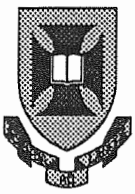
Symposium on parasitic diseases of aquatic animals: 10th International Congress of Protozoology

Dr R.J.G. Lester



THE UNIVERSITY OF QUEENSLAND

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Project No. 97/336

NON TECHNICAL SUMMARY

97/336	**Symposium on parasitic diseases of aquatic animals: 10th International Congress of Protozoology**

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OBJECTIVE :

To bring three overseas experts to explain about current developments in marine parasitology that relate to wild and caged tuna and other fish, prawns and oysters.
The experts were to speak at the International Congress in Sydney and then in one or more informal sessions to researchers and members of the industry in other parts of the country.

NON TECHNICAL SUMMARY:

The 10th International Congress of Protozoology held in Sydney 21-25 July, 1997, provided the opportunity to bring three experts in disease in aquaculture to Australia. They were Dr Mike Hine, NZ, Prof. Tim Flegel, Thailand, and Dr Mansour El-Matbouli, Germany. They spoke at a special symposium entitled 'Aquaculture'.

Dr Hine, NIWA, NZ, an expert on oyster and fish diseases, spoke on the the "protozoan parasites of farmed molluscs: host parasite interactions". He used electron microscopy to demonstrate mechanisms used by molluscs to overcome disease organisms and discussed how these mechanisms might be facilitated in the future. After the Congress, he travelled to Launceston where he gave a seminar and met with Judith Handlinger and other interested parties.

Prof. Flegel, Mahidol University, Bangkok, an expert on prawn diseases, detailed progress in the use of a DNA probe to study *Agmasoma penaei*, a microsporidian parasite of prawns. This parasite is a problem in farmed *P. merguiensis* in Thailand. Its source is unknown. His group have developed the probe and were screening possible alternate or reservoir hosts in the expectation that the numbers of these could be controlled and thus reduce the prevalence of infection.

Following the Congress, Prof. Flegel was keynote speaker at the Annual Meeting of the Australian Prawn Farmers' Conference. He gave two talks, the first on diagnosis and

control of major diseases currently threatening Asian shrimp aquaculture, and the second on future trends in the control of shrimp diseases.

Both at the Congress and later at the University of Queensland, Dr El-Matbouli, University of Munich, an expert on myxosporeans of fish, spoke about his recent discoveries on the life cycle of a freshwater myxosporean *Myxobolus cerebralis*. This parasite is closely related to the *Kudoa* species that cause problems in the flesh of tuna, couta and billfish in Australia. He showed that *M. cerebralis* undergoes sexual reproduction in an aquatic worm and that strictly speaking the worm is the definitive host of the parasite and the fish an intermediate host. It is not yet known how *Kudoa* species are transmitted. The compete text of his talk was published in the International Journal for Parasitology (vol 28, pp 195-217, 1998).

Prof Bob Lester, symposium chair, reviewed recent work by him and his colleagues, Dr Diggles and Dr Adlard, on *Cryptocaryon irritans*, the cause of 'white spot' disease in marine fish. The parasite was shown to be exceedingly common on wild fish, especially bream, in SE Queensland and this appeared to be the major source of local infection. Morphological and DNA studies suggested that the same species of ciliate was found worldwide, there were several strains, and that it was not closely related to *Ichthyophthirius multifiliis*, the ciliate that causes 'white spot' in freshwater fish. The results have been published in a series of papers in the Journal of Parasitology, Diseases of Aquatic Organisms, and elsewhere.

Other experts in aquaculture diseases attracted to the Congress to attend the Symposium and to talk in other sessions were Prof F. Perkins (USA), Dr M. Kent (Canada), Dr R. Olsen (USA), Dr G. Burreson (USA), Ms N. Stokes (USA), Prof H. Yokoyama (Univ.Tokyo), Dr B. Munday (Univ.Tas), Dr B. Jones (WA), Dr L. Goggin (CSIRO) and Dr M. Byrne (Univ. Syd.).

