastal ejido communities as part of a study on land reform (18). Additional short visits were carried out in 2004–2005 to interview and informally meet heads of laboratories, farmers associations, and key suppliers to ask specific questions about information and farm management decisions. The focus of the field work was in southern Sonora. Field work in Thailand was also carried out in two phases. The first was between May 2000 and December 2001 when 294 interviews were collected from shrimp farmers by using a closed questionnaire, and an additional 52 in-depth interviews were undertaken with traders, suppliers, hatchery operators, government officials, village leaders, and others (2). In 2004–2006 we collected an additional 20 formal interviews with leaders in the shrimp aquaculture industry at both local and national levels, for example, with leaders of various associations and clubs, industry magazine editors, and researchers in academia and government, to better understand innovations and perspectives on research needs and gaps.

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