



# HATCHERY

FEED & MANAGEMENT

## WATER QUALITY

Hatchery Nutrition  
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Lior Shak is a live feed specialist at Dagon.

## INTERVIEW *with Lior Shak*

**HFM:** Dagon is a fish breeding center situated on the eastern shore of the Mediterranean Sea. Would you briefly tell us more about the company's journey?

**LS:** Dagon began its journey in the 1980s, in Kibbutz Ma'agan Michael, cultivating and breeding ornamental fish. Today, Dagon is one of the top-quality koi suppliers worldwide, breeding outdoor, bio-secure koi, goldfish, and eco-friendly fish.

Making the most out of our experience in the ornamental fish market, in the past 20 years, Dagon expanded to new markets and developed new fish breeding lines. Located on the shore of the Mediterranean Sea, we've established our marine fish hatchery to start breeding, hatching, rearing larvae, and nursing fingerlings of marine finfish.

Our first marine finfish program was hybrid striped bass. We've accomplished outstanding results in both local and global markets. By exclusively providing a year-round supply of hybrid striped bass (that became a top-shelf product in Israel), Dagon has based itself as a main supplier in Europe.

Our success in the European market has led us to research and develop breeding programs for highly valued marine finfish species. Today, we are a multi-species hatchery providing year-round fingerlings of the hybrid striped bass, barramundi (*Lates calcarifer*), red-drum (*Sciaenops ocellatus*), gilthead seabream (*Sparus aurata*) and seabass (*Dicentrarchus labrax*) and we are the only breeders of the grey mullet (*Mugil cephalus*) in the world.



**HFM: Do you produce all these species all year round? What are your current markets?**

**LS:** We are producing all of our fingerling types year-round, in response to our market's demand. Making the most out of our local Israeli market, we are now focused on marketing hybrid striped bass, seabream and grey mullet to fish farms in Europe, North Africa, and the Middle East. The demand for both our barramundi and hybrid striped bass has grown dramatically in the US and Europe, and most of our red drum products are demanded by our local markets for ecological solutions.

Our facility is thoroughly designed to support the simultaneous production of multiple types of fish fingerlings. To have full control of the production process, we had to create a full supporting system for each development stage. We have gradually created a broodstock that is manipulated to spawn year-round. We produce live feed for the early-stage larvae, which are fed in fully automated rearing ponds. Our young fingerlings are then transferred to a monitored nursery for their grow-out before delivery.

**HFM: As for hybrid striped bass, how do you manage both striped bass and white bass broodstocks?**

**LS:** Unlike other species, hybrid striped bass fingerlings are only produced artificially under hatchery conditions. They are a cross between a striped bass (*Morone saxatilis*) and a white bass (*Morone chrysops*). Therefore, hybrid striped bass fingerling production requires the spawning of wild broodstock (wild parental species), a demanding operation for most finfish farming facilities.

The establishment of a new white and striped bass broodstock is a very demanding and challenging process, which requires highly professional handling. Over the years, we gradually gained the optimal management practices for the striped and white broodfish to induce batches of eggs throughout the year. In the department managed by Gilad Hasson, we cycle broodstock populations to produce viable eggs out of their natural spawning season. To increase protein values before spawning, we use a significantly high quality dry and live feed.

**HFM: The company has been developing grey mullet culture for the past few years and is now working on all-female culture. What are the objectives of the project?**

**LS:** Our all-female project is a joint project of Dagon and our collaborators in the Volcani Center, a governmental

agricultural research organization. The project is managed together by both sides' professional teams of researchers, including Prof. Lior David, and Itay Oz from Robert H. Smith Faculty of Agriculture, Food and Environment, the Hebrew University of Jerusalem.

First, we want to test the possibility of creating a single-sexed fish population to establish an all-female broodstock to achieve better population growth rates and increase the maximum size of adult fish. Secondly, we are aiming to reach out to new opportunities in the Karasumi-Bottarga markets (a dish made of grey mullet eggs).

**HFM: Dagon has also been working with groupers. What were the main challenges in developing a successful larval-rearing process? What is your current survival rate?**

**LS:** The White Grouper Program, managed and designed by Yoav Magnus, is now stepping into its final stages of establishing a steady, year-round egg-producing broodstock. Dagon's broodstock genetic lines originate from endemic south Mediterranean sea populations. After years of gradual rearing and acclimatization to intensive-indoors conditions, Dagon is on the brink of establishing a larvae-rearing multi-stage protocol.

The first few stages of development and industrial implementation of a fish species require a well-prepared supporting system. This system includes feeding types with the species' specific nutritional profile, health care, veterinarian professional guidance, and suited facilities that meet its needs.

In order to supply the local Israeli market's demand, Dagon's R&D team designed and built a grow-out facility (greenhouse with deep intensive ponds) that perfectly suits the white grouper's requirements. The greenhouses are facilitated with innovative RAS systems which receive a continuous saltwater supply. In order to achieve complete control of the fish's nutritional profile, Dagon designed a nutrition plan for white grouper-specific feeding pellets.

**HFM: For all these species, are you running any breeding programs?**

**LS:** Our hatchery contains rearing ponds for future broodstock for all of our species. We consistently refresh our populations with individuals received from

outside institutions. We populate a new broodstock with individuals from both partner institutions, to keep a wide genetic pool to ensure a high genetic variance.

Our main concern is inbreeding and limited variability in our broodstock. Therefore, although the insertion of outside sources may cause biosecurity problems, we must strengthen our broodstock with new individuals consistently.

**HFM: Rearing this wide range of species requires different sizes of live feeds, especially rotifers. How do you manage first feeding? Do you grow different rotifer strains?**

**LS:** Rotifers plankton is a main feed source for the larvae's early stages. It serves as a valuable nutrient capsule needed for the proper larvae's development. Our live-feed facility is designed for the mass production of various feed types with a wide range in shape and size, to precisely adjust our live feed size to the fish larvae's feeding capabilities.

In order to produce the optimal feed size for the newly hatched fish larvae, we culture several rotifer strains of *Brachionus rotundiformis* – a small type of rotifer, that ranges in size from 60 to 170 microns. We enrich the rotifers with fresh, self-produced live microalgae a few hours before larvae feeding to maximize our live feed nutritional profile.

**HFM: How about microalgae? Do you produce your own microalgae? What production system do you utilize?**

**LS:** The production of multi-species requires an in-house production of live microalgae types which are known for their high fatty acids composition. In addition to being a high-quality feed source and a fresh-enriching supplement for our rotifers, live algae can ecologically balance the larvae tanks and dramatically increase the larvae's feeding efficiency and rotifers' uptake. We cultivate our selected microalgae types *Nannochloropsis salina*, *Chlorella Vulgaris*, *Tetraselmis suecica*, *Isochrysis*, and *Nannochloris bacillaris*, in both open and indoor systems.

**HFM: How about the hatchery system? Do you run RAS or an open system?**

**LS:** Our live feed and larval departments are mostly run by open-water systems. In the rest of the hatchery, in our



broodstock and nurseries, we replace 10% of our fresh and sea water daily using RAS systems.

“Without any exception, both RAS and the open water system in the Dagon’s hatchery are planned and engineered by Dagon,” added Moti Shlomovitch, Dagon’s chief operating officer and former hatchery manager, “aiming to be ‘farmer-friendly’ and completely suit the facility’s specific requirements.”

**HFM: How do you manage to keep optimal environmental and biosecure conditions for all these species?**

**LS:** One of our hatchery’s biggest challenges is to maintain a continuous, multi-species fingerling production throughout the year. In order to do so, we had to adopt a strict biosecurity protocol. Full separation and designated staff to each department, together with support and

routine check-ups from the veterinary services, enable us to control our facility’s health and keep it safe.

**HFM: Dagon delivers fingerlings worldwide. What are your projections looking forward?**

**LS:** “Dagon is aiming for increasing production and expanding the market. The concept is to transfer fingerlings worldwide,” added Boaz Ginzbourg, Dagon’s CEO. “On the other hand, we are now seeking joint venture partners to transfer our technology and eggs to hatcheries in adjacent countries.”

Our pioneering developments keep Dagon at the forefront of both hatchery production and grow-out farming in the region, and the company could serve as a blueprint for sustainable aquaculture development throughout the Middle East/North Africa and beyond.

# NEWS REVIEW

Highlights of recent news from Hatcheryfm.com

## Ecuadorean shrimp larvae producers warn about the proliferation of illegal hatcheries

The Association of Shrimp Larvae Producers estimates that approximately half of the hatcheries operating in the country are illegal. The association is requesting mitigation measures from the Ecuadorean government which has agreed to carry out roadside checks to certify that the larvae circulating in the country are legally produced and work together with the Internal Revenue Service to prohibit the issuance of sales receipts or withholdings to those who do not have authorization.



## New leadership for Benchmark Genetics



Jan-Emil Johannessen, head of Benchmark Genetics, is turning 63 years old in April and has decided to retire after a lifelong involvement in the aquaculture industry. His successor, Geir Olav Melingen, currently commercial director salmon at Benchmark, will take over the position. Jonas Jonasson is stepping down as CEO of Benchmark Genetics Iceland and will continue as the global production director for salmon in Benchmark Genetics, a role he has served since 2019. Benedikt (Benni) Hálfðanarson was appointed as general manager. Hálfðanarson has a proven track record in international business and extensive experience in management in the aquaculture industry.

## New partnership takes a leap forward for farmed Atlantic bluefin tuna

The production of juvenile Atlantic bluefin tuna within aquaculture systems has moved a step forward thanks to a new cooperation agreement signed by tuna farming start-up Next Tuna and Skretting. Through the agreement, both parties will jointly develop dry feed for Atlantic bluefin from the first feeding to transfer at 10 kg.



## AquaGen appoints managing director in Scotland



The company appointed Keith Drynan as managing director of AquaGen Scotland. In his new role, Drynan will be responsible for all commercial activities of AquaGen in Scotland as well as overseeing the day-to-day operations of the facility, ensuring that the company continues to deliver high-quality salmon eggs with the AquaGen genetics based on more than 50 years of breeding. With a strong commitment to aquaculture, being customer-oriented in combination with a business mindset and a proven track record, Keith is well-positioned to contribute to the company's achieving its long-term goals.

## Skretting India opens state-of-the-art shrimp and fish feed facility in Surat

The facility will cater to both shrimp and fish cultures. Shrimp will include white tiger and black tiger, while fish will include Indian major carps and high-value fish like snakehead, and seabass, among others.

“We have been meeting the needs of shrimp hatcheries, nurseries, and farmers since 2018 in India, and supporting customers across feed-farm-health with our high-quality feed and services. The new facility enables us to contribute our bit to the prestigious Atmanirbhar Bharat – Make in India initiative, while simultaneously improving the efficiencies for a closer connection with our customers. We will cater to the domestic market and also customers in Bangladesh, Sri Lanka and the Middle East,” said Saurabh Shekhar, general manager – Nutreco South Asia.



## CFEED attracts new investor

An international investment company, Kaltroco Ltd., has completed the purchase of shares from SINTEF Venture IV and other shareholders, together with an equity issuance to secure CFEED's development. The goal is to significantly increase revenue, production, and global growth in the coming years.

After an equity issuance, the copepod producer CFEED aims to realize the plans laid out for the next five years. This includes increased production capacity and further development of its technology, in addition to starting the construction of a new modern factory.

## GenoMar takes next step in its expansion in the Americas



The company imported the first genetics lines into Colombia from GenoMar's breeding center in the Philippines. The fish will be grown to maturation and serve as the parent stock for commercial fingerlings to Colombian farmers. The first fingerling deliveries are expected to happen in the third quarter of 2023.

## Morocco to develop its first marine fish hatchery

AgriGo Group, through its Moroccan subsidiary company AquaGo, signed two agreements for the construction of a marine fish hatchery in Tahaddart, in northern Morocco, with the Ministry of Agriculture, Maritime Fisheries, Rural Development and Water and Forests and the National Agency for the Development of Aquaculture. This will be the first commercial marine hatchery in Morocco to offer local premium quality fingerlings of seabream, seabass and meagre with a production capacity of 10 million fingerlings per year.