Financial support from FRDC enabled the overseas speakers to take part in the Aquaculture symposium and for industry representives to meet them to discuss possible solutions to some disease issues in Australia.

Key words: aquaculture, health, disease, protozoa.

Background

A symposium on protozoan diseases of aquatic animals was planned as a feature of the 10th International Congress of Protozoology. Speakers invited for the symposium were: Dr Mike Hine, NIWA, NZ, an expert on oyster and fish diseases, Prof. Tim Flegel, Mahidol University, Bangkok, an expert on prawn diseases, Dr El-Matbouli, University of Munich, an expert on myxosporeans of fish, and Prof. Bob Lester, University of Queensland, to talk on white spot disease in fish and to chair the symposium.

Need

The overseas speakers agreed to come, speak at the Congress and speak to at least one other group while in Australia if there was some assistance with their travel expenses. Their visit provided an opportunity for members of the fishing and aquaculture industry to hear about latest developments in disease research. Advertisement of the symposium attracted other experts in marine disease to come to Australia for the Congress and they were able to also meet special interest groups while here.

Objective

To bring three overseas experts to explain about current developments in marine parasitology that relate to wild and caged tuna and other fish, prawns and oysters.
The experts were to speak at the International Congress in Sydney and then in one or more informal sessions to researchers and members of the industry in other parts of the country.

Methods

Three experts were sought, one on protozoan diseases of molluscs (Dr Hine), the second on protozoan diseases of crustacea (Prof. Flegel), and the third on protozoan diseases of fish (Dr El-Matbouli).

Their post-congress talks were provisionally planned as follows:
Hine - NSW BWFRS Open Day followed by seminar at the Department of Aquaculture, University of Tasmania (Launceston)
Flegel - Keynote speaker at the 1997 Prawn Farmers' Conference, Brisbane, and
El-Matbouli - Invited seminar, Parasitology, The University of Queensland.

Industry representatives who supported the proposal included:
Mr Col Baldwin and Ms Liz Evans, Australian Prawn Farmers Association
Mr D. Ogburn, representing NSW Oyster Farmers
Mr R. Arnold and Mr J. Bender, Qld. Oyster Growers Association
Dr B. Munday, Aquaculture Tasmania
Ms K. Rough, SA Tuna Boat Owners Association
Dr P. Montague and the Fish Health Section of the Aquaculture CRC

Results/Discussion

At the Congress, Dr Mike Hine spoke on the the "protozoan parasites of farmed molluscs: host parasite interactions". He used electron microscopy to demonstrate mechanisms used by molluscs to overcome disease organisms and discussed how these mechanisms might be facilitated in the future (abstract attached). After the Congress, he travelled to Launceston where he gave a seminar and met with Judith Handlinger and other interested parties. He was unable to attend the NSW BWFRS Open Day as the date was changed to later in the year.

At the Congress, Prof. Tim Flegel detailed progress in the use of a DNA probe to study *Agmasoma penaei*, a microsporidian parasite of prawns. This parasite is a problem in farmed *P. merguiensis* in Thailand. Its source is unknown. His group have developed the probe and were screening possible alternate or reservoir hosts in the expectation that the numbers of these could be controlled and thus reduce the prevalence of infection.

Following the Congress, Prof. Flegel was keynote speaker at the Annual Meeting of the Australian Prawn Farmers' Conference. He gave two talks, the first on diagnosis and control of major diseases currently threatening Asian shrimp aquaculture, and the second on future trends in the control of shrimp diseases. His abstracts to these talks are attached.

Both at the Congress and at the University of Queensland, Dr El-Matbouli spoke on his recent discoveries about the life cycle of a freshwater myxosporean *Myxobolus cerebralis,* a relative of the *Kudoa* species that cause problems in the flesh of tuna and other fish. He showed that *M. cerebralis* undergoes sexual reproduction in an aquatic worm and that strictly speaking the worm is the definitive host of the parasite and the fish an intermediate host. It is not yet known how marine myxosporeans are transmitted. His abstract is attached and the compete text of his talk was published in the International Journal for Parasitology (vol 28, pp 195-217, 1998).

