Research Issues in Sustainable Coastal Shrimp Farming: a Private Sector View

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Abstract

The research needs of the private sector are frequently overlooked in establishing research programs intended to improve the industry itself. The reasons for this vary. Often, the private sector fails to grasp the relevance of particular research areas and there is a dearth of people within the private sector who can communicate the needs of the sector or keep up with the research being carried out. It is also true, however, that a large communication gap exists between the research community and the private sector. Expectations from research often fail to be met, with the private sector looking for short-term, fast answers and researchers looking for longer-term projects which can maintain funding for their laboratories and staff. The level of application of existing research is disappointingly low, reflecting a lack of attention to the development phase of research work to include implementation on the farm. This does not reflect any fault so much as a lack of recognition of the importance of extension as a component of applied research. There also exists a great deal of competition in the supply of information to farmers so that the lack of extension from reliable or unbiased sources leads to the farmers obtaining the majority of their information from groups with a particular vested interest. These issues need to be tackled if any program designed to improve the sustainability of shrimp farming is to succeed. This paper highlights some of the factors governing the application of research work in Southeast Asia and those areas which, in the authors opinion, need to be addressed to improve the industry's ability to meet the demands of the future.

SHRIMP farming in Southeast Asia has been one of the success stories of modern aquaculture. The speed with which the industry developed from a cottage and backyard level, consisting of little more than tidal entrapment, to a large, multidisciplinary and highly sophisticated industry, has been truly remarkable. The profits to be made by shrimp farming attracted many entrepreneurs and increased investment in rural areas suitable for growing shrimp.

The growth of the shrimp industry has taken place in a largely undirected and unconstrained manner. In recent years, problems have continued to mount as outbreaks of disease and the consequences of over-expansion and pollution become more evident. The shrimp industry has reached a watershed in its development as the conditions and forces shaping the industry change. It is timely to look at the industry and assess the current status of its technological development and research needs, to allow it to continue to develop into a more consistent and predictable activity.

Before addressing the question of researchable issues in shrimp farming, it is useful to address three key questions:

- What is the 'shrimp industry'?
- How do we envisage the shrimp industry in 5–10 years time?
- How do we get it there?

The Shrimp Industry

The term 'shrimp industry' covers many different components which comprise the business environment of the industry. In Asia, the various components

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of the chain of production are mostly independent with little vertical integration. Broodstock fishermen catch wild broodstock and spawners and sell these on to hatcheries or nauplius producers. The nauplii are either stocked in the hatchery or sold on to other hatcheries for growing on to postlarvae. In some countries there is no dependence upon wild fry for stocking shrimp ponds other than the few extensive ponds operating on tidal entrapment. The on-growing of the shrimp to market size is undertaken by independent farmers who sell their shrimp, either directly or through brokers, to processors and exporters.

Outside of the production chain, there are several other groups who are also stakeholders in the business of growing shrimp. These are mostly suppliers, such as feed companies and companies selling other goods and services required by the farmers such as chemicals and fertilisers. These groups also comprise part of the industry although their dependence upon production levels and successes is less direct.

It is important to consider these various groups as their individual goals differ markedly depending upon how they view their involvement. These goals have a significant impact on the promotion, acceptance and adoption of new ideas and practices developed as part of a research strategy. They can also provide valuable insights into the best means of integrating these into the production system and the most effective intervention levels for their promotion.

The shrimp farming industry in Asia is dominated by small-scale farmers who have only a few ponds. Various estimates place the percentage at 70–80% of farms. This is extremely important to take into account in any planning for development of the industry. The planning and decision-making processes are much more complex than they would be for an industry dominated by a few key players. The idea of sustainable development has to be brought to these farmers and they need to be convinced, as the industry's development is nothing more than the sum total of the decisions, right and wrong, made by these farmers. It is essential that information is provided to these farmers in such a way that their decisions can be informed ones. The alternative approach is to enforce or impose regulations upon them. However, these regulatory approaches have so far failed to influence the development of the industry in any country.