## Imenco acquires Vard Aqua

International shipbuilding group Vard Group has sold its equipment supplier Vard Aqua to the Norwegian company Imenco. "We at Imenco continue to invest heavily in aquaculture and fish farming. This is one of the main areas in which we have decided to grow and take a significant part of the market. Now it is a natural step for us to search for exciting product areas, which will bring us new customers and markets, as well as where we can supplement with cameras and software that already exist in our product portfolio," said CEO of Imenco, Rune Bringedal.

## Nofima opens training and research RAS facility in Tromsø

Nofima opened a new hall at the Aquaculture Research Station in Tromsø, one of the world's most advanced research facilities for onshore fish farming. The newly constructed 1,350 m<sup>2</sup> hall (RASforsk) with an investment of NOK 90 million (USD 9.1 million) will focus on training, education and research.



## Canada rejects Discovery Islands salmon farm license renewal

The Canadian government announced its decision not to renew licenses for fifteen open-net pen Atlantic salmon aquaculture sites in the Discovery Islands. The Canadian Aquaculture Industry Alliance calls for an immediate re-examination and reversal of this decision. "We are deeply

disappointed and disturbed at the Canadian government's decision to ignore their own science and the requests of First Nations, by declining to renew select salmon farming licenses in the Discovery Islands region of British Columbia," the alliance said in a statement.

## ScaleAQ acquires fish vaccination specialist

ScaleAQ has signed an agreement to take over vaccination specialist Skala Maskon AS. With this acquisition, the company aims to expand its value chain to be a total supplier and a partner for the farming industry. Maskon, established in 1991, is a specialist in fully automatic vaccination machines for fish. Until the acquisition, the company was part of the Skala group, which is owned by Nortura and Tine. Maskon will continue as an independent company in ScaleAQ, maintaining its innovation and product development, while at the same time gaining access to all the advantages of being part of a global supplier to the aquaculture industry.

## Distribution agreement brings energy-efficient oxygen concentrators to the Norwegian market

Benchmark International and supply company, Redox AS, signed a new dealer and distributor agreement within the Norwegian market. This partnership will bring the latest technology in oxygenation systems to the Norwegian aquaculture market, providing farmers with the tools they need to improve efficiency and decrease costs while maintaining the highest standards of fish welfare.

Under the terms of the agreement, Redox will be the exclusive dealer and distributor of Benchmark International's VPSA Oxygen Concentrators in Norway. These state-of-the-art systems use vacuum pressure swing adsorption technology to produce high-purity oxygen from the air, reducing energy consumption by up to 50% compared to traditional oxygen generation methods.



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# Shrimp hatchery production: The next generation

**Eamonn O'Brien**, Skretting

“Life start sets life performance” is a term that is extensively used by Skretting and means that in every instance, the beginning of life is an extremely delicate period; laying the foundation for the future. Shrimp hatchery production is certainly no exception – it involves very sensitive, precision-focused phases where numerous critical factors must align to ensure quality production and profitability.

Despite the pressure of multiple, highly dynamic forces that require producers to react quickly to meet changing supply and demand situations, the global shrimp industry has grown rapidly in recent years. This is as much a testament to the novel approaches, science and professionalism that have been brought into the industry as it is to the effective ways that it adapts to local conditions.

A big part of this success comes from the hatcheries. These differ greatly in the facilities that they comprise and the production approaches that they take. To a large extent, the hatchery period dictates the performances that can be expected in grow-out – both in terms of shrimp robustness and final production economics.

### **First 21 days**

In this period, the transition from a tiny planktonic egg to a young shrimp post larvae takes place. Massive physiological changes occur at this stage, with the animals transitioning from pelagic filter-feeding behavior to benthic hunting mode.

To start the process, carefully selected breeder shrimp are sourced. Great care and attention are invested to continually develop genetic lines with specific performance traits that can be best suited to operational requirements and biosecurity. The industry relies on these animals receiving the best possible nutrition to fulfill optimal offspring performance.



### **Reducing the reliance on fresh feed**

One of the greatest challenges is the use of locally sourced fresh feeds. These are often contaminated with pathogens and also fluctuate in availability, price, and quality. Hatcheries also face the dilemma of whether to continue with the status quo or instead establish feed programs that reduce the overall dependency on fresh feeds. Both options have perceived risk but increasing industry consolidation is driving it toward more sustainable and safer practices.

Through the use of Skretting's Vitalis broodstock feeding program, a total fresh feed reduction of 70% can be achieved while also reducing the number of fresh feed vectors from several to just one.

This simple feeding protocol offers the same performance standards but consistent total operational control and performance. The Vitalis feed program also offers the perfect opportunity to condition broodstock animals for transport and maintain the animals in quarantine facilities.

## The right feed for the right phase

Hatchery feeding essentially revolves around three feeding phases: algae, Artemia and formulated feeds. As a first feed, algae quality and quantity are essential to ensuring the correct transition through the larval stages and early post larvae. Modern hatcheries have invested heavily to secure the best possible algae production.

During the larval stage, Artemia and formulated diets are presented to the animals. Artemia is often presented “cooked” whereby the animals are immobilized by first dipping them in hot water making them easier to capture. Afterward, live Artemia nauplii are presented.

There is little doubt that Artemia has been one of the significant enablers in the development of the industry. In more recent times, the development and exploitation of additional resources around the world have ensured a relatively steady supply to the industry. Furthermore, the development of ready-to-use nauplii has simplified the process for hatcheries and reduced the overall variation that can often occur in hatcheries’ best practices.

This development also increases the overall efficiency of the available Artemia resources. Artemia hatcheries can utilize lower-grade hatching Artemia that would normally not be suitable – simply being too difficult to use under normal hatchery conditions.

## Artemia supply challenges

However, the Artemia supply is finite and can fluctuate significantly. Also, many key production sites are environmentally challenged. The Great Salt Lake, the largest resource for Artemia is sinking at an [alarming rate](#), largely due to increased water consumption in urban and agricultural developments. A recent study by Brigham Young University fears that within five years, the lake could disappear. A detailed report can be found [here](#).

In addition, avian flu is also prevalent on the lake as it is home to millions of migratory birds. As the lake shrinks,

salinity increases and primary biological processes begin to shift which can ultimately impact Artemia production coupled with increased complexity in accessing the remaining water.

There are excellent initiatives underway through the Great Salt Lake Trust, which aims to align all stakeholders to improve water flows to the lake and sustainably manage the resource on a wider scale.

The impact of availability can weigh heavily on shrimp hatchery production management strategies. Total Artemia consumption shows plenty of room for optimization, with current consumption varying from 1.5 to >5kg per million PLs produced.

## Ensuring effortless feeding

Finally, formulated diets form the basis for the exit strategy from the hatchery. It is common practice for hatcheries to have their own cocktail of varying diet mixtures for feeding during specific stages, and very often the approach is based on mixing low-price/quality diets with more premium feeds to reduce overall costs.

In Asia, diets are frequently replaced by dark flakes in the last days before exit, while in Latin America dark flakes are often fed just before sale to pigment the post larvae. With so many variables, it can become difficult for large integrated producers to justify the added cost and complexity of their production.

At Skretting, we have focused our efforts on making shrimp hatchery feeding as effortless as possible. Using our *Inspired by Nature* concept, we have developed a new diet called Elevia. This feed, high in hydrolyzed marine proteins, fuels optimal growth, survival and robustness.

This standalone feed offers the possibility to replace cocktails and at the same time to replace dark flakes. The roll-out of this exciting new diet will take place in the coming months and is set to elevate shrimp hatchery production.

### More information:

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# Cost-effective formulated diets under super-intensive culture system of red tilapia and hybrid grouper

**Farshad Shishehchian, Nik Siti Zaimah Binti Safiin, Blue Aqua International**

The global aquaculture feed market is set to grow by USD 21.68 billion from 2020 to 2025 with accelerated market growth at a CAGR of 6.72% (FAO, 2021). The development of innovative ingredients with positive attributes gives a huge impact on the growth of the global aquaculture feed market. Superintensive aquaculture systems are currently being implemented in some farms to strike a balance between high animal productivity, good water quality, zero water discharge, the presence of microbial flocs and greater biosecurity (Haslun *et al.*, 2012). Nutritional balance in this intensification system plays an important role in growth optimization, and maintenance of energy demands to ensure the success of commercial operations (Emerenciano *et al.*, 2022). This system has a critical implication for the designation and efficacy of the formulated feed to meet the fish's nutritional demand with the provision of essential nutrients (Emerenciano *et al.*, 2022).

Red tilapia (*Oreochromis* sp.) and hybrid grouper (*Epinephelus fuscoguttatus* x *E. lanceolatus*) are the most popular cultured species in the world. The positive

attributes and high consumer demand in the market gave a great impact on the total production. Meanwhile, red tilapia has a wide range of nutrient demands that can easily be manipulated and targeted to produce a diet with profitable outcomes. The aquafeed industry plays a crucial role to provide the optimum requirement for these species to hasten their growth and find the best nutritional needs. Therefore, the modification and combination of high-quality ingredients rich in protein with balanced amino acids profiles, higher lipids contain with essential fatty acids, natural feed additives and potential marine sources are particularly crucial to develop high-quality and cost-effective formulated feeds for these fish under an intensification system (Emerenciano *et al.*, 2022).

Blue Aqua International Pte. Ltd. aims to develop cost-effective diets that can support profitable production in an outstanding super-intensive cultured system. The main approach is to formulate a 'novel' feed to maximize the nutrient bioavailability that is stable and has nutritional balance in the long-term operation under the super-intensive culture system.



Red tilapia and hybrid grouper

## Material and methods

A feeding trial in red tilapia and grouper fingerlings was conducted at the Aquaculture Research Facility at Temasek Polytechnic. The experimental feeds used a combination of various protein sources and other ingredients to produce sustainable cost-effective diets that can optimize both fish performance at the end of the trial. The ingredients were ground in a laboratory grinder and sieved to pass through at 50-100 $\mu$ m sizes. The experimental feeds were analyzed for chemical compositions (Table 1, 2). Culture conditions under different super-intensive conditions are shown in Table 3 and 4.

## Results

Tables 5 and 6 show the growth and feeding performances of red tilapia and hybrid grouper. The survival (95-100%) of red tilapia and hybrid grouper at the end of the feeding trial was not significantly affected by the test and control diets. In trial 1, red tilapia fed test diet showed significantly higher ( $P < 0.05$ ) final body weight, SGR and weight gain compared to control diet. Feed intake was higher with the test diet when compared to the control diet. Fish fed with the test diet performed comparably better FCR than the control diet. Meanwhile, red tilapia fed with the control diet showed significantly (trial 2) and relatively (trial 3) better growth

Table 1. Proximate and chemical composition (% “as-is” basis) of experimental diets for red tilapia

Proximate and chemical Composition (%)	Trial 1		Trial 2		Trial 3	
	Test	Control	Test	Control	Test	Control
Moisture	6.69	6.69	8.70	6.20	8.90	6.20
Crude protein (N $\times$ 6.25)	41.74	43.57	27.60	51.90	41.10	51.90
Crude fat	7.63	10.20	11.10	16.00	8.60	16.00
Crude fiber	4.09	5.62	N/A	N/A	N/A	N/A
Crude ash	6.80	10.16	7.10	10.60	6.70	10.60
<sup>1</sup> NFE	33.05	23.76	45.50	15.30	34.31	15.30
<sup>2</sup> Gross energy (kcal/kg)	4417.34	4383.08	4465.60	5053.70	4525.15	5053.70
Calcium	0.74	1.82	1.02	2.28	0.75	2.28
Phosphorus	0.57	0.46	1.38	1.34	1.07	1.34
Calcium:Phosphorus (Ca: P)	1.3:1	4.0:1	0.7:1	1.7:1	0.7:1	1.7:1

<sup>1</sup>Nitrogen-Free Extractive, calculated as 100 - (moisture + crude protein + crude fat + crude fibre + ash).