Prof Bob Lester discussed recent work by him and Dr Diggles and Dr Adlard, his colleagues, on *Cryptocaryon irritans*, the cause of 'white spot' disease in marine fish. The parasite was shown to be exceedingly common on wild fish, especially bream, in SE Queensland and this appeared to be the major source of local infection. Morphological and DNA studies suggested that the same species of ciliate was found worldwide, there were several strains, and that it was not closely related to *Ichthyophthirius multifiliis*, the ciliate that causes 'white spot' in freshwater fish. The abstract is attached and the results published in a series of papers in the Journal of Parasitology, Diseases of Aquatic Organisms and elsewhere.

Other experts in aquaculture diseases attracted to the Congress to attend the Symposium and to talk in other sessions were Prof F. Perkins (USA), Dr M. Kent (Canada), Dr R. Olsen (USA), Dr G. Burreson (USA), N. Stokes (USA), Prof H. Yokoyama (Univ.Tokyo), Dr B. Munday (Univ.Tas), Dr B. Jones (WA), Dr L. Goggin (CSIRO) and Dr M. Byrne (Univ. Syd.).

The financial assistance provided by the Fisheries Research and Development Corporation was acknowledged at the start of the Symposium verbally by the chairman and in an

overhead transparency and later verbally (by Prof Flegel) at the start of the Prawn Farmers' Conference.

Benefits

I anticipate that members of the oyster and prawn industry who saw the speakers benefitted directly. Other members will benefit through their local disease experts who attended the sessions and discussed local issues. This is as planned.

As a consquence of the symposium Ms S. Hallett, an Australian student, applied for and was awarded a DAAD (German) scholarship to work with Dr El-Matbouli on the transmission of marine myxosporea.

Further development

Industry representatives may agree that to bring overseas experts in a particular field to Australia every two years is a good investment.

Conclusion

The project was completed successfully.

Appendix 1:
Intellectual property

Most of the work is now published and therefore in the public domain.

Appendix 2:
Staff

R. Lester, the University of Queensland, M. Hine, T. Flegel and M. El-Matbouli donated time to the project. The FRDC grant provided partial reimbursement to the speakers for travel and accommodation costs. Other costs were borne by the CRC Aquaculture, The Australian Prawn Farmers' Association and the University of Queensland.

Payments from FRDC grant:

Dr El-Matbouli (Germany)	$3,838.46
Mahidol University (Thailand, Prof Flegel)	$2,186.09
NIWA (NZ, Dr Hine)	$2,091.71
University of Queensland (Prof Lester)	$ 233.74
Total FRDC grant	$8,350.00

Appendix 3.

Part of program and abstracts from the 10th International Congress of Protozoology, Sydney, July 1997. (attached).

Appendix 4.

Details and abstracts from the visit of Prof.Flegel (attached).

Friday 25 July 1997

SYMPOSIUM 1 - MOTILITY — Wallace Lecture Theatre
Chair - Peter Satir

0830 **THE LINKING OF EXTRINSIC STIMULI TO BEHAVIOUR: ROLES OF CILIA IN CILIATES**
Hans Machemer, R. Bräucker, S. Machemer-Röhnisch, U. Nagel, D. C. Neugebauer. Ruhr-Universität Bochum, Germany

0900 **THE ROLE OF CILIA AND FLAGELLA IN PROTOZOAN MOTILITY AND BEHAVIOUR**
Michael A. Sleigh. University of Southampton, UK

0930 **MODELLING THE AXONEME**
Michael E. J. Holwill. King's College London, UK

1000 **MECHANISM OF CILIARY MOTILITY: AN UPDATE**
P. Satir. Albert Einstein College of Medicine, USA

1030 Morning Tea & Poster Exhibition - Refectory

SYMPOSIUM 2 - NEW TECHNOLOGIES — Woolley Rm395
Chair: Anthony Smithyman

0830 **APPLICATION OF ISCOM ANTIGENS IN ELISAS FOR PROTOZOAL INFECTIONS WITH EMPHASIS ON NEOSPOROSIS**
Camilla Bjorkman. Swedish University of Agricultural Sciences, Sweden