To some extent, uncontrolled and unsustainable development is inevitable in any new venture that appears to give easy profits and high returns on investment. A 'gold rush' mentality leads to many investors rushing in to take advantage of the situation without being fully aware of the risks involved. This leads to an almost inevitable 'boom-and-bust' cycle as the shrimp farming activity exceeds the available resources, whether they be physical, technical, economic, human or infrastructure. As the risks become more apparent, many short-term investors pull out, leaving those who are genuinely interested in making a livelihood from shrimp farming. Then follows a period of consolidation and slower development from a more professional, knowledgeable base. The key to reducing the short-term impact and increasing the long-term sustainability lies in making the inevitable boom-and-bust as short and as small as possible, and promoting the development of a more professional and informed farming sector.

The Next Ten Years

In order to develop an effective strategy for research that will be adopted by the industry, it is necessary to have some idea of the ultimate goal. Visions of the future shape of the shrimp industry vary somewhat but generally tend to assume that it will develop into a similar 'commodity' producer as the chicken and salmon industries. If that vision is accepted, then comparisons will indicate some of the key areas in which knowledge is lacking. However, two caveats need to be considered. One, that the vision of the industry's future is shared by those who currently are involved, and two, that the current climate of public opinion and acceptance of industrial development is quite different to that which prevailed when both of the chicken and salmon industries went through their early development. It should also be considered that the development of the industry along these lines would have a great impact on the kind of people who will remain in and enter into the industry.

This medium to long-term view of the future should be developed in consultation with industry. This consultation can be difficult as many researchers, particularly government ones, tend to be caught between the need to regulate and the desire to assist. There is often a feeling of being outside the industry and a lack of appreciation of the role that economic and managerial considerations play in decision making, even at a small farm level. The fault is not entirely one-sided as, unfortunately, there also exists a lack of appreciation of the role of research and development in the industry's success even among technicians involved in the industry. However, there

are scientists and industry managers who do appreciate the role and responsibility of both sectors in pushing the industry forward and it is important that the dialogue be not only continued but increased to allow a balanced development of the industry.

Problems with Research Implementation

For the purposes of this paper, the issues described will be those related to production rather than those related to the various service providers, except where service-oriented research has a direct bearing on production.

Before going into detail on the researchable issues, it may be useful to examine the differences in the way that research activities are viewed by the scientific and farming communities. Scientists are generally more involved in obtaining results rather than implementing them. There is a tendency to regard publication of results or papers as the end point and the implementation or adoption of new practices as a result of the work is the responsibility of someone else. The time taken to achieve results varies, but it is not uncommon for research activities to take several years to yield results.

Those involved in the private sector, on the other hand, tend to be less interested in how results are obtained than in how they can be applied. At the same time, they have little time to devote to scouring the technical literature and developing practical means of application. Time frames for results also tend to be far shorter, measured in weeks or months rather than years.

The differing attitudes to research and development (R&D) have been summarised as **R**&D versus R&**D**. In other words, most researchers place the emphasis on research with some development activities, whereas the industry demand is for more development and application of existing research information. Indeed, the word 'development' is frequently omitted by scientists when discussing their work. At the same time, many researchers become frustrated at the lack of application of their research findings while being unable or unwilling to effectively put them across to a non-technical audience. There is a need to address this issue by increasing the emphasis on communicating results and explaining the implications for industry. The effectiveness of this depends very much on finding people who can bridge the gap of understanding between the two groups.

From a commercial point of view, it is important that any research program or activity designed to be implemented by the industry should include a requirement and commitment by the project team to undertake activities to ensure that development activities towards successful implementation are carried out. This moves away from the traditional form of investigative research into applied research. Project plans and programs can be developed either jointly or in consultation with industry and the progress monitored together. In my experience, the greater the involvement of the eventual user in the project, the greater the rate of implementation.

The consequence of this gap can be seen in one key area of contention within the modern shrimp industry—the use of drugs and chemicals. A simple theoretical example can serve to demonstrate the difference between the points of view of scientists and farmers and the dynamic which leads to increased drug use despite a wealth of information demonstrating that it may not work.