<sup>2</sup>Calculated as: 5.6 kcal g<sup>-1</sup> crude protein; 9.5 kcal g<sup>-1</sup> crude fat; 4.1 kcal g<sup>-1</sup> NFE.

Table 2. Proximate and chemical composition (% “as-is” basis) of experimental diets for hybrid grouper

Proximate and chemical Composition (%)	Trial 1		Trial 2		Trial 3		Field	
	Test	Control	Test	Control	Test	Control	Test	Control
Moisture	2.35	4.86	7.30	7.20	8.80	7.20	2.35	7.20
Crude protein (N $\times$ 6.25)	49.99	56.05	45.20	51.70	52.30	51.70	49.99	51.70
Crude fat	13.31	13.36	14.10	16.00	11.80	16.00	13.31	16.00
Crude fiber	1.75	2.16	N/A	N/A	N/A	N/A	N/A	N/A
Crude ash	14.86	10.74	10.30	10.70	10.80	10.70	14.86	10.70
<sup>1</sup> NFE	19.49	14.99	23.10	14.40	16.30	14.40	19.49	14.40
<sup>2</sup> Gross energy (kcal/kg)	4862.84	5022.59	4817.80	5005.60	4718.10	5005.60	4862.84	5005.60
Calcium	3.46	1.26	2.44	2.36	2.47	2.36	3.46	2.36
Phosphorus	0.99	0.39	1.47	1.31	1.54	1.31	0.99	1.31
Calcium: Phosphorus (Ca: P)	3.5:1	3.2:1	1.7:1	1.8:1	1.6:1	1.8:1	3.5:1	1.8:1

<sup>1</sup>Nitrogen-Free Extractive, calculated as 100 - (moisture + crude protein + crude fat + crude fibre + ash).

<sup>2</sup>Calculated as: 5.6 kcal g<sup>-1</sup> crude protein; 9.5 kcal g<sup>-1</sup> crude fat; 4.1 kcal g<sup>-1</sup> NF

# NUTRITION

Table 3. Summary of red tilapia culture

Parameter	Trial 1	Trial 2	Trial 3
Initial weight (g)	37.1	73.8	7.3
Stocking number (ind.)	20	20	20
Stocking density (ind./L)	0.2	0.1	0.2
Initial biomass (g)	742.0	1,476.0	146.0
Feeding frequency	5 times/ day	5 times/ day	2 times/ day
<b>Water Parameter</b>			
Temperature (°C)	29.1±1.8	29.2±1.8	29.4±1.9
DO (mg/L)	6.1±0.8	6.3±0.9	6.0±0.8
pH	7.8±0.4	7.9±0.5	8.0±0.4
Ammonia, TAN (mg/L)	0.2±0.1	0.2±0.1	0.2±0.1
Nitrite (mg/L)	0	0	0
Nitrate (mg/L)	0	0	0

Table 4. Summary of hybrid grouper culture

Parameter	Trial 1	Trial 2	Trial 3	Field
Initial weight (g)	21.3	20.2	6.5	8.76
Stocking number (ind.)	20.0	20.0	20.0	30.0
Stocking density (ind./L)	0.2	0.1	0.2	0.3
Initial biomass (g)	426.0	404.0	130.0	262.8
Feeding frequency	5 times/day	5 times/ day	2 times/ day	2 times/ day
<b>Water Parameter</b>				
Temperature (°C)	29.1±1.8	29.2±1.8	29.4±1.9	31.5±1.9
DO (mg/L)	6.1±0.8	6.3±0.9	6.0±0.8	6.1±0.6
pH	7.8±0.4	7.9±0.5	8.0±0.4	8.0±0.6
Ammonia, TAN (ppm)	0.2±0.1	0.2±0.1	0.2±0.1	0.2±0.2
Nitrite (ppm)	0	0	0	0.1±0.1
Nitrate (ppm)	0	0	0	10.0±5.0
Salinity (ppt)	30.0	30.0	15.0	15.0

performances than the test diet. Both trials showed significantly better FCR compared to the test diet.

In hybrid grouper trial 1, the fish fed with the control diet showed relatively better ( $P>0.05$ ) growth performances and significantly better FCR compared to the test diet. In trial 2, hybrid grouper fed both test and control diet showed no significant difference in the growth and feeding performances. There were relatively higher ( $P>0.05$ ) growth and feed performances in the test diet compared to the control diet. Control diet showed better ( $P<0.05$ ) growth and feeding performances of hybrid grouper compared

to test group in trial 3. The higher ( $P<0.05$ ) total and feeding intake were observed in fish fed control diet compared to the test group but no significant ( $P>0.05$ ) difference was detected in the FCR. In the field trial, the growth of hybrid grouper fed with the test diet had relatively higher ( $P>0.05$ ) growth performances and better FCR compared to the control diet.

## Discussion

Tilapia trial 1 and 3 used the combination of fishery-based, poultry hydrolyzed protein meal, plant-based meal and feather meal in test diet. The positive

Table 5. Red tilapia performances in different intensification system

Parameter	Trial 1		Trial 2		Trial 3	
	Test	Control	Test	Control	Test	Control
Initial body weight (g)	36.29±1.48	37.76±2.13	72.41±17.00	75.19±2.77	7.03±0.27	7.60±0.27
Final body weight (g)	113.08±8.99*	101.00±9.50	161.81±28.70	220.49±23.49*	33.40±2.23	37.60±1.42
Specific growth rate (%/day)	3.91±0.13*	2.10±0.10	2.32±0.24	3.09±0.21*	5.20±0.13	5.30±0.03
Weight gain (%)	211.32±12.26*	167.20±11.20	125.98±18.40	195.57±21.87*	374.30±19.00	395.30±4.32
Survival (%)	100.00±0.00	98.00±3.80	95.00±5.00	96.67±2.89	100.00±0.00	100.00±0.00
Total feed intake (g/fish)	66.14±5.62	17.21±1.66	115.45±7.67	118.50±5.48	24.31±1.89	24.13±0.80
Daily feed intake (g/fish/day)	2.20±0.15	0.57±0.06	3.84±0.03	4.47±0.83	0.90±0.07	0.90±0.03
Feed conversion ratio (FCR)	0.83±0.03	0.82±0.13	1.36±0.09	0.83±0.04*	0.90±0.00	0.80±0.01*

Means with asterisk (\*) in the same row are significantly different (t-test, p<0.05) among each trial

Table 6. Hybrid grouper performances in different intensification systems

Parameter	Trial 1		Trial 2		Trial 3		Field	
	Test	Control	Test	Control	Test	Control	Test	Control
Initial mean body weight (g)	20.76±1.05	21.67±0.19	20.35±0.23	20.04±0.61	6.49±0.05	6.36±0.08	8.74±0.09	8.78±0.10
Final body weight (g)	38.73±1.88	42.47±1.94	47.79±3.75	46.55±4.09	9.36±0.05	13.15±0.16*	26.56±2.25	26.31±1.91
Specific growth rate (%/day)	2.08±0.00	2.24±0.00	1.98±0.18	1.95±0.20	1.31±0.04	2.60±0.05*	2.64±0.23	2.61±0.16
Weight gain (%)	86.68±6.65	95.88±7.26	134.77±18.44	132.28±20.41	44.15±1.68	106.99±2.94*	204.16±28.80	199.73±19.34
Survival (%)	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	95.56±3.85	97.78±3.85
Total feed intake (g/fish)	21.07±0.86	17.21±1.66	38.34±0.43	38.88±1.15	8.99±4.52	18.88±2.33*	19.24±0.70	18.68±1.35
Daily feed intake (g/fish/day)	0.70±0.03	0.57±0.06	0.90±0.03	0.89±0.01	0.32±0.00	0.67±0.05*	0.05±0.00	0.05±0.00
Feed conversion ratio (FCR)	1.16±0.11	0.82±0.13*	1.43±0.20	1.47±0.23	3.14±0.07	2.78±0.22	1.08±0.04	1.07±0.08

Means with asterisk (\*) in the same row are significantly different (t-test, p<0.05) among each trial

attributes of digestible ingredients used in these trials improve the feed performances compared to control diet, suggesting that the red tilapias efficiently utilized the nutrient for growth and energy balance.

The inclusion of the poultry hydrolyzed protein meal promoted better nutrient absorption in red tilapia. The hydrolysis process modifies the functional properties of feeds and promotes the break of protein chains into amino acids and multiple-sized peptides with high protein content which are more digestible, attractive and easily absorbed by the fish (Martínez-Alvarez *et al.*, 2015). The protein hydrolysates can improve resistance to infectious diseases, thus improving health and well-being, as well as growth performance and feed efficiency (Martínez-Alvarez *et al.*, 2015).

The inclusion of feather meal in the tilapia test diet affected the growth and feed efficiency. Feather meal is high in crude protein and its amino acid profile is quite similar to fishmeal. A significant amount of certain sulphur amino acids like cysteine, methionine and a

sulfur-derived component such as cystine are available in feather meal (Coolsaet, 2015).

In tilapia trial 2, the combination of low fishery-based and plant-based ingredients (fermented soybean meal, wheat flour and rice bran) were used as a protein source in the tilapia test diet. There was an adverse effect on the growth performances of red tilapia. It is speculated that the high inclusion of fermented soybean meal and low inclusion of fishmeal in the diet reduced some bioactive factors provided by fishmeal, and aggravated the imbalance of amino acids, thereby lowering nutrients utilization. Similar results from a previous study indicated that high inclusion of plant-based sources might reduce the liver's ability to metabolize and synthesize nutrients and result in liver performance being decreased in terms of the hepatosomatic index (HSI).

In hybrid grouper trial 1, 2 and field, the combination of fishery-based, poultry hydrolyzed protein meal, krill meal and polychaete meal in the hybrid grouper test

# NUTRITION

diet resulted in comparable final body weight, SGR and weight gain with control diet. The positive attributes of poultry hydrolyzed protein meal are that it promotes better feed utilization and nutrient absorption in carnivorous species like the hybrid grouper to improve nutrient uptake. Several studies have shown that protein hydrolysates enhance nonspecific immunity in fish and are an interesting alternative to antibiotics for controlling the propagation of infectious diseases. The *in vitro* stimulatory effect of some protein hydrolysates on fish leucocytes suggests that the inclusion could be effective in reducing disease-related losses among farmed fish (Martínez-Alvarez *et al.*, 2012). Generally, aquafeed formulation with krill meal can enhance feeding and fish growth performance. Dietary incorporation of krill meal increased the stimulation and showed higher feed consumption than the control diet. Krill meal is rich in chitin from the exoskeleton and soluble compounds like trimethylamine oxide (TMAO), free amino acids and nucleotides that may all act as feeding stimulants. The presence of the natural astaxanthin in krill meal act as an antioxidant to offer health benefits and disease resistance, especially under intense condition (Nunes *et al.*, 2020).

Polychaete meal are considered to have a well-balanced nutritional profile. The nutritional value of polychaete meal has been specifically attributed to the high content of protein and n-3 polyunsaturated fatty acids (ARA, EPA and DHA), which have been proven to be an important vector to transfer essential fatty acids to marine fish particularly hybrid grouper in current test diet. The bromophenols appeared to be essential ingredients in marine fish aquafeed due to their function on satisfactory feed intake that is similar to natural 'ocean flavor' (Cameron, 2014). The fermented soybean meal improves intestinal health, promotes immunity and enhances disease resistance without negative effects on carnivorous fish growth including other grouper species (Einstein-Curtis, 2019). It promoted better intestinal absorption for nutrient uptake due to its key mechanism of the digestive enzyme to help digest cellulose when fish were fed high plant-based diets. Furthermore, the proper inclusion of fermented soybean meal improved the resistance to bacterial infection (Yang *et al.*, 2022).

In hybrid grouper trial 3, the same blended ingredients in trial 1 were used, however, there were some

limitations observed in the total fish performances. The nutrient limitation in the test diet and fish size difference might affect the digestibility tolerance of hybrid grouper when challenged under the intensification system.