0900 **MODERN IMMUNODIAGNOSTIC METHODS FOR PROTOZOAL DISEASES**
A. M. Smithyman. Cellabs Pty Ltd., Australia

0930 **METAL-INDUCED CHANGES IN *CHILOMONAS PARAMECIUM*, DETERMINED BY X-RAY MICROSCOPY**
Joanna Abraham-Peskir, R. Medenwaldt. University of Aarhus, Aarhus, Denmark

1000 **AMEBIASIS - WHAT'S NEW FOR DIAGNOSIS IN THE '90S?**
William A. Petrie, Jr., M.D., Ph.D

1030 Morning Tea & Poster Exhibition - Refectory

SYMPOSIUM 3 - AQUACULTURE — Old Geology Lecture Theatre
Chair: Robert Lester

0830 **PROGRESS IN THE USE OF A DNA PROBE TO STUDY *AGMASOMA PENAEI* A MICROSPORIDIAN PARASITE OF PENAEID SHRIMP**
Timothy W. Flegel, Tiraskak Pasharawipas. Mahidol University and Rangsit University, Thailand

0900 **PROTOZOAN PARASITES OF FARMED MOLLUSCS: HOST PARASITE INTERACTIONS**
P. M. Hine. National Institute of Water and Atmospheric Research, New Zealand

0930 **THE LIFE CYCLE OF *MYXOBOLUS CEREBRALIS* WITH SPECIAL REGARD TO THEIR DEVELOPMENT IN *TUBIFEX TUBIFEX***
Mansour El-Matbouli, R. W. Hoffmann. University of Munich, Germany

1000 **REVIEW OF THE BIOLOGY AND SYSTEMATICS OF *CRYPTOCARYON IRRITANS***
R. J. G. Lester, B. K. Diggles, R. D. Adlard. The University of Queensland, Australia

1030 Morning Tea & Poster Exhibition - Refectory

1100 **PLENARY - PARASITES OF FARMED AQUATIC ANIMALS** — Wallace Lecture Theatre
Frank O. Perkins. North Carolina State University, USA

Stream 1 - Marine Protozoa — Wallace Lecture Theatre
Chair: Louise Goggin and Barry Munday

1200 **INTRASPECIFIC AND INTERSPECIFIC COMPARISONS OF PKX, THE CAUSATIVE AGENT OF PROLIFERATIVE KIDNEY DISEASE OF SALMONID FISHES, USING SMALL SUBUNIT RIBOSOMAL DNA SEQUENCE**
M. L. Kent, R. H. Devlin, D. M. L. Hervio, J. Khattra. Department of Fisheries and Oceans, Canada

PROTOZOAN PARASITES OF FARMED MOLLUSCS: HOST PARASITE INTERACTIONS

P. M. HINE. National Institute of Water and Atmospheric Research, New Zealand

Molluscs utilise a wide range of strategies to combat infection by protozoan parasites. *Perkinsus*, a protist parasite that has a wide host range in Australian molluscs, is a good example. Molluscs may be refractory to *Perkinsus* infection and able to kill the parasite in surface tissues. If infection occurs, the parasite may not proliferate, or the host may contain infection by encapsulation of the parasite or by utilising phagocytes that kill and remove the infection. Some hosts may be largely refractory but occasionally individuals suffer overwhelming infections. Haplosporidia, and a similar parasite, *Bonamia*, use different compartments in their oyster hosts, requiring opposite infection strategies. Haplosporidia are extracellular and must evade immune surveillance by mimicking host cells. *Bonamia* grows and divides in phagocytic haemocytes and must be recognised as foreign by haemocytes in order to be phagocytosed. Once in the host haemocytes, cellular killing mechanisms are avoided by suppression of the respiratory burst, and formation of a parasitophorous vacuole, as utilised by other protozoa in phagocytic cells. This paper considers many aspects of the host:parasite interaction, including molluscan defence mechanisms, parasite strategies, and the nature of virulence and resistance to infection.