In an outbreak of a disease, the ponds of 100 farms are affected. Of the 100, 50 farmers resort to a particular drug or chemical claimed as a cure and 50 carry on without any drug use. Of the group using the drug, 25 report an improvement and harvest, while 25 show no improvement and have a poor harvest. Of the group not using drugs, the same scenario develops—25 improve, 25 do not. Based on scientific analysis, there is no difference between the groups using or not using the drug and the conclusion would be that the drug did not work for the particular problem affecting the farms.

However, in reality, the 25 who used the drug and whose shrimp improved, would promote the use of the drug among their friends and among other farmers, sometimes at the request of a salesman. The 25 who did not use the drug and whose shrimp got worse, would be tempted to use the drug at the next outbreak. The 25 who used the drug and whose shrimp did not recover would be inclined to think that, since the drug did work on some farms, they either used it wrongly, too late or did not use enough. The final group, those whose shrimp recovered on their own, would generally not say much as the available evidence (the 25 who used it and got a good result) would tend to convince them that it may indeed help. They may even be tempted to use it in future to obtain an even better result.

Thus it can be seen that, even under conditions where scientific analysis of the available evidence demonstrates that a particular treatment does not

work, its use in the farm could increase dramatically. This demonstrates the impact of marketing of information on farming practice. The vacuum created by the lack of reliable, unbiased information is taken up by providers of goods and services in the form of technical support. This support does not come free and, in the case of unscrupulous salesmen, is frequently biased in such a way as to promote the use of their product, often by dubious or tenuous associations. It should be mentioned that not all salesmen behave in such a cynical manner although, in my experience, the number of salesmen who do is significant. In general, this problem is most frequently encountered with salesmen who work independently or for smaller companies looking to make fast returns. More responsible or larger companies tend to take account of the effect on the entire market potential and avoid creating situations where short-term gain may cause long-lasting damage to their market prospects.

Researchers who wish to present information to farmers have to realise that they are in competition with alternative information sources and that the farmer often finds it difficult to judge between them. Viewed purely as a marketing exercise, the researcher may have a good product whose benefits can be justified but the battle for the farmer's mind is being lost in the marketplace. It is of vital importance that this gap is addressed as the consequence is that the credibility of scientists as a source of practical and useful information to farmers is under threat. As a result, scientists are frequently perceived as being out of touch and impractical compared to the purveyors of technical sales support, a perception bolstered by the lack of 'farmer-friendly' presenters of unbiased technical information.

Researchable Issues

The success of shrimp farming and some of the impressive rates of growth in production masks the primitive state of much of the technology involved. Despite the many grandiose claims made by various people concerning new advances and improvements, the majority of farmers still depend on a healthy dose of luck. The current level of sophistication of shrimp farming is still quite low. Broodstock are fished from the sea, there is a reliance upon wild spawners, hatchery methods lack standardisation, efficiencies are low, fry are stocked into ponds in which relatively few tools are available to control the production environment, and the yield and quality of the end product are largely uncontrolled. All of these factors combine to place the future sustainability of shrimp farming in considerable doubt and they need to be addressed so that the industry can develop in ways which will prove to be of long-term benefit.

It is also true to say that production efficiency has not so far been a major concern within the industry, with the possible exception of feed-use efficiency (feed costs represent around 50% of variable costs so there is a direct economic benefit in its efficient use). It may be trite but nonetheless should be kept in mind, that the producer's main aim is to maximise his profit for the lowest expenditure of time and energy. If profits are high without any great need to spend a lot of time and energy, the incentive to improve efficiency may be low. This is another reason behind the lack of application of research findings.

Hatchery issues

The current reliance on wild supplies of broodstock imposes a severe constraint on the future development of the industry. An animal production industry which depends on wild stocks alone cannot achieve long-term sustainability or begin to make any improvements in the genetic suitability of the stocks for cultivation. Closed-cycle rearing of broodstock from pond-reared shrimp has been achieved several times in several countries but has so far failed to develop into a commercially viable operation. The reasons behind the lack of interest in applying these methods demonstrate the differences in outlook between the scientific and commercial sectors. To date, the reported rates of nauplius production from pond-reared broodstock have been much lower than those from wild spawners. Although this is understandable given the current state of knowledge of shrimp reproduction, it reduces the attractiveness of the pond-reared stock as the cost of producing a fixed number of nauplii is perceived to be high due to the larger number of females needed. The resulting lack of commercial interest had stifled the development of closed-cycle breeding until relatively recently, when the appearance of several new virus diseases prompted renewed interest in it as a means of reducing the disease risks associated with wild stocks.