Current trials on red tilapia and hybrid grouper feed use a combination of highly digestible protein sources, high-quality ingredients and feed additives to produce high-quality feed has resulted in relatively better fish performances compared to the control feed in some trials. These results proved that the formulation and chemical composition of tested diets were promising and effective to improve the fish's growth performances.

## Conclusion

The ingredients used to formulate this "novel" fish feed for super-intensive systems have shown a significant and relatively better improvement in fish growth performances. The combination of different protein sources can reduce the overreliance on fisheries-based protein, produce cost-effective formulated feed and stimulate selected growth promoters to fulfill the nutrient requirement to achieve maximum production efficiency in an intensive system. This novel feed can optimize production efficiency, mitigate the environmental impact and improve fish resilience and welfare.

Blue Aqua International has developed BlueFeed for Marine Fish to cater to the nutritional gap in high-performance culture methods. These trials will drive the industry to produce more super high-quality feed to support the aquaculture industry.

*References available on request.*

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# Advanced technology and automation can enhance the consistent production of high-quality larvae and algae

**Steven Weschler**, Ferry Cove Shellfish



Ferry Cove Oyster Hatchery is a 20,000-square-foot hatchery on the Chesapeake Bay in Sherwood, Md.

Ferry Cove Oyster Hatchery opened in 2022 on Maryland's Eastern Shore and had an immediate impact on the region's aquaculture community. The hatchery's early success in cost-efficient oyster rearing and algae production was credited to several factors: state-of-the-art equipment, design decisions and staff expertise.

Bivalve hatcheries are challenged by constantly changing environmental factors – such as temperature, pH and salinity – that can't be addressed with traditional hatchery practices and can hinder production and

revenue. Hatcheries operate with lower profit margins than other aquaculture businesses and must produce extremely high volumes of larvae or higher-margin products like oyster seed to be profitable. Regardless of the approach, managing overhead costs is key to long-term financial viability.

Ferry Cove founders understood those challenges before breaking ground at the 70-acre campus. They addressed these issues – as well as distribution and marketing needs – in the initial design and

## LIVE FEEDS



Ferry Cove has seven algae photobioreactors to meet its algae requirements. Each bioreactor produces a single species of algae.

construction decisions. The hatchery, on the shoreline of the Chesapeake Bay, was designed to produce several billion Eastern oyster (*C. virginica*) eyed larvae a year. Designers worked with biologists and engineers experienced with hatcheries and aquariums who asked “how can we build this to address our needs and also advance hatchery science and processes?” This is in keeping with the mission of Ferry Cove, to work with scientists, watermen, business owners and policymakers to address the current and future needs of the aquaculture industry.

### Technology and automation systems

The facade of this hatchery is reminiscent of the oyster houses that once dotted the bay. Inside the building, advanced technology and automation systems were incorporated to minimize labor costs, conserve energy use and maximize production. The equipment controls water quality, manages feeding systems and automatically activates backup systems when needed.

To address potential water quality challenges, the facility incorporated a brine dosing system and a pH dosing system that maintain production in times of low



An open floor plan provides ample natural light in the main production area.

salinity and pH levels. In addition, the seawater reuse system allows Ferry Cove to recover seawater that has been salted or heated. The water is processed through a filtration system for reuse, thereby reducing the need in incurring the additional cost of adding salt or heating in

colder weather. In addition, an artificial seawater system serves as a backup system when bay water is unsuitable and would cause larval crashes.

Six full-time hatchery and facility staff operate the facility, on-site or remotely using automated control and monitoring systems. These systems alert staff to issues such as faulty pump operations, low tank levels and improper water quality. Notifications are sent if an aquatic system is not functioning within the range in which it was programmed. Most of these systems have backup processes. For example, if a seawater pump or air pump fails for any reason, a second pump automatically activates, without a flip of a switch or a click of a button.

### Microalgae production

As with any shellfish facility, high volumes of dense microalgae are required to feed bivalve broodstock, larvae and seed. At some hatcheries, live-feed algae production becomes a bottleneck that forces hatchery managers to make tough husbandry decisions.

The development of the Industrial Plankton photobioreactors, which include automation and advanced features, solves the problem of under-producing microalgae. Ferry Cove has seven of these compact photobioreactors culturing microalgae. These photobioreactors have proven reliable, efficient and capable of producing microalgae in a high-production (e.g., produce 35 trillion cells iso equivalence per day) and algae-demanding environment. Coupled with automated algae delivery systems, the photobioreactors are efficient and simple to use. This allows Ferry Cove – and other hatcheries that install this system – to maximize biomass output and increase the longevity of cultures with minimal overhead. This effort is enhanced because Ferry Cove’s reactors can be monitored and controlled remotely, allowing staff to examine past logged data to make programming decisions. Sharing data-driving results contribute to Ferry Cove’s educational commitment.

The flexibility of the hatchery design allows for experimentation. And it enables oysters to be produced most of the year, far beyond the natural spawning cycle in warm summer months. By increasing the production of oyster larvae and seeds, Ferry Cove expects to dramatically increase the number of farm-raised oysters grown in the Mid-Atlantic region.

Ferry Cove completed its first successful production season and is gearing up for its second. The team has been pleased with how the facility’s systems have operated, especially the photobioreactors. While nothing is certain, Ferry Cove’s staff members feel confident that the facility is prepared to continue to produce in the constantly changing environmental conditions of the Chesapeake Bay.

These initial steps are in line with Ferry Cove’s mission to demonstrate measures other aquaculture businesses can employ to control costs and improve margins. This positions Ferry Cove to become an international leader in hatchery technology.

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# The future of aquaculture

Sonali Kaththriarachchi, Cryogenetics



Aquaculture is one of the largest industries in Norway, that caters most recognized and valuable seafood products in the world, such as Atlantic salmon (*Salmo salar*) along with rainbow trout (*Oncorhynchus mykiss*). The goal of the Norwegian aquaculture industry is to increase the export volume to NOK 200 billion by 2030 in a sustainable manner, ensuring fish welfare and environmentally sound fish farming (Fiskeridirektoratet, 2020). However, to reach this goal, the industry will have to simultaneously improve production efficiency while reducing its environmental impact. This can only be achieved through a massive interdisciplinary research and innovation effort (Industries, 2016).

Efficient production is relying on gametes i.e., sperm and oocytes with good quality. Sperm quality varies throughout the year, in which high-quality milt is

generally detected in the normal spawning season while lower quality is found during early, late and off seasons. However, the use of high-quality spermatozoa is of utmost importance to maintain sustainable egg production in the aquaculture industry. Most fish species in aquaculture are subjected to photoperiod manipulation to accelerate or delay spawning. Hence, spawning can be manipulated to obtain milt all year round. A decrease in milt quality is seen as the spawning season progresses (Hajirezaee *et al.*, 2010; Rurangwa *et al.*, 2004). Therefore, the timing of sperm collection is crucial to obtain good quality milt. Increasing the efficiency of cryopreserved milt of genetically superior males during the normal season for use in early, late and off-seasons ensures high-quality milt for all seasons.

### Long-term preservation of fish milt

Cryopreservation has become a recognized commercial application in the aquaculture industry and is found to be a very valuable tool to enhance the use of collected fish milt (Noröberg, Johannesen, & Arge, 2015). It is a long-term storage method to preserve biological material at low temperature, i.e. -196°C and remain viable upon thawing (Tiersch, 2008). Unlike oocyte, fish sperm consists of a simple and small cellular structure with a high freezing tolerance. Since it is easily accessible, the cryopreservation of fish sperm has become one of the commercialized preservation methods (Asturiano, Cabrita, & Horváth, 2017).

Several benefits of sperm cryopreservation include (i) synchronization of gamete availability of both sexes, (ii) sperm economy; (iii) broodstock management, (iv) transport of gametes between different fish farms (v) gene bank for genetic selection programs or conservation of species (Cabrita *et al.*, 2010). Most importantly, cryopreserved fish milt can be used for a longer period beyond the lifespan of broodstock and reduces the need for maintaining live animals. The latter is especially beneficial during the off-season, when milt is known to be of poor quality. Milt that has been collected and cryopreserved at the highest peak of spawning season can substitute fresh milt (Yang, Hu, Buchanan, & Tiersch, 2018).

### Leaders in preserving aquatic genes

Cryogenetics is one of the leading Norwegian biotechnology companies within its field that contribute immensely toward the betterment of salmonid aquaculture worldwide. The company's line of business includes mainly cryopreservation of fish milt, serving major salmon and trout producers in the world. It was established in 2002 with the goal to develop cryopreservation tools for Atlantic salmon. Today, Cryogenetics provides reproduction services to over 16 fish species and has the knowledge and expertise to develop species-specific cryopreservation tools for any aquatic species at the request of their clients. In addition, the company provides other various products and services for the egg production process to the fish farmers, such as (i) cryo-storage (ii) equipment for the reproduction process, (iii) consulting within fish reproduction and breeding, (iv) training within reproduction for aquatic species(v) and reproduction enhancing remedies.

Cryogenetics' continuous research and development strengthen their competence in fish reproduction which helps to improve and develop new products to meet client requirements. Adapting innovative ideas into commercially applicable tools is one of the key characteristics of Cryogenetics.

### Efficient repository of male gametes

Traditional packaging of cryopreserved sperm is usually done in standard straws with very low volumes (0.5ml) which is ideal for research-related work but found to be less effective in large-scale egg production facilities. Cryogenetics boasts a patented packaging, the SquarePack® that enables clients to use a higher volume of cryopreserved milt (11ml) for a large volume of oocytes in their production facilities. A combination of a good cryopreservation protocol and a SquarePack® would result in a higher fertilization rate in production facilities. Additionally, there are several interconnected series of events involved to achieve this, such as integrated practices for milt collection, and temperature maintenance during storage and transportation (Jun, Qinghua, & Shicui, 2006). Each egg production

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# EQUIPMENT

facility has adapted its own quality standards and practices to avoid genetic and pathogenic cross-contamination in its production line. Yet there could be several other factors that can affect the production efficiency in those hatcheries.

Therefore, Cryogenetics offers training to their clients on clean extraction and handling of gonads, usage of AquaBoost® products that are specified to increase the milt storage time until cryopreservation, educating staff about the importance of maintaining the optimal temperature of collected milt throughout the transportation process, etc.

The AquaBoost® product portfolio is designed by Cryogenetics to increase the efficiency during the different stages of the egg production process in both fresh and marine fish species. These reproduction-enhancing remedies are used in activating sperm cells upon in vitro fertilization with both fresh and cryopreserved milt, a storage solution intended for extraction of milt from gonads, a non-activating fish milt dilutor for fertilizing with fresh milt and a fixation solution for fertilized eggs.

## Heading to a sustainable aquaculture

Cryopreservation has more potential in aquaculture with new improvements and developments in Cryopreservation techniques. Since the transportation of cryopreserved gametes is easier than transporting live animals, the distribution of important genetics worldwide is achievable. In addition, it will reduce animal health and welfare issues that can rise due to the transportation of live animals.

Hence, in the future, it is found to be a promising tool within aquaculture that will enhance genetic progress and allow for sustainable land-based production.

*References available on request.*

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## Life, the universe and aquaculture

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Black-spot bream (*Pagellus bogareveo*) thriving together

I guess there's no getting away from it: life, for any living organism, is a series of challenges. In nature, even the humblest phytoplankton cell must defend itself against microbial attack, both structurally and biochemically, while struggling to synthesize enough biomass to reproduce. There's not much it can do if it bumps into a larger herbivore such as a copepod, of course, but perhaps one or two of its clones will survive

to reproduce another day by pitting their own scarcity against the pressing needs of their grazers to find something to eat. And so on, up the food chain.

