The survival of young fish in their vulnerable larval state is crucial to the success of aquaculture, but establishing positive larvae-microbe interactions seems to be a major obstacle. By analysing the mechanisms through which microbes interact with these creatures, scientists are devising new strategies to sustain them, thereby improving the productivity of aquaculture

Improving larval survival in aquaculture

Overfishing and the deterioration of marine ecosystems have prompted investment in aquaculture as an alternative to wild catches. In 2010, this vast industry produced fish with a value of more than $217bn. According to the United Nations Food and Agriculture Organization, natural extraction has effectively levelled off in recent years, but aquaculture production continues to burgeon, presently accounting for around 60 million tonnes of production - 60% of the world total in 2011, and increasing by 7% per year.

Despite carefully managing their waters, larviculture may still flounder due to biological hazards. Temperature, feed, water quality and sanitation are all carefully modulated, because concentrating large quantities of fish in comparatively small spaces may exacerbate threats. Stocking densities, behavioural interactions, disease and parasitism all pose risks to young fish, which are especially susceptible to these ills, as larvae can only rely on their innate immune system to combat infections. The majority of diseases in fish larvae are thought to be caused by opportunistic microorganisms, which become pathogenic when their host's resistance is lowered by environmental stress factors. These can be partly mitigated by hygienic measures, such as filtering and disinfection of the water. Despite the ubiquity of these countermeasures, the high (and poorly predictable) mortality observed in the rearing of most species suggests that the present countermeasures provide limited protection. Moreover, it has been proposed that they may even affect the microbial communities negatively. "This is a significant issue, both within academia and industry," says Professor Olav Vadstein, a specialist in microbial ecology at the Trondheim-based Norwegian University of Science and Technology. (NTNU). "Survival of larvae is generally very low. This threatens animal welfare, production and profitability."

If widely acknowledged as a significant contributor to larval mortality, the processes through which microbes interact with their hosts have hitherto remained enigmatic. "Recent advances in molecular biology tools in combination with strictly controlled microbial environmental conditions for these larvae have been a catalyst to revisit this problem," says Vadstein. "Thanks to the recent methodological revolution in molecular biology, we are now able to comprehensively examine this problem. Not only have we devised analytical models to examine relationships between microorganisms and their hosts, but we have also considered how to potentially mitigate their most detrimental effects".

Ghent University, Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Wageningen Univeristy, NTNU and SINTEF have all been important contributors to a 3m project titled 'Microbes As Positive Actors For More Sustainable Aquaculture'. Since commencing in 2009, the project has developed several novel techniques to improve the survival of hosts. The project's findings suggest promising new management techniques for the aquaculture industry. Fostered by a progressing understanding of factors

affecting the interplay between microbiological organisms and their hosts, the latter phase of the project tested the responses of larvae to benign microorganisms, to assess whether they could counter biological threats. Traditionally there has been more focus on malign than on benign microbe-fish interactions, despite the fact that being healthy should be the normal situation. Trials were also conducted to ascertain the benevolent effects of microbes, as an agent to combat invasive pathogens.

"Using molecular tools, we've generated some quite unexpected results," says project coordinator Professor Peter Bossier of Ghent University. "We can now revisit much of our prior work on larvae. Formerly, only the growth rates and enzyme activity of larvae were quantified, but now we can also examine how the development of the fish and the experimental situation are linked to expression of genes, including specific responses to well defined microbial communities. We've obtained far more information about the varied mechanisms which govern healthy development of larvae than we had previously, although much remains to be learned about the molecular basis of host-microbe interactions in the larval phase."

To enhance the microbial quality of the aquatic environment and to suppress the proliferation of damaging microbes within it, the group suggests a two-pronged intervention. The first of these is related to improved health by steering microbiota in the water. By channeling water through biofilters, microbes are forced to compete for nutrients, resulting in exclusion of opportunistic bacteria and creating a more stable and diverse microbial environment. The group found that such a microbial community results in more viable larvae, and in experiments with Atlantic cod larvae, managing bacterial communities in this way resulted in a 60% higher survival rate compared to a conventional setup. The system limits the availability of nutrients within larval tanks and stabilises the amount of waste organic matter available to the microbial biomass in the tank, thus restricting microbial growth and minimising oscillations in microbial biomass and activity. "We've consequently developed the possibility of steering, or controlling microbial community composition and activity in a way which enhances appetite, growth and survival of larvae," says Vadstein. "Formerly, the general thinking was that microbiological water quality is critical to larvae only for the first few days, and, thereafter, it's primarily the microbiota of their diet which affects them. Our findings indicate that this is incorrect. Moreover, recirculating aquaculture systems seem to function as a microbial management technology - an aspect that has been almost completely overlooked."

"We've consequently developed the possibility of steering, or controlling microbial community composition and activity in a way which enhance appetite, growth and survival of larva"

Finally it appears that is not only possible to steer microbial community composition but also their activity. Depending on the microbe-host interaction under study, it has been established that the outcome of these interactions might be determined by secreted quorum-sensing molecules. Such types of molecules contribute to the production of virulence factors. Interference with the production of these quorum-sensing molecules can be beneficial to the host. Quorum quenching, as the technique is called, can be realised through the addition of antagonistic molecules (contrary to antibiotics, these compounds inhibit certain microbial activity rather than trying to eliminate them) or through the addition of microorganisms able to degrade quorum-sensing molecules. Future full-scale experiments are needed to establish whether this can become a reliable microbial management technique.

"Relationships between the larvae and microbiota should be mutualistic and symbiotic," summarises Vadstein. "There is no uniform solution, or magic ingredient you can simply add to the water which improves larval survivability. Nonetheless, we have begun to explore and control a complex of underlying mechanism at work here." ★

AT A GLANCE

Project Information

Project Title:
PROMICROBE: Microbes as positive actors for more sustainable aquaculture

Project Objective:
This project suggests bringing together various European research groups that have contributed to some important methodological breakthroughs that can be used in the study of host/microbe interactions and can help to disentangle the complex interplay between the different components of the aquaculture ecosystem

Project Duration and Timing:
5 years, Feb 2009 to April 2013

Project Funding:
EU FP7

Project Partners:
1 Coordinator Ghent University (Ugent) Belgium
2 Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) France
3 Wageningen University (WU) The Netherlands
4 Norwegian University for Science and Technology (NTNU)Norway
5 SINTEF Materials and Chemistry (SINTEF-MC) Norway
6 SINTEF Fisheries and Aquaculture (SINTEF-FA) Norway
7 Flanders Institute for Biotechnology (VIB) Belgium

MAIN CONTACT

Peter Bossier
Peter Bossier has been a researcher for 30 years in the domains of microbial ecology, molecular genetics (of stress response) and fish quality. At the moment, his focus is on host microbial interactions in larviculture. His research output stands at 167 A1 papers.

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