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