The development of closed-cycle breeding programs has demonstrated its worth in other areas of animal husbandry. The chicken, swine and cattle industries as we know them today would not exist in the absence of breeding programs to select for specific desirable attributes. Even the relatively young

salmon farming industry has progressed at a tremendous rate since the development of controlled breeding programs.

The health status of broodstock sources has generally been neglected although there are a few recent reports that include estimates of prevalence of specific viral diseases in wild shrimp. However, the available information is often sketchy and no epidemiological study has been performed. There is a need for these kinds of study to be undertaken to identify the disease status of different stocks and to develop means of controlling the entry and movement of pathogens into the breeding and farmed populations. The information gained is also essential for the development of any certification program for disease control.

Hatchery production levels in Asian hatcheries are generally rather low. Various estimates are available but the average survival rates are generally accepted to be between 20–30% on an annual basis. This implies a great inefficiency in production, especially since survival rates in excess of 70% can be obtained on an occasional basis, suggesting a tragic waste of the resources available. Any consistent improvements in survival would help to remove the hatchery as a bottleneck in production and reduce the costs associated with postlarvae, which can represent 10–15% of the direct cost of production.

Overcoming restrictions in postlarvae supply would also allow a greater focus to be placed on the quality rather than the quantity of production. At present, many quality assessment programs for postlarvae fail due to a lack of postlarval supply. This forces farmers to accept lower quality postlarvae simply to ensure that their ponds are stocked. Removing the production bottleneck would allow hatcheries to differentiate their postlarvae based on quality. Farmers show great loyalty to hatcheries with a good record of supply and post-stocking performance and are willing to pay a premium for postlarvae that give better production performance.

Farming issues

The relative lack of sophistication and low efficiencies of production extend also to the farming sector. Relatively few major advances impacting positively on yields and efficiencies have occurred in the past ten years. It is to some extent true that this is due, at least in part, to the lack of sufficient research funding and expertise available in those countries in which shrimp are farmed. Even Thailand, with its large shrimp industry and well-organised government support, still suffers from a heavy reliance on a small group of people and a limited budget.

The situation can be clearly seen from an analysis of production data from Aquastar Ltd and contract farms in southern Thailand over the period 1989–1995. In the first crops, when farmers had little experience, stocking densities were kept low at around 18–20 shrimp/m^2. Yields averaged around 4 t and survival rates averaged around 65%. By 1995, stocking densities had increased to an average estimated at 60 shrimp/m^2 (having been as high as an estimated 75 shrimp/m^2), but yields had increased only slightly to 4.5 t due to a drop in average survival to around 35%. Although these figures include the effects on production of two serious viral diseases, it can be clearly seen that efficiencies, far from improving, actually declined. The example of Aquastar's contract farmers holds true for the industry in general, although it is difficult to obtain exact figures for the whole country due to the many shifts in production areas (previous shrimp farms closing down, new areas opening up).

It is widely stated and believed that shrimp farms have a limited lifetime for production although no good explanations exist for why this should be. Self-pollution as a factor is widely suspected but measurements of the organic content of pond soils generally fail to demonstrate any convincing relationship with productivity. Some ponds and farms have continued to produce consistently (allowing for disease impacts) over many years, proving that extended production in one area is possible. Obviously many factors are at work, including intensification, postlarval availability and quality, impacts of new diseases, impacts of feed quality and availability, development of new pond management techniques (which can have both positive and negative impacts) and economic factors, among others. However, there has been very little concerted effort to identify and assess the relative importance of these. Scientific research in particular tends not to consider the impact of economic factors on farmers' decision making and hence productivity. Explanations are therefore sought in purely technical terms.