In our hatcheries, we try to buck this trend by concentrating energy and bioresources, such as feeds and other nutrients, into a relatively small space while attempting to exclude the other living organisms – the predators and competitors – which would interfere with



European sea bass (*Dicentrarchus labrax*) weaning onto dry feed



Turbot (*Scophthalmus maximus*) juveniles stacking up

the achievement of our production targets. As farmers addressing our aquatic livestock, the deal we offer them is essentially “I’ll feed you and protect you if you will grow and reproduce”. What we don’t tell them is that we’ll need to keep them at unnaturally high densities in order to make this effort worth our while, hoping that they won’t notice.

Algae – if we care to produce them ourselves – are kept at close to peak cell densities while still in a state of exponential growth, and we try to achieve a similar state of equilibrium with our rotifers. Meanwhile, we import and process vast numbers of *Artemia* cysts for use as another live feed and add large masses of other

organic materials, such as enrichments and dry diets, to our systems to feed our livestock every day. Small wonder that our facilities make such an attractive residence for opportunistic invasive species. I think it is a testament to both the resilience of the species that we cultivate and to our own skills as engineers and biotechnologists that – even without fully achieving our goal of blocking out all of these – we manage to keep them under control and make our systems work.

When it comes to survival and growth, I am frequently astonished by the population densities that so many of our animals – which are still practically wild-type – are ready to tolerate. Rotifers thrive at densities of several million individuals per liter, while young benthic-stage flatfish often appear even happier lying on top of each other, leaving just their heads exposed, than spreading themselves out over all the available tank area. In practically every case, the benefits of an abundance of food and the absence of predators seem to outweigh any negative effect of a high population density, as reflected by survival, growth and reproductive rates. (There are limits to this rule of thumb, of course, but these are orders of magnitude higher than what we tend to observe in the wild.)

What we are all aware of, though, is that working at relatively high population densities requires us to be a lot more careful when managing other potential

environmental stressors such as water turbidity, oxygen and metabolite concentrations, and feed quality. Not only are our systems more precarious in the event of an equipment failure, but our fish are also more sensitive to any adversity which is created. When close to the upper limit of the density tolerance of a species, a short-term sub-lethal oxygen drop often turns into a harbinger of disease.

I clearly recall, many years ago, asking a fitter who breezily announced his intention to immediately cut the power supply to the whole of our hatchery for “only 15 minutes”, whether he would like to try holding his own breath for a similar period before starting the job.

One thing which I find curious is that our fish sometimes appear to react to certain environmental cues in similar ways to ourselves: particularly with regard to stressors. If one imagines one's personal income as a variable that is metaphorically akin to the population density that a fish population is held at, both species seem more tolerant of a slow deterioration (impoverishment by inflation/biomass accumulation) than of a sudden set-back (pay-cut/population regrouping) even though the final status may be the same in either case.

I think we can apply this similarity to our advantage if we are careful in how we manage our stocks. For example, when we need to redistribute fish within a limited space during a routine multi-tank grading operation, I have seen it makes a noticeable difference to the operation's success if we manage to carry out all movements on the same day. If final population densities similar to the originals are re-established quickly, the livestock will usually survive and continue to grow at the same rates as before they were graded. If, however, we spread the operation over several days, or take a break for the weekend before finishing it, the fish's response is often worse.

Above all I think we should aim to avoid exposing any of our stock to an extended "luxury" period of relatively low density before adding a lot more fish to their enclosure several days later, thus causing what they might perceive as a major setback. (Successful businessmen and politicians are often skilled at avoiding creating the same feelings among their employees or electorate.) While it's true that stress is an accumulative concept and extending the handling of fish over time delays the start of their adaptation and recovery, I imagine that what they might perceive as a "sudden loss of luxury" also hurts them subconsciously.

I'm sure this little idea of mine will sound a bit crackpot to more than a few of you. However, I have not really advanced it to try to convince anyone it's true, but instead to open the door to my main theme, which is the "superpower" to which I referred to at the end of my previous column: I was – and am – talking about Empathy.

Just as every dairy farmer has learned over the millennia, farm animals in frequent contact with humans need to be treated with consideration if they are to yield the best results. This is particularly important for

reproduction. When working with fish it is sometimes difficult to imagine what they want, but I have found that even these will soon learn to recognize who is about to handle them and if they are likely to be hurt as a result. (White lab coats are not recommended.)

Empathy is also essential when we are dealing with fish in their early life stages when it's all too easy to subject them to short-term operational stress during grading, for example, or long-term stress through inadequate feeding.

So how do we get empathy? I think that most of us were probably taught it as youngsters at school and at home, but later in life, these lessons sometimes get lost when we enter the competitive world of having to earn a living. In my own case, I feel that the need to learn Spanish as a foreign language by ear, as an adult, probably provided me with the necessary incentive to recover the skill. In such circumstances, one needs to receive a lot of empathy from native speakers just to be able to communicate. Since this is clearly a situation where "you get what you give", I also had to learn again to make the effort to gauge what and how my colleagues were thinking.

I imagine and hope that what I am proposing resonates with at least some of you who are reading this column; particularly those of you who did not learn English during your infancy. Perhaps you will agree with me that, having developed the skill of empathy towards one's fellows, it's just a small step further to apply it to other stress-sensitive beings such as fish. Even after achieving this level of sensitivity, though, as production biotechnologists, we still feel uneasy sometimes when defending our "gut feelings" against pressure from economic interests to expand the limits of our comfort zone. In this – my last column in the series – please hear my recommendation to stand by one's gut feelings in such circumstances. For all the technical and scientific progress that has been achieved in our sector over recent decades, we remain – essentially – animal husbandry men and women. Finally, allow me to repeat what I have argued in earlier columns are the cardinal sins of aquaculture: Complacency and Arrogance. If we manage to avoid these and combine that far-from-easy accomplishment with the superpower of Empathy; success in aquaculture becomes a little more achievable. I am told that these skills are valuable in other industries, too.

# Monitoring water quality during aquatic transportation

Kristin Elliott, Aquasend

The transportation of live aquatic products is a necessary yet challenging process. Whether it's fry and fingerlings, broodstock or market fish, conditions must be kept at optimum levels. Fish and other aquatic products are harvested and moved within the farm and often travel long distances to customers, live fish markets, public waters for restoration, private recreational lakes, ponds and more. Similarly, larger brood fish must be transported to hatcheries for spawning. While the requirements for successful transportation can vary based on a host of variables, experienced farmers and contract fish transporters appreciate the importance of information to minimize loss through low oxygen conditions and temperature-

induced fish mortalities. Transportation is necessary for hatchery operations, but the experience can cause fatal levels of stress among fish. As Yanong & Francis-Floyd (2002) define it, stress in these scenarios is "a condition in which [the] animal cannot maintain a normal physiological state because of various factors adversely affecting its well-being."

Some stressors, such as the season and altitude, are beyond hatcheries' control, but must be considered as they affect overall water quality; similarly, factors like stress stemming from confinement, handling or individual travel tolerance are inevitable within the transportation process. However, there are still measures that transporters can take to effectively

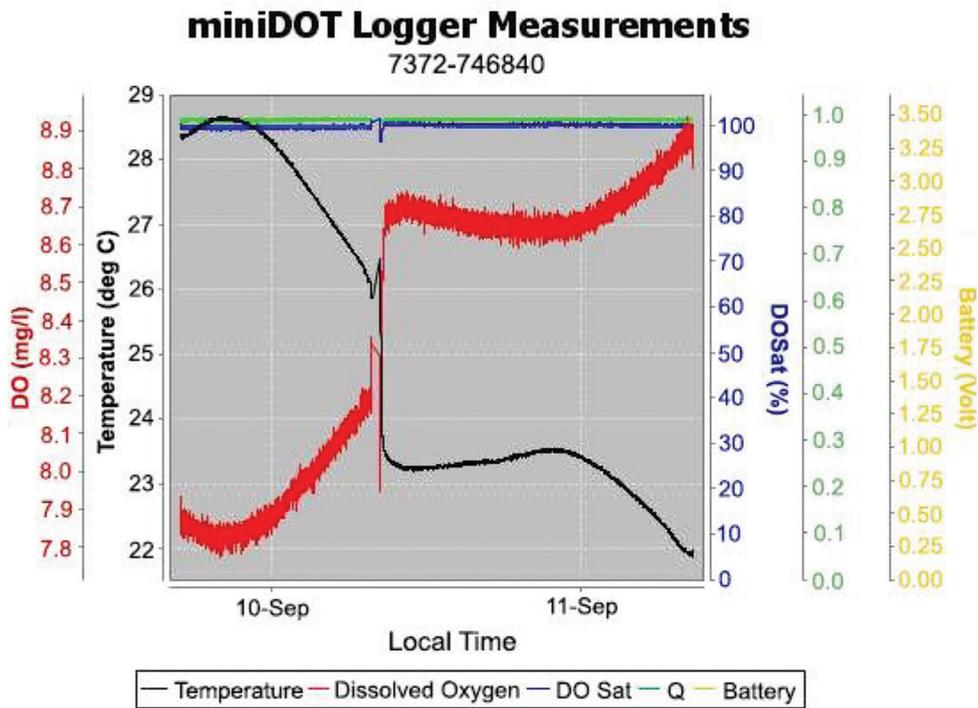


Figure 1. The program reads all the miniDOT Logger's data files in the selected folder. It concatenates these and presents the plot shown below.



Figure 2. Aquasend's miniDOT® Clear Logger records dissolved oxygen and temperature data.

minimize several stress-inducing variables. By maintaining optimal water quality and temperature throughout the transportation process, transporters can prevent these variables from contributing to the overall stress and possible subsequent fish death. Aquasend's miniDOT® Clear Logger is a water quality monitoring device that records dissolved oxygen and temperature measurements in real-time. By offering quick and accurate readings of oxygen level and water temperature, the miniDOT® Clear Logger arms transporters with the information they need to keep their aquatic products healthier for longer.

### Qualities of healthy water

#### *Dissolved oxygen*

Dissolved oxygen (DO) is widely accepted as accurately indicative of water quality, specifically regarding its ability to support aquatic life. In their 2008 study, Onyia, Ladu & Onyia compared fluctuations in DO levels across several containers commonly used in fish transportation, citing a direct link between mortality rates and the depletion of DO. According to the United States Geological Survey's Water Science School, outside of biological activity, the three primary factors which determine DO levels are salinity, atmospheric pressure and water temperature. On a similar note, Wilson

(2010) explains in their discussion on DO that lower atmospheric pressure and water temperatures both correspond to higher levels of dissolved oxygen, while higher rates of salinity have been linked to decreased levels of DO.

Lethal DO levels for fish are typically between 1 and 3mg/L with minimal fish activity in this range. Wilson (2010) identified minimum DO levels to sustain the life of several fish species; for example, DO levels at 1 to 1.1mg/L resulted in death for juvenile catfish, adult catfish at 1 to 2mg/L led to a decrease in food intake, 50% of rainbow trout (6 months old) at 1.3 to 1.6mg/L experienced death, 50% of rainbow trout yearlings at 1.3 to 2.5mg/L experienced death, salmonids at less than 3.0mg/L resulted in death and brown shrimp at less than 0.7mg/L resulted in death. For normal levels of activity, DO levels above 3mg/L generally seem sufficient for many species (Wilson, 2010).

#### *Temperature*

Variables such as container population and length of time in transit can exacerbate stress levels and accelerate DO depletion, but temperature fluctuations can cause harmful disruptions despite careful consideration. Fish are poikilotherms and are unable to regulate their body temperature, making



Figure 3. The completely submersible logger includes an optical DO sensor, a temperature sensor, batteries and a micro-SD memory card.

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water temperature especially critical to successful transportation outcomes (Harmon, 2009). Because ideal transportation temperatures are unique to a species and can change depending on the season of transport, a high degree of precision is required. For example, Piper (1982) recommends channel catfish be transported at temperatures of 7.7-10°C (45-50°F) in winter and 15.6-21.1°C (60-70°F) in summer. In that same study, Piper (1982) also recommended hauling striped bass at 12.8-18.3°C (55-65°F) to optimize fish health. Meanwhile, Yeager *et al.* (1990) found hybrid bass had better transportation results when tank water was cooled to <18.3°C (65°F). Because temperature fluctuations can occur relatively quickly and have the potential to be so impactful, real-time and reliable monitoring can allow transporters to make necessary adjustments to maintain optimal conditions.