THE LIFE CYCLE OF *MYXOBOLUS CEREBRALIS* WITH SPECIAL REGARD TO THEIR DEVELOPMENT IN *TUBIFEX TUBIFEX*

MANSOUR EL-MATBOULI, R. W. HOFFMANN. University of Munich, Germany

Whirling disease caused by *Myxobolus cerebralis* has become the most widely known disease of salmonids in the 1990s. In the last five years we have studied many aspects regarding host/pathogen relationships of this parasite. *M. cerebralis* has been found in more than 20 countries and recorded in 18 species of salmonids. The American Rainbow trout *Oncorhynchus mykiss* is the most seriously effected species, brook trout *Salvelinus fontinalis* less severely, whereas the European brown trout *Salmo trutta*, seems to be the most resistant. The parasite's histozoic development causes significant damage to cartilage and induces central nervous symptoms by pressure on brain and spinal cord.

M. cerebralis has a two-host life cycle involving a salmonid fish and a tubificid oligochaete. Two different stages of sporogony occur, one in each host. Early developmental stages in the fish can be found in epidermis, peripheral and central nerve tissues, involving presporogonic multiplication, followed by a migration to vertebral and cranial cartilages, where the first sporogonic phase occurred. *M. cerebralis* spores matured in fish cartilages are the infectious stages for *T. tubifex*, when ingested by the oligochaete after destruction of the affected fish together with diet particles. In the gut lumen of the tubificid, the spores extrude their polar capsules and attach to the gut epithelium by polar filaments. Afterwards the shell valves opens along the sutural line and the sporoplasm penetrates between the gut epithelium. The binucleated sporoplasm multiplied in a schizogonic phase producing many one-cell stages, which begin the gametogonic development. As a result of this multiplication process, the intercellular space of the epithelial cells in more than 10 neighbouring worm segments can be shown to be infected. At this time (60-90 days post infection) pansporocysts with 8 zygotes start the sporogonic phase. The final stage of this development is a pansporocyst containing 8 folded *Triactinomyxon* spores. Shortly afterwards, the spores are liberated into the gut lumen. The spores reach the water either by egestion or following death of infected tubificids. Infected tubificid can release *Triactinomyxon* through out more than one year. The ultrastructure of all three phases (schizogony, gametogony, sporogony) as well as the factors that control the amount and release of the triactinomyxon stages from their worm hosts are demonstrated and discussed.

REVIEW OF THE BIOLOGY AND SYSTEMATICS OF *CRYPTOCARYON IRRITANS*

R. J. G. LESTER, B. K. DIGGLES, R. D. ADLARD. The University of Queensland, Australia

The ciliate, *Cryptocaryon irritans*, the cause of 'whitespot' disease, is an ongoing problem in marine aquaria and holding tanks. A unique method for screening wild-caught fish showed that 95% of bream *Acanthopagrus australis* and 50% of whiting *Sillago* spp. from Moreton Bay were infected at a mean intensity of 11 and 6 trophonts per infected fish, respectively. At Heron Island on the Great Barrier Reef, *C. irritans* was found on 38% of the bream *Gymnocranius audleyi* and 73% of emperor *Lethrinus miniatus* with an average of 2 and 4 trophonts per infected fish.

Several authors have suggested that *C. irritans* is a species or strain complex. Parasites from Moreton Bay grew into larger trophonts than those from Heron Island when grown under identical conditions on barramundi, *Lates calcarifer*, their tomonts developed in a shorter time and the resulting theronts were larger, indicating the existence of two strains. Sequences of rDNA from the two strains differed by one base in the 18-S region and 7 bases (4.1% divergence) in the ITS-1 region. Isolates from the USA and Israel differed from the Australian isolates (wild-caught fish) by up to 4.7% and 5.3% respectively. The prominent post-oral groove evident in Australian material has not reported elsewhere. Thus there is evidence for at least 4 strains of *C. irritans*. When the Moreton Bay isolate was passaged in the laboratory it was subject to a founder effect, exhibiting up to 3.5% sequence divergence from fresh isolates from Moreton Bay.