Pond management has been frequently found to be by far the greatest determining factor in the success or failure of a shrimp farm operation. The levels of interest and skill have far more effect on the success of a farm than any other single factor. Even during problem periods, 'good' farmers tend to have better production than 'bad' farmers. Given this, it may be expected that an assessment of what makes a 'good'

farmer would be quite useful. The information gained could be used to assist in the development of a 'best practice' for pond management.

The development of a range of best management practices would greatly improve the consistency of production. To do so would require a high level of cooperation between the scientific community and the production and business sectors. Even the adoption of uniform measures, targets and objectives would greatly assist in achieving such a goal. To give some examples, terms such as 'extensive', 'semi-intensive' and 'intensive' are widely applied, although there are no uniform definitions of these words. Even when they are defined, the definition depends upon the level of intensification that exists at that point in time or in one locality. Stocking densities are still frequently used by scientists and farmers despite the fact that the number of shrimp stocked has no real bearing on production due to differences in survival rate. Final yields are frequently used to measure success, although the final measure of a farmer's success is actually the profit from the crop. The development of clear definitions is, in my opinion, central to the success of any program intended to improve sustainability in shrimp farming at any level.

Good feed management is one of the most important factors in the success or failure of a shrimp farm operation. Feed costs represent between 40–60% of the direct cost of production in a farm. Good yields with poor feed conversion ratios (FCRs) can still result in a farm going out of business. A great deal of attention is paid by good farmers to keeping FCRs below 2:1 and a good farmer can consistently achieve an FCR of around 1.6:1. Having said that, the basis for feed management requires many assumptions to be made about the way in which shrimp feed. Many of these assumptions are anecdotal and untested. Research into these could assist in developing feeds and feeding strategies which will improve the average FCR, the profitability and the economic sustainability of farms.

Virtually all shrimp feeds sold are pelleted feeds. This imposes some severe restrictions on the formulator as the formulation must allow the production of a good, water-stable pellet. This limits the amount of fat which can be included in the diet, for example. The average FCR for salmon has decreased dramatically over the past ten years, partly due to the switch to extruded, rather than pelleted feeds. Extruded diets allow more fat to be included, which allows a reduction in the protein content. As protein is the most expensive ingredient, this can make the feeds cheaper to produce. The reduction in protein also reduces the pollution due to feed as the nitrogen content is reduced. The reason for a lack of acceptance of low pollution (low nitrogen, low protein) feeds is the common belief among farmers that high protein levels are necessary for good growth of the shrimp. This belief stems, in part, from feed companies competing on the basis of protein content. This has back-fired, as attempts to reduce protein content by feed companies are now perceived by the farmer as an excuse to cut their costs and increase profits at the expense of the farmer. More research into low pollution, cheaper feeds which achieve the same or better performance on the farm would benefit the farmer financially as well as reducing the pollution load on the environment.

The large impact of shrimp farming on the environment is due to the large volume of water discharged. The further development of systems which use lower rates of water will greatly alleviate the pressure on the environment as well as reduce the cost of pumping which, although often neglected, can be significant. A further area which is often neglected is the development and dissemination of techniques utilising full-strength seawater. It is still widely believed that fresh water is needed to mix with the seawater to achieve intermediate salinities in order for shrimp farms to succeed. However, large farms utilising ambient seawater do exist and production levels are comparable with farms situated in brackish-water or freshwater areas. The farmers in the Aquastar system in southern Thailand have been growing shrimp in ambient seawater conditions for the past eight years and production levels have been comparable to those of the industry in general. The benefit of such systems is that they can be situated in open coastal areas where the carrying capacity of the receiving water is much less of a problem than in estuarine or freshwater environments where user conflicts may be higher and where carrying capacities can be limited. The techniques required to successfully grow shrimp in ambient seawater are different from those for brackish water and still require a great deal of development. Additional research into the control of water quality and phytoplankton communities in seawater systems would further improve the performance and acceptability of such systems.