## How to make transport successful

Aquasend's miniDOT® Clear Logger is a valuable tool for aquatic product transporters and hatcheries who want to minimize losses and gain valuable insight. The miniDOT® Clear Logger is a completely submersible instrument that logs dissolved oxygen and temperature measurements. It has an internal LCD screen that displays real-time measurements to the user. To optimize data collection, the miniDOT® Clear Logger offers customizable time and sample intervals via a USB cable and software. The oxygen sensor is an optode

that measures dissolved oxygen concentration in water through a fluorescence method. These features allow users to view vital water quality data just by looking at the device to save valuable time if dissolved oxygen or the temperature dip below species optimal levels.

Not only does the miniDOT® Clear Logger allow for quick access to water quality data, but it also records all data throughout the entire transport which can be retrieved to provide a water quality report to the customer regarding transportation conditions. Aquasend focuses on product engineering to develop durable instruments that improve water quality with continuous monitoring to transform aquafarms and hatcheries worldwide. Aquasend's mission is to increase aqua farm and hatchery productivity by applying sensor, software and aquatic monitoring innovations while decreasing maintenance, labor costs and power consumption and measuring real-time transport conditions and ensuring water is measured in real-time.

References available on request

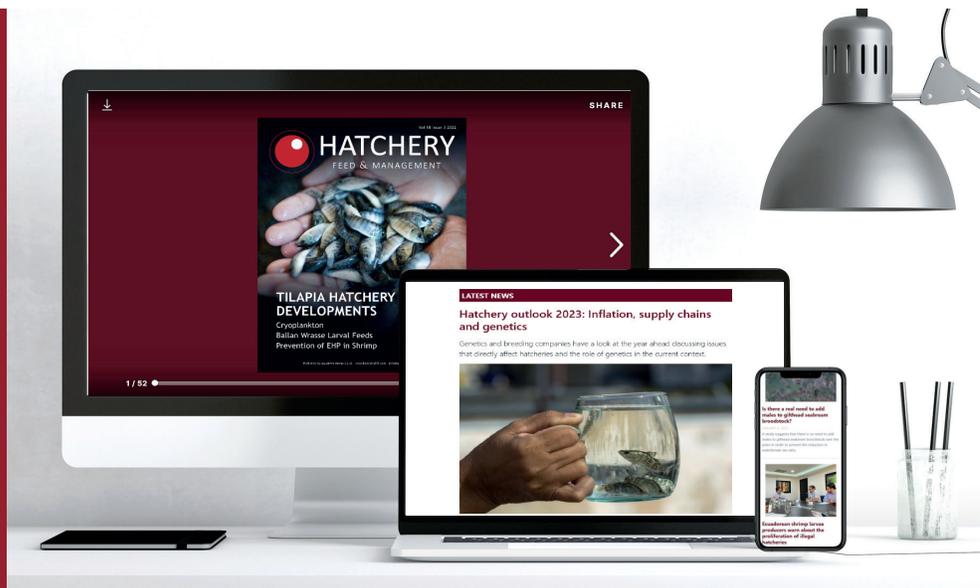
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# A sustainable approach to disinfection

James Leigh, Evoqua Water Technologies



With global warming increasing the number of parasites present in aquaculture environments, new strategies for water disinfection are vital to protect the industry and the environment. But these disinfection solutions must be sustainable, as well as operational and cost-efficient to meet the needs of operators of recirculating aquaculture systems (RAS).

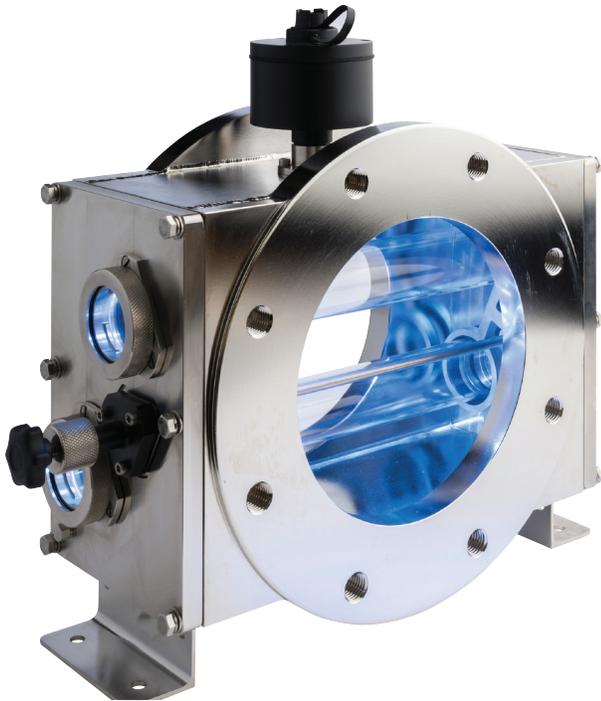
## A complex landscape

We know farming using RAS has many benefits, including giving operators complete control over water quality parameters during hatchery production. This enables farming at higher densities at stable and optimal conditions, thus leading to higher yield and profit

compared to traditional systems. Most importantly of all, using RAS significantly reduces the risk of diseases and infection.

However, using RAS, a closed loop system, fish waste or byproducts can exist in the form of carbon dioxide, ammonia and suspended solid waste products (i.e. feces or organic matter). These potentially dangerous components will accumulate in a closed-loop system. Therefore, it is essential to remove or control waste products for successful production, disease management and yield using effective biological and mechanical filtration and disinfection systems that recycle and treat the used water from aquatic farming.

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The innovative Evoqua Wafer™ UV Disinfection System

Effective filtration and disinfection are also critical when it comes to the management of parasites. Rising sea temperatures may be a factor in increasing parasite numbers and the global warming picture is stark. An Intergovernmental Panel on Climate Change report showed that the average sea surface temperature of the Indian, Atlantic, and Pacific Oceans has increased by 0.65°C, 0.41°C, and 0.31°C between 1950-2009 (Hoegh-Guldberg *et al.*, 2014).

The new *Vibrio* bacteria species found in UK waters is evidence of this. Research scientists from the University of Exeter have found the presence of a wider diversity of bacteria. Species *V. rotiferianus* and *V. jascida* have never been found in UK waters before, and usually inhabit warmer waters. The presence of these two previously absent species in the region provides evidence that as sea-surface temperatures rise, UK waters are becoming increasingly hospitable for a wider variety of invasive bacteria and micro-organisms (Harrison *et al.*, 2022).

### Turning to innovative solutions

The rise of parasites raises concerns for the health of hatcheries and highlights the importance of effective water disinfection to mitigate the issue. Two highly effective, proven methods of disinfection are ultraviolet (UV) and ozone.

UV disinfection works by applying light in wavelengths that damage and destroy the DNA of biological organisms. This prevents the build-up of harmful populations of heterotrophic bacteria and opportunistic pathogens (ciliate parasites such as *Trichodina* sp.) in RAS. The effectiveness and efficiency of the UV disinfection unit depend on the turbidity of the water, size, and species of the target organism in the RAS. Although UV is highly effective, it cannot inactivate 100% of bacteria. Therefore, UV is best used in combination with mechanical filtration that effectively removes organic matter from the water.

Importantly, UV disinfection systems support an organization's sustainability goals as they are low-energy and high-quality lamps have a long operational life, minimizing replacement costs. And, with large-scale fish farming increasing, UV technology's ability to disinfect water in one cycle provides advantages for efficiency by increasing throughput.

The disinfection process of a RAS can be further enhanced with ozone technology. Ozone is one of the most powerful commercially available oxidizing agents. Oxidation and disinfection occur when ozone meets substances including bacteria, viruses, parasites and algae that exist in aquaculture systems. It breaks down long complex protein molecules and damages the cell nucleic acids of microorganisms.

It works by ozone gas simply mixing into the water creating the solution for disinfection. The gas quickly dissolves in water, contacts wet surfaces, and then decomposes back to oxygen in solution, leaving effectively no residuals in the treatment system. When ozone is dosed into the protein skimmer it eliminates the need for an additional separate ozone reaction chamber in the RAS system.

Both ozone and UV disinfection are superior disinfection solutions. They are not only effective at removing pathogens and parasites but also reduce water usage by increasing recirculation rates, support healthy hatchery growth levels and are chemical-free and safe for the environment and operators. Importantly though, using industry-leading technology systems will reduce operating costs, minimize maintenance requirements and support ongoing sustainability initiatives.

### UV disinfection in practice

A new hatchery in Norway required a UV plant for its

recirculation aquaculture system, for protection against fish disease, mainly infectious salmon anemia, along with general disinfection of the recirculation loop. Their requirements were 150m<sup>3</sup>/hr, UVT 90% and NVI dose of 25mJ.

The hatchery turned to Evoqua and the Wafer® UV system, approved by the Norwegian Veterinary Institute (NVI), which comprises 2 x 2.5kW lamps. Both lamps would run at 50% power when first commissioned and then gradually ramp up in power over the 8,000 hours running period, always complying with the specification, but only running at full power near the end of lamp life. This provided a fit-for-purpose sustainable solution for the hatchery and the environment. Evoqua's solution adhered to all required validations. The compact design enabled the unit to fit into the limited space available.

Furthermore, in certain applications, sacrificial anodes are installed to protect the system from corrosion. Sacrificial anodes are easily corroded materials deliberately installed in a pipe or tank to be sacrificed to corrosion, leaving the rest of the system relatively corrosion free.

### A more sustainable future

As water temperatures continue to rise, now is the time to take a proactive, sustainable approach to water treatment and ensure any disinfection system is not only effective against invasive species but supports safety, efficiency, and environmental goals. New disinfection strategies will not only safeguard fish and the environment but will reap cost and operational benefits that will make a real difference to the business. It's vital to ask more about technology and demand these benefits. Hatchery professionals worldwide should work alongside the right partners who can support their sustainability initiatives, not only with a range of technology solutions but long-term strategies that offer continuous improvement for a better future.

*Evoqua UV disinfection generator systems undergo third-party validation testing in accordance with the UVDGM (USEPA, 2006). Validated products are tested to confirm a minimum inactivation equivalent of 3 log (99.9%) for microorganisms in accordance with NSF/ANSI 50 and the UVDGM. Performance is not claimed nor implied for any product not yet validated; unvalidated products use single-point summation calculations to provide delivered*



The Evoqua MG Series Ozone Generator

*dose recommendations. Performance limitations depend on feed conditions, overall installed system design, and operation and maintenance processes.*

*Evoqua Ozone Generation systems undergo factory acceptance testing to ensure they are capable of producing the desired ozone concentration, based on operational parameters outline in the Operating Manual. System performance of microorganism inactivation depends on the CT value, pH, and temperature of water. Performance limitations depend on feed conditions, overall installed system design, and operation and maintenance processes.*

*References available on request.*

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# Hydrogen sulphide toxicity: Understanding and mitigating in recirculating aquaculture systems

Caspar Yan Hansen, David Owen, Blue Unit AS

Elevated levels of hydrogen sulphide (H<sub>2</sub>S) are often associated with lethal effects on fish. This adverse effect is present at different concentrations since multiple parameters, such as temperature, oxygen saturation and salinity as well as redox potential, influence the toxicity of H<sub>2</sub>S in water. The presence of oxygen will work as a protector against the presence of H<sub>2</sub>S by oxidation, but it is too slow a process to protect fish on occasions of sudden H<sub>2</sub>S release to the environment.

Anaerobic environments with H<sub>2</sub>S can be formed anywhere on a fish farm, particularly in biofilters with insufficient aeration and stagnant piping systems. The concentration of sulphate (SO<sub>4</sub><sup>2-</sup>) is significantly higher in seawater (2,700 mg/L) as compared to freshwater (5-50 mg/L) (Letelier-Gordo *et al.*, 2020). However, a fish farm needs to operate below 5ppt in salinity before SO<sub>4</sub><sup>2-</sup> becomes limiting for H<sub>2</sub>S<sup>-</sup> formation.