Though *C. irritans* is often classified with *Ichthyophthirius*, comparison of 224 bp of the 18S region of *C. irritans* with an isolate of *I multifiliis* and 6 other ciliates indicates that *C. irritans* is not a close relative of *I. multifiliis.* The sequences suggest a close relationship to colpodid ciliates though the simple apical cytostome suggests affinities with prostome ciliates.

Appendix 4. Details and abstracts from the visit of Prof Flegel

Itinerary of trip to Australia

Date	Activity	Place
20 July, 1997	Departed for Australia	Bangkok
20-25 July	Attended Protozoology Congress	Sydney
25 July	Presented a paper on a shrimp microsporidian at the Aquaculture Session	
25 July	Departed for Brisbane	
26 July	Made two presentations at the APA meeting	Brisbane
27 July	Participated in the APA meeting	
28 July	Visited the CSIRO lab at Little Pocket and had discussions with Dr. Walker's group	
29 July	Visited the CSIRO lab at Cleveland Bay and had discussions with Dr. Preston's group	
29 July	Departed for Bangkok	

Abstract of presentation at the Aquaculture Session of the Protozoology Congress:

Progress in the use of a DNA probe to study *Agmasoma penaei*, a microsporidian parasite of penaeid shrimp. by Timothy W. Flegel and Tirasak Pasharawipas, Dept. Biotechnology, Mahidol University and Dept. Microbiology, Rangsit Unviversity, Thailand

The microsporidian, *Agmasoma penaei* , infects two species of commercially reared penaeid shrimp in Thailand (i.e., *Penaeus merguiensis* and *P. monodon*). The parasite is rarely problematic with *P. monodon* , but is more serious with *P. merguiensis* which it frequently attacks in high numbers in rearing ponds. This can result in a low selling price for farmers because of the characteristic white discoloration of the musculature (cotton shrimp or white back shrimp) caused by massive production of spores. We have developed a specific DNA fragment for use in following the parasite in the shrimp farming system. By labelling the fragment with digoxygenin, it was used successfully by *in situ* hybridization to visualize the parasite in histological sections and haemolymph smears from pond-reared, infected shrimp. It was also developed for dot-blot hybridization and PCR amplification assays. Dot blot hybridization and PCR amplification assays were used to identify two candidate fish (*Scatophagus argus* and *Priacanthus tayenus*) as potential alternate hosts for the parasite. *In situ* hybridization assays with one of these (*S. argus*) fed on infected shrimp meat indicated that goblet cells of the fish intestinal epithelium may be primary targets for the parasite. However, we have not yet succeeded in transmitting the parasite from shrimp to this fish and then back to shrimp again. Results will also be presented from another survey that is in progress to determine by normal histology and by DNA diagnostic techniques whether the high incidence of abnormally small *P. monodon* from rearing ponds is correlated with infection by *A. penaei*.

Abstracts of two presentations at the annual meeting of the Australian Prawn Farmers Association:

Diagnosis and control of major diseases currently threatening Asian shrimp aquaculture

The disease state in shrimp (or any animal) results from an interaction of three main factors. These are the shrimp (animal) itself, the environment and the pathogen. Usually all three of these need to be in an appropriate state for disease to occur. Therefore, for effective disease control, we need to adopt a wide focus which includes more than just the pathogens themselves. Insuring high health through good nutrition and a rearing environment free of stress can go a long way towards disease prevention, even if a pathogen is present. I believe that good environmental management and shrimp pond management can reduce the risk of bacterial, fungal and parasitic disease to innocuous levels. The major elements in good pond management include selection of high quality fry, use of reasonable stocking densities, provision of high quality feed in appropriate quantity and maintenance of optimum water quality. Viral diseases are another matter. Some of these are so infectious and so virulent that even good shrimp health and low stress cannot prevent severe losses if they are introduced into a pond. Two major viral diseases that currently threaten Asian shrimp farmers are good examples of this. These are white-spot baculovirus (WSBV) and yellow-head virus (YHV). The only way of currently dealing with these diseases is to exclude them from the rearing pond if possible. Yellow-head disease first hit Thai shrimp farms in 1991, but the causative virus was not discovered until two years later. This was the first step in a program to diagnose, understand and control yellow-head disease. The most important outcomes from the program were a series of practical control measures for farmers, and the realization that a high degree of cooperation amongst the farmers was required if these measures were to succeed. The second major virus, WSBV, hit Thai shrimp farms hot on the heels of YHV, and with even more devastating effect. The losses to yellow-head disease in 1994 were in the order of US$40 million, but for white-spot disease in 1996, they were in the order of US$500 million. Again, the first step towards the control of white-spot disease was the discovery of the causative virus (WSBV) and the development of rapid