Health management

Health management (as opposed to disease control) is one of the key areas in which developments are needed both as a matter of short-term urgency and for

long-term development of the industry. For many years the focus of terrestrial farming systems has been on health and productivity schemes, encompassing both prevention strategies and focusing on productivity of farmed stocks rather than the 'fire brigade' approach which still predominates in the shrimp industry. The absence of clinical or obvious disease problems does **not** indicate that there are no fundamental problems within the system. However, this still tends to be the dominant attitude among farmers.

Much can be done to improve the situation using currently available knowledge within the scientific and farming communities. For example, there is sufficient information and experience to allow for rudimentary risk assessment to be carried out for a number of diseases to determine the likelihood and severity of problems that may be encountered. This information will be paramount in developing strategies to deal with the specific diseases as well as suggesting generic strategies that can be implemented to deal with all diseases sharing common points in their epidemiology. The relative costs and benefits associated with diseases and prevention/treatment strategies can also be calculated. This will assist in deciding upon the most effective strategy from an economic and technical standpoint.

One of the most important factors in dealing with a disease outbreak is information. Knowledge is needed on the type of disease and the factors determining its occurrence. Also, knowledge is needed on the condition of the shrimp stocks and of the environment in the pond. These are key elements in deciding upon the best means of dealing with a disease. The relevant knowledge is not, generally speaking, easily available to farmers and is subject to the pressures of the 'information market' mentioned in the early part of this paper. Among the greatest aids to dealing with any disease outbreak is to ensure that the correct information is available to farmers as soon as possible. This may be as simple as providing them with the most up-to-date information on the spread, impact and diagnosis of the disease in terms that are easy to understand. If treatments are available, or just as importantly if they are not, this should be mentioned. When such information comes from a recognised, impartial body (such as the relevant government authority), farmers may be more inclined to accept it.

During the initial impact of the white spot epidemic in Thailand, for example, a working group was assembled to assess all available information on the disease. This working group comprised representatives from the private sector, including suppliers such as feed companies, as well as the academic and government sectors. Based on the discussions of the working group, the Department of Fisheries (DOF) undertook to produce a leaflet for farmers explaining what the disease was, how to diagnose it and what steps could (and could not) be taken to deal with an outbreak in a farm. The information contained in the leaflet was agreed upon and accepted by all members of the working group and all parties undertook to provide support for the dissemination of the information. This involved some companies funding the printing of additional copies of the DOF leaflet for distribution to their customers. In addition to the leaflet, a national task force was established to identify the key areas in which information necessary to develop a strategy to deal with the disease was lacking. Research proposals to carry out the necessary work were quickly developed and approved, the budget coming from a combination of government and private sector funding. As a result of the response by the working group and DOF, the impact of the white spot epidemic was significantly reduced. One single piece of information, that the disease was due to a virus and that there were no cures, probably saved most farmers from spending significant sums on bogus 'cures' and from additional losses by waiting too long before harvesting.

To date, almost all of the effort has concentrated on those diseases that cause direct losses through mortality. Relatively little attention has been paid to diseases which, although not fatal, can have a high economic cost. Diseases that affect productivity, by reducing growth rates or affecting the quality and value of the shrimp at harvest, can have a high economic cost. Any program dealing with shrimp health improvement must include non-lethal diseases and disease syndromes.

Present disease diagnostic capabilities depend largely upon the availability of sophisticated laboratories to conduct the tests necessary to establish a clear diagnosis of the problem. Techniques such as histology and polymerase chain reaction (PCR) testing, for example, require a fair degree of sophistication and qualified personnel to conduct. Very few countries or shrimp farming areas have easy access to the facilities and expertise required. Also, the majority of the tests do not give results quickly enough to allow them to be used as part of a decision-making process on the farm. There is a need to develop simple tests that can be used on the farm with a minimum of training to allow for real-time, pond-side diagnostic capabilities. This would allow farmers to make

faster and better informed decisions to deal with problems when they arise. Further development and simplification of gene probes and rapid staining techniques show great promise in this respect but it is necessary to take the procedures out of the laboratory and explore ways in which they can be better applied under farm conditions.