Sulphate-reducing bacteria (SRB) compete with nitrate-reducing bacteria (NRB) for carbon in the form of volatile fatty acids. If a fish farm operates at a higher nitrate level, then NRBs can outcompete the SRBs for limiting volatile fatty acids. Some evidence even supports it being used as a remedy for H<sub>2</sub>S accumulation rather than a preventive measure in shrimp ponds (Torun *et al.*, 2020). This solution however presents issues with nitrogen discharge which is less environmentally sustainable.

Different species of fish have different sensitivity to H<sub>2</sub>S in the water. The literature suggests fish are highly sensitive to H<sub>2</sub>S. Levels of 2µg/L in freshwater and 5µg/L in salt water can cause acute stress and even mortality with 2-4 weeks of chronic exposure according to newer unpublished research (Nofima, 2022). Some literature suggests concentrations above 25µg/L can be lethal for fish. Recent research proposes a critical H<sub>2</sub>S concentration 60.7 ± 13.2 µg/L at 14°C (Bergstedt & Skov, 2023). However, there is not final consensus on the exact lethal concentration.

Biofilters have been reported to be able to generate upwards of 139 g H<sub>2</sub>S per m<sup>3</sup> biofilter volume, when mixing and aeration are insufficient. Consequently, it is of paramount importance to keep biofilter performance monitored (Rojas-Tirado *et al.*, 2021).

The relative concentration of H<sub>2</sub>S is most dangerous at lower pH values. Conversely, it becomes less dangerous at higher pH values, where it exists at HS<sup>-</sup>. H<sub>2</sub>S gas readily binds into the water and exists in equilibrium in its aqueous form of H<sub>2</sub>S as well as HS<sup>-</sup> and S<sub>2</sub><sup>-</sup>. At pH 7.4, around 72% exists as HS<sup>-</sup> and 28% as aqueous H<sub>2</sub>S (Li & Lancaster, 2013).

## Removing and monitoring hydrogen sulphide

Luckily, there is constant removal of H<sub>2</sub>S and HS<sup>-</sup> across fish farms. HS<sup>-</sup> binds with metals to form



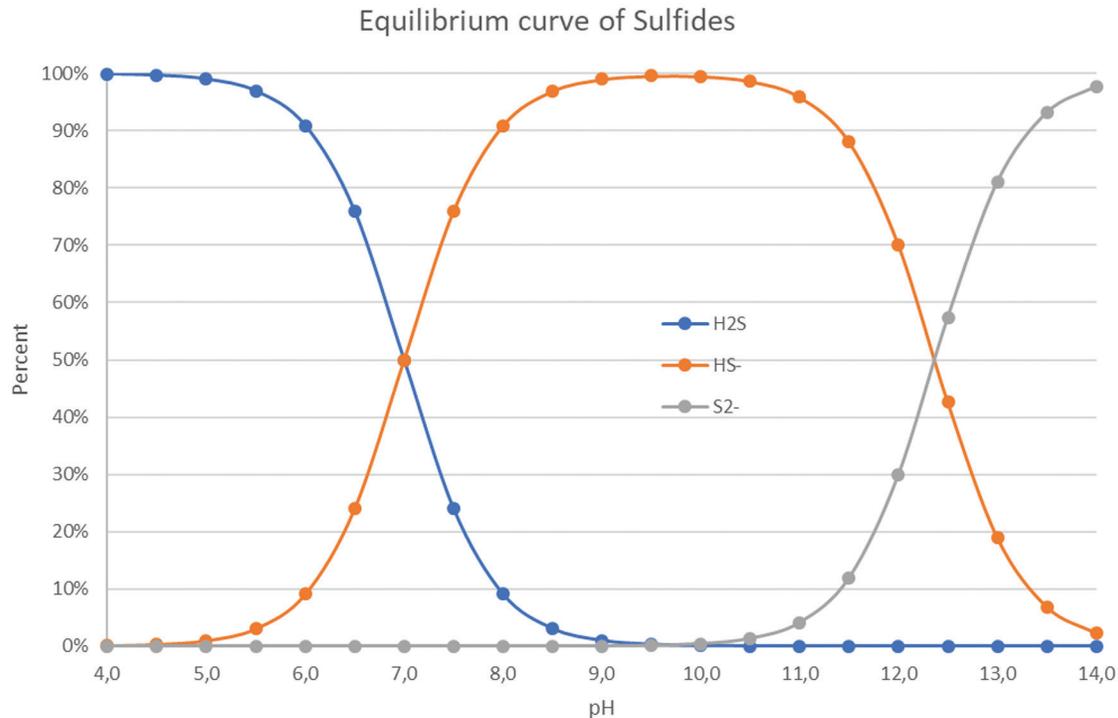


Figure 1. S-curve of hydrogensulfide, bisulfide and sulfide in water. Relative % as a function of pH.

metal sulphides, H<sub>2</sub>S can be degassed, and chemically oxidized by ozone, peroxide, or oxygen and in biological oxidation processes with nitrate by microbes (Bergstedt *et al.*, 2022). Chemical oxidation via oxygen or peroxide has been proven particularly effective in aquaculture since this is already commonly used for disinfection or oxygenation. This targeted approach often proves very potent due to targeting the larger HS<sup>-</sup> pool rather than the H<sub>2</sub>S pool which is significantly smaller at the operational pH level (Bergstedt *et al.*, 2022; Bögner *et al.*, 2021).

Fish farms ought to minimize the accumulation of H<sub>2</sub>S. There are systems today that can measure total HS<sup>-</sup> several times a day across many locations on a RAS, creating up to 72 data points daily. This technology effectively measures both the H<sub>2</sub>S and HS<sup>-</sup> in the water sample by lowering the sample pH. This creates a higher proportion of gaseous H<sub>2</sub>S which can be extracted by running the more acidic water sample across a dual membrane system. This allows for earlier detection of changes in concentration than other systems that purely measure H<sub>2</sub>S, since the detection limit effectively gets artificially lowered.

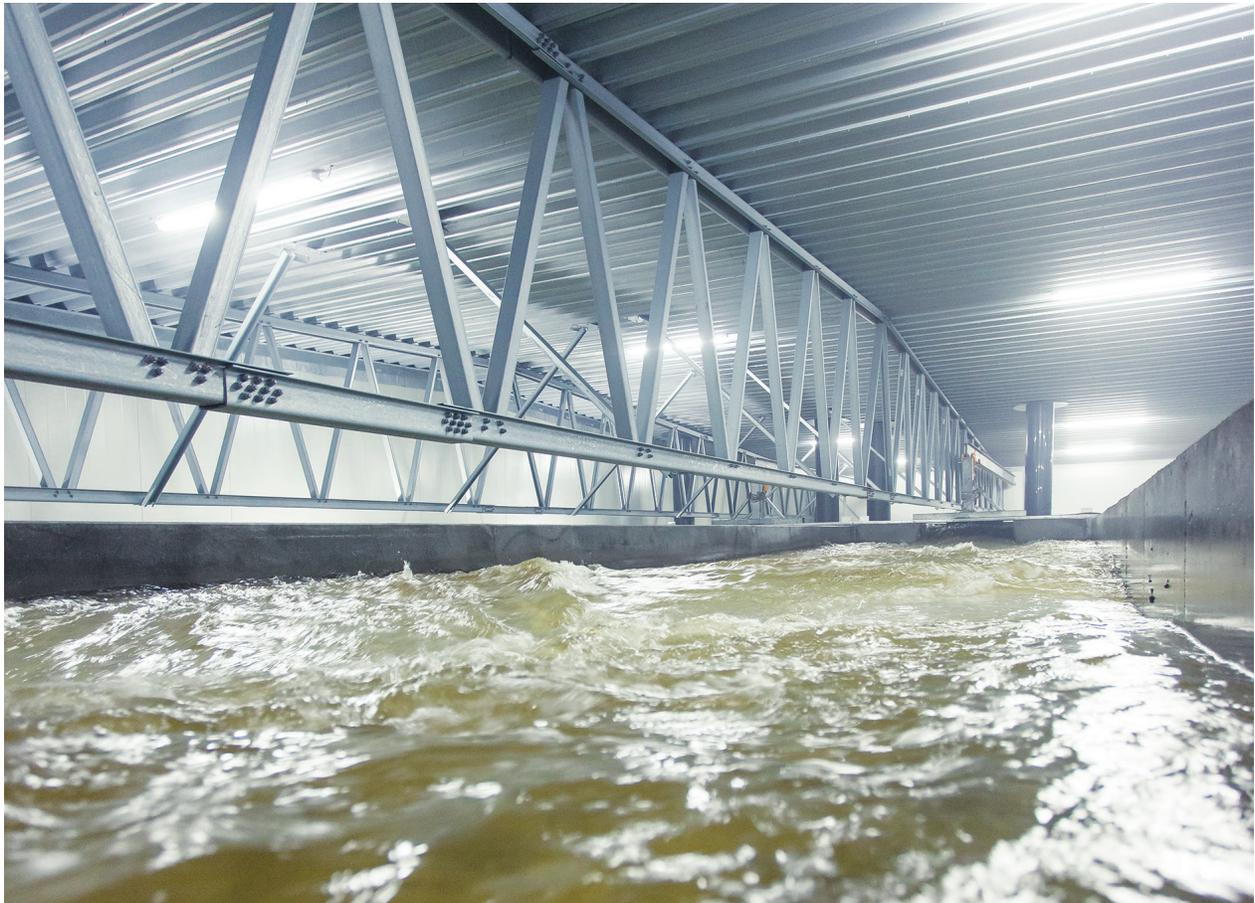
Monitoring H<sub>2</sub>S down to the microgram concentration is not on its own the most important defense against H<sub>2</sub>S sudden release. It is also a well-documented issue that feces and the residual biological matter will create a basis for H<sub>2</sub>S releases in recirculation systems (Rojas-Tirado *et al.*, 2021). Consequently, understanding fecal matter removal and associated biofilter health is critical in defense against H<sub>2</sub>S in recirculation systems.

While modern fish feeds are generally optimized to produce robust feces, the hydrodynamics in fish tanks will often smash the feces into smaller particles, before they can be efficiently removed mechanically. Data indicates that some fish tank designs result in dissolved feces to form a “soup” that raises the risk of H<sub>2</sub>S release and must be entirely cleaned by expensive biological means.

By monitoring turbidity and particle sizes before and after fish tanks<sup>1</sup>, the manager can monitor directly how many fecal particles are being smashed before mechanical filtration. By monitoring turbidity and particle sizes on either side of a mechanical filter, the manager can see how many particles are escaping mechanical removal. Finer particles escaping

<sup>1</sup>Turbidity measures the interaction of light on suspended particles of varying size, shape, color and reflectivity. Particle counting can quantify both particle size and number and is potentially an even more useful tool.

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mechanical removal typically end being trapped inside the biofilter. Again, by monitoring either side of the biofilter, the manager can monitor particle quantity and size being accumulated or released over time. This provides a rich picture of both biofilter health as well as overall farm health.

The most effective way to monitor these gradients and manage fish tank and filter performance is by using advanced centralized measurement technologies. This also brings the cost of acquisition down on a farm since it allows for single high-end sensors to monitor multiple places on a farm instead of having to invest in multiple lower-end sensors for the same cost. Installing multiple sensors is furthermore accompanied by high technician prices to properly install them. Companies providing a turnkey solution of data sampling often have a cloud solution associated so the client can watch their data online in real-time or near real-time from all over the world either on a computer, tablet or even phone. However, these technologies can be tooled with many additional parameters. For example, by monitoring total

inorganic carbon, pH, oxygen and ammonia gradients the manager can better manage a healthy biofilter with fewer anaerobic zones that can generate H<sub>2</sub>S.

*References available on request.*

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# Ultrafiltration of inlet water: How and why?