diagnostic methods for it. The subsequent introduction of appropriate control methods probably averted an even greater disaster than the one that occurred in 1996, and only time will tell whether and how well the industry will recover. However, the lessons gained with these two viral diseases are very clear. First of all, new viral diseases are very likely to arise, and we must be prepared to deal with them quickly and effectively. Secondly, the only way to control viral diseases is with effective prevention programs, and the success of these programs depends upon a high degree of cooperation amongst shrimp farmers. Thirdly, we must consider our current predicament and begin rational programs that will result in more fundamental, long-term solutions to disease problems. This will be the topic of my second talk.

Future trends in the control of shrimp diseases

The aquaculture industry now produces approximately 700,000 metric tons of shrimp per year. At an estimated US$5 per kg profit for shrimp farmers, this represents about 3.5 billion dollars per year. In spite of the size and value of this industry, it is surprising how little we know about the cultivated species and their pathogens. It is also surprising that most of the industry depends on wild captured females for production of the fry used to stock shrimp ponds. These are major problems which I feel hinder long-term stabilization of the shrimp culture industry. I am deliberately leaving out wider environmental issues. The problem of seed supply is one which will get progressively worse with time. Ultimately there will be no choice but to develop domesticated stocks, and it is fortunate that there are already some initiatives and progress in that direction. The program with *Penaeus vannamei* at the Oceanic Institute in Hawaii pioneered the field, and other programs are underway with *P. monodon* in Australia, the Philippines and Thailand. Preliminary results from these initiatives indicate that we will be able to develop domesticated shrimp varieties that grow two times faster, are more uniform in size and have higher disease resistance than their wild relatives. It is obvious that these improvements will benefit shrimp farmers. Perhaps not so obvious, will be the benefit of uniform stocks for experimental work on shrimp nutrition and defense against disease (i.e., the "white mice" of shrimp research). Lack of such animals for research means that we often cannot get clear answers to the fundamental questions necessary for further progress. With respect to defense against disease, we know far too little about shrimp. With man and with domesticated animals like swine and sheep, we have good base line information for various health measures like temperature, blood cell counts and blood chemistry. We can quickly perform a few simple tests to establish general health status. We do not have such baselines for shrimp and they are badly needed. We do know that shrimp do not have antibodies like the vertebrates (from fish to man), so it is not likely that vaccination processes will prevent them from being infected by viruses. However, there is evidence that shrimp do not always die when infected with viral diseases, including Taura syndrome in the Americas and white-spot disease and yellow-head disease in Asia. In other words, they can tolerate viral infection under some circumstances, and the tolerance appears to be specific for each virus. Preliminary work in Thailand indicates that this tolerance may be inducible by a process similar to vaccination using inactivated virus particles that we prefer to call "tolerines" rather than vaccines. The problem is that tolerines do not prevent infection, they only reduce the probability of massive mortality after infection, if the shrimp are reared under conditions of low stress. Infected, tolerant shrimp must be treated very carefully, since some kinds of stress can induce a sudden viral explosion and massive mortality. We urgently need to understand this phenomenon. Finally, I return to the pathogens themselves. Just like the shrimp, we know too little about the pathogens. How do they infect the shrimp? How do they cause death? A group of scientists should be permanently maintained to work on these problems while they serve as "firemen" always available to respond quickly should a new disease emergency arise.