The range of chemotherapeutic drugs approved for use in aquaculture is frustratingly small and has led to a widespread use of non-approved drugs. The non-approval is, in many cases, the result of a lack of sufficient data to support approval rather than the presence of data to support a ban. More work has to be done to demonstrate the efficacy or otherwise of the available drugs to obtain the appropriate conditions of use and approvals. A 'fast-track' or 'pending' approval procedure may be useful for those drugs approved for use in other food animals while the relevant data are being obtained for shrimp. The development of chemotherapeutic approvals should also include the dissemination of relevant guidelines on their proper use, control and application.

The establishment of safe residual levels of chemotherapeutics for shrimp is also necessary. The current situation is that, in many countries, no residuals of drugs commonly allowed in other food products such as beef and poultry are permitted in shrimp. This is frequently due simply to the lack of information on residuals. Acceptable residual levels of chemotherapeutics should be allowed for shrimp in the same way. Exporting and importing countries should work together to establish these standards.

Nutrition plays a large part in the management of shrimp health. Monitoring of the feeding behaviour and patterns of the shrimp is one of the main ways in which farmers can get early indications of pending problems. The role of nutrition in the shrimp's defence mechanisms is still very poorly understood. It is difficult to get good data on this in the field as feed companies do not (nor should they) publish details of their formulations. However, the effects of variations in raw material quality and the effect of the processing of the feed are poorly understood. A better understanding of these would allow feed companies to improve their formulations and processing to take account of these variations. At present, feed formulations tend to be compared on an 'as formulated' basis. However, the most important consideration at the farm level is what the formulation is at the point of ingestion by the shrimp. Feeds can change considerably once placed in the water as water-soluble components leach out and water stability affects the availability and palatability of the feed. Feed research should also include comparisons of formulations after one hour in water. This would better reflect the feed as eaten by the shrimp and may point the way to more far-reaching improvements in formulations.

Shrimp health enhancement programs are already being pursued in several countries. Development of *specific* pathogen-free (SPF) and *specific* pathogen-resistant (SPR) stocks has already taken place with some species of penaeid. (The use of the word *specific* should be noted here, as there has been much confusion over the terms. SPF/SPR shrimp are not 'disease free' or 'disease resistant' but have been specially bred and maintained to exclude particular disease organisms for which this approach is appropriate.) These programs are highly dependent upon the establishment of breeding programs using pond-reared stocks, emphasising the importance of closed-cycle breeding for the future of the industry.

The development and testing of immunoenhancers, immunostimulants and vaccines is still at a very early stage. Indeed, there is still a lot of controversy over the concept of vaccination as applied to shrimp because they have no specific immune system. Recent work has shown that disease 'tolerance' may also be a mechanism in the shrimp's arsenal of defences against infection. This work needs to be continued and refined to develop practical and applied measures that can be taken at the farm to reduce the risk of catastrophic losses to disease. The impact of vaccines and immunostimulants on the salmon industry in Europe has been substantial and demonstrates the benefits that may be gained from their application in shrimp culture.

One of the least investigated, yet potentially most significant, factors in the success or failure of shrimp farming may be the impact of pesticides or other harmful substances on the shrimp. Many shrimp farms are located in areas of high agricultural activity where the risk of contamination is high. Most farming activities nowadays involve the use of herbicides and insecticides. Some of these, particularly the insecticides, can be toxic to various life stages of the shrimp at extremely low levels. Bioassay experiments can be conducted on the farm to confirm the acute toxicity of the most common toxicants used in the vicinity of the farm, but the existence of chronic or sub-lethal effects requires more sophisticated facilities and equipment. Considering the potential synergistic/antagonistic effects of toxicants on shrimp in field conditions, it is surprising that so little work appears to have been done in this field.

Postscript

This paper has done little more than skim the surface of some of the major issues as perceived from the private sector. Obviously, such a brief presentation can do no more than highlight a few issues. Many more exist and the priorities may be regarded differently by other people. However, there remains one key issue which can and should be addressed in any program intended to enhance or influence the development of the industry, and that is communication. The better the dialogue between the private and public sector, the better the understanding will be. This will inevitably lead to an improvement and increase in the implementation of research findings. To do so will require some shifts in attitudes on both sides and the recognition that the communication of information and development of applied methods based on research results is a distinct skill and is essential to any applied research program.