Margit E. Jakobsen, FiiZK Aqua

Inlet water is a central factor for land-based aquaculture. It is a resource laying the foundation for the growth of aquatic organisms on land and is also a potential risk factor. Deviating water quality can eliminate the entire production. Membrane technology is proposed as a potential solution to ensure optimal water quality for aquaculture.

## Principles of membrane filtration

Membranes are selective barriers; some components go through the membrane while others are retained (Fig. 1). Which components are held back is determined by the characteristics of the membrane, such as pore size and surface chemistry. When membranes are used for water treatment, pressure is applied to drive water through the membrane. Membranes are classified depending on their pore sizes: microfiltration (MF) has pores in the range of 0.1-1  $\mu\text{m}$ , ultrafiltration (UF) of 0.01-0.1  $\mu\text{m}$ , nanofiltration (NF) of 0.001-0.01  $\mu\text{m}$  and reverse osmosis (RO) of under 0.001  $\mu\text{m}$  (Fig. 2). The pressure needed to drive the process is inversely proportional to the pore size – the tighter the pores, the higher the pressure needed to push water through the membrane.

## Membrane filtration plants

When membranes are used to treat large volumes of water they are integrated in process plants (Fig. 3). Different suppliers deliver a wide range of setups, but the fundamental principles for the process will be the same. One or several pumps will supply the membranes with water with the correct pressure. This water has to be prefiltered to remove large components before it reaches the membranes. The prefiltration will depend on the membrane type, and will, in the case of ultrafiltration, be a mechanical filter with a relatively large pore size. Membranes will be fouled over time and

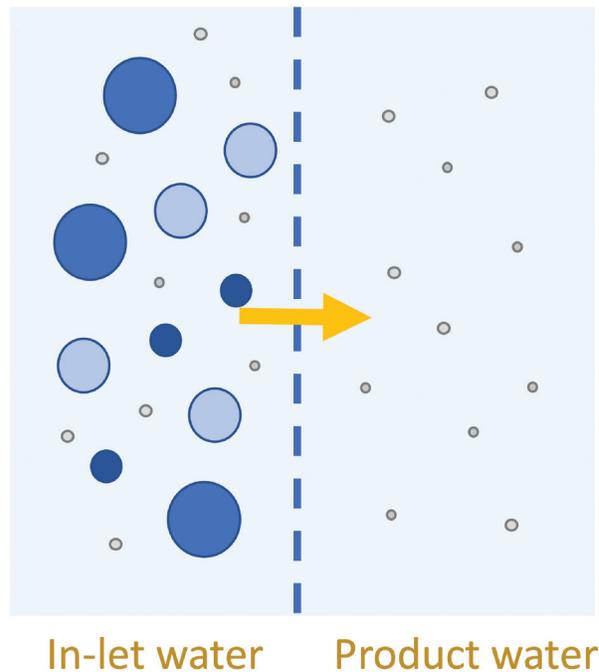


Figure 1. Membranes are selective barriers. When used for water filtration, pressure is applied to drive the process.

will need a cleaning system. For ultrafiltration, periodic backflushing will be applied. At certain intervals, chemicals will be dosed during the backwash to remove more resilient fouling. Using modern technology, the plants can be automated and remotely controlled and can easily be operated by the technical staff. Membrane filtration has been used for drinking water and wastewater applications for decades, while it is only recently that a few suppliers specializing in aquaculture application have been established.

## Ultrafiltration of seawater

Ultrafiltration can be used for both seawater and freshwater purification. For seawater, the main concerns will be pathogens and particles. The pathogens may

# WATER QUALITY

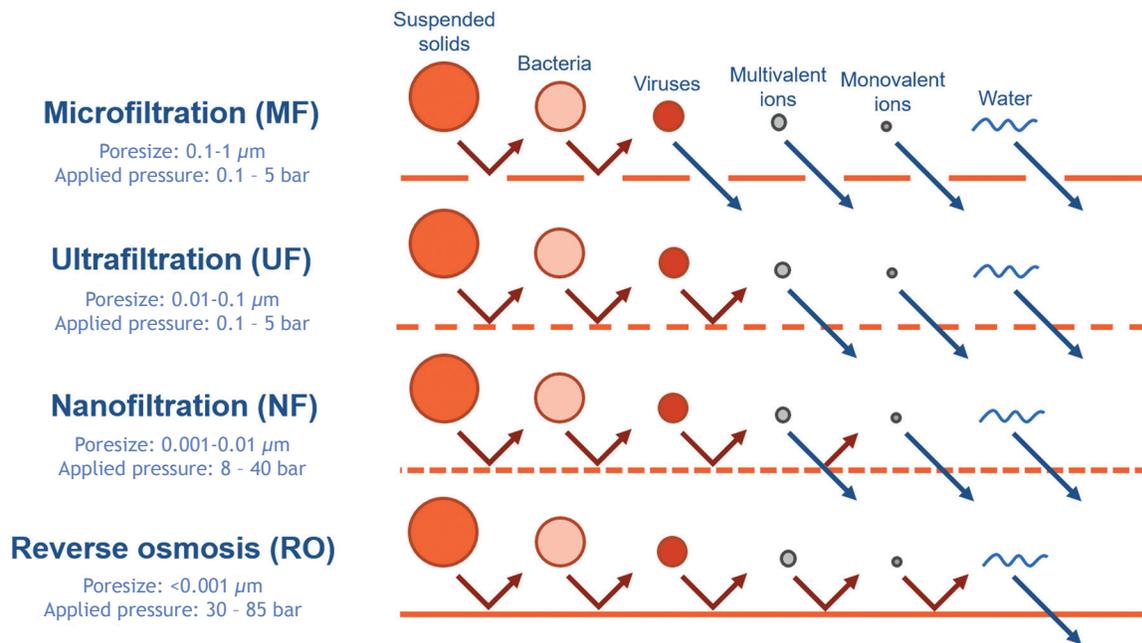


Figure 2. Membranes are classified based on pore sizes. Different membranes are used to remove different components.

lead to disease and extensive disinfection procedures. Particles are also important to remove, especially as they may reduce the efficiency of UV treatment of the water which may be a second pathogen barrier together with the ultrafiltration. The ultrafiltration membranes used in the FiiZK Aqua plants have a pore size of 0.02  $\mu\text{m}$ , which has proven sufficient to remove both pathogens and the main bulk of particles from the inlet water.

## Ultrafiltration of freshwater

Freshwater sources used for land-based aquaculture, in general, have three main components that should be filtered out: pathogens, organic particles, and metals. Pathogens are eliminated by the FiiZK Aqua ultrafiltration membrane by simply being bigger than the 0.02  $\mu\text{m}$  pores. However, the main load of organic particles will be very small humic acids that can pass through the pores. Humic acids are organic compounds created by the breakdown of organic materials, such as leaves, and they usually have a negative charge. The negative charge leads them to attract positive metals, and therefore, the humic acids often come together with metals such as iron, aluminium, and copper. The humic acids are not necessarily harmful to aquatic organisms but may lead to a build-up of sludge



Figure 3. Commercial ultrafiltration plant by FiiZK.

in pipes and tanks. However, the metals bound to the acids may damage gills if they are released from the humic acids. Such a release is easily promoted by a sudden drop in pH, for instance because of an increased  $\text{CO}_2$  production by the fish or technical failure of the aeration system.

To remove the humic acids and their attached metals, coagulation may be necessary. Ironically, this is achieved by adding more metals in the form of a metal coagulant. If properly executed, this is both a safe and effective treatment setup. The metal coagulant is added



Figure 4. Salmon eggs in water cleaned using a combination of coagulation and ultrafiltration.

together with a compound for pH adjustment prior to a coagulation volume. In the coagulation volume, the chemical reaction is allowed to take place before the mix reaches the membranes. If done properly, the humic acids have formed larger flocs before they reach the membranes and the humic acids and metals are then deposited on the membranes. This will again be flushed to waste by regular backwashes and chemical cleanings (CEBs and CIPs). The coagulant is acidic so the entire operation can easily be monitored and controlled by a series of inline pH sensors. Industrial plants are operated successfully for several years without fault in the coagulation process.

## Scientific testing of pathogen removal using ultrafiltration

To verify the pathogen removal efficiency by the FiiZK Aqua membranes, a test was conducted in cooperation with NOFIMA (The Norwegian Food Research Institute). The results were published by Vasco *et al.* (2022). In the study, seawater was spiked with concentrates of *Aeromonas salmonicida* (causative agent of furunculosis) and infectious pancreatic necrosis virus (IPNV). These pathogens have a diameter of 500-2000 nm and 55-70 nm, respectively, indicating that they should be rejected by the membrane completely. IPNV was specifically chosen because it is one of the smallest viruses relevant for fish farming, together with the ISAV (45-140 nm). The results were verified by qPCR for both pathogens, in addition to TCID50-assays for IPNV and a cell culturing of the *A. salmonicida*. The tests were conducted by filtration of three batches of each concentrate for both low (4-7°C) and high (16-19°C) temperatures. The results were 100% removal for all parallels during all conditions tested, therefore confirming the pathogen removal properties of the membranes.

## Live feed production

Both freshwater and seawater can be used as inlet water for live feed production, depending on the organisms. In a typical setup, algae can be grown as feed for crustaceans. The elimination of non-target species of algae, competing crustaceans, and pathogens will be important to ensure stable



Figure 5. Inlet water pre (left) and post (right) treatment using coagulation and ultrafiltration. Color number reduction from 40 mgPt/L to 2 mgPt/L.

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production. Ultrafiltration of the inlet water will ensure the removal of these elements and is used industrially by both live feed producers and for on-site growth.

## Summary

Ultrafiltration is a technology that can remove harmful components such as pathogens and metal-carrying humic acids from both freshwater and seawater. It can also ensure the elimination of competing organisms for live feed production. The technology is easy to scale up to commercial dimensions and some suppliers have specialized in customizing the technology for aquaculture purposes.

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# Industry Events

## 2023

### MARCH

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28 - 30: Aquafuture Spain [aquafuturespain.com](http://aquafuturespain.com)

### APRIL

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13 - 14: Vietshrimp Aquaculture International Fair, Vietnam [vietshrimp.net](http://vietshrimp.net)

18 - 21: LACQUA 2023, Panama [www.was.org](http://www.was.org)

### MAY

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7 - 11: 46th Larval Fish Conference, Portugal [larvalfishconference.com](http://larvalfishconference.com)

10 - 11: Aqua Expo Manabí, Ecuador [aquaexpo.com.ec](http://aquaexpo.com.ec)

29 - June 1: World Aquaculture 2023, Australia [www.was.org](http://www.was.org)

### JUNE

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21 - 22: Oceanovation Festival, The Netherlands [www.oceanovation.live](http://www.oceanovation.live)

### JULY

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10 - 12: Aqua Farm 2023, Australia [aquacultureconference.com.au](http://aquacultureconference.com.au)

11 - 13: Aqua Expo El Oro, Ecuador [aquaexpo.com.ec](http://aquaexpo.com.ec)

24 - 26: Shrimp Summit, Vietnam [responsibleseafood.org](http://responsibleseafood.org)

### AUGUST

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22 - 24: Aqua Nor 2023, Norway [www.aquanor.no](http://www.aquanor.no)

### SEPTEMBER

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5 - 7: Global Shrimp Forum, The Netherlands [www-shrimp-forum.com](http://www-shrimp-forum.com)

11 - 14: 21st International Conference on Diseases of Fish and Shellfish, UK [www.delegate-reg.co.uk](http://www.delegate-reg.co.uk)

18 - 21: Aquaculture Europe, Austria [www.aquaeas.org](http://www.aquaeas.org)

### OCTOBER

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2 - 5: The Responsible Seafood Summit, Canada [events.globalseafood.org](http://events.globalseafood.org)

23 - 26: Aqua Expo Guayaquil [aquaexpo.com.ec](http://aquaexpo.com.ec)

### NOVEMBER

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13 - 16: Aquaculture Africa 2023, Zambia [was.org](http://was.org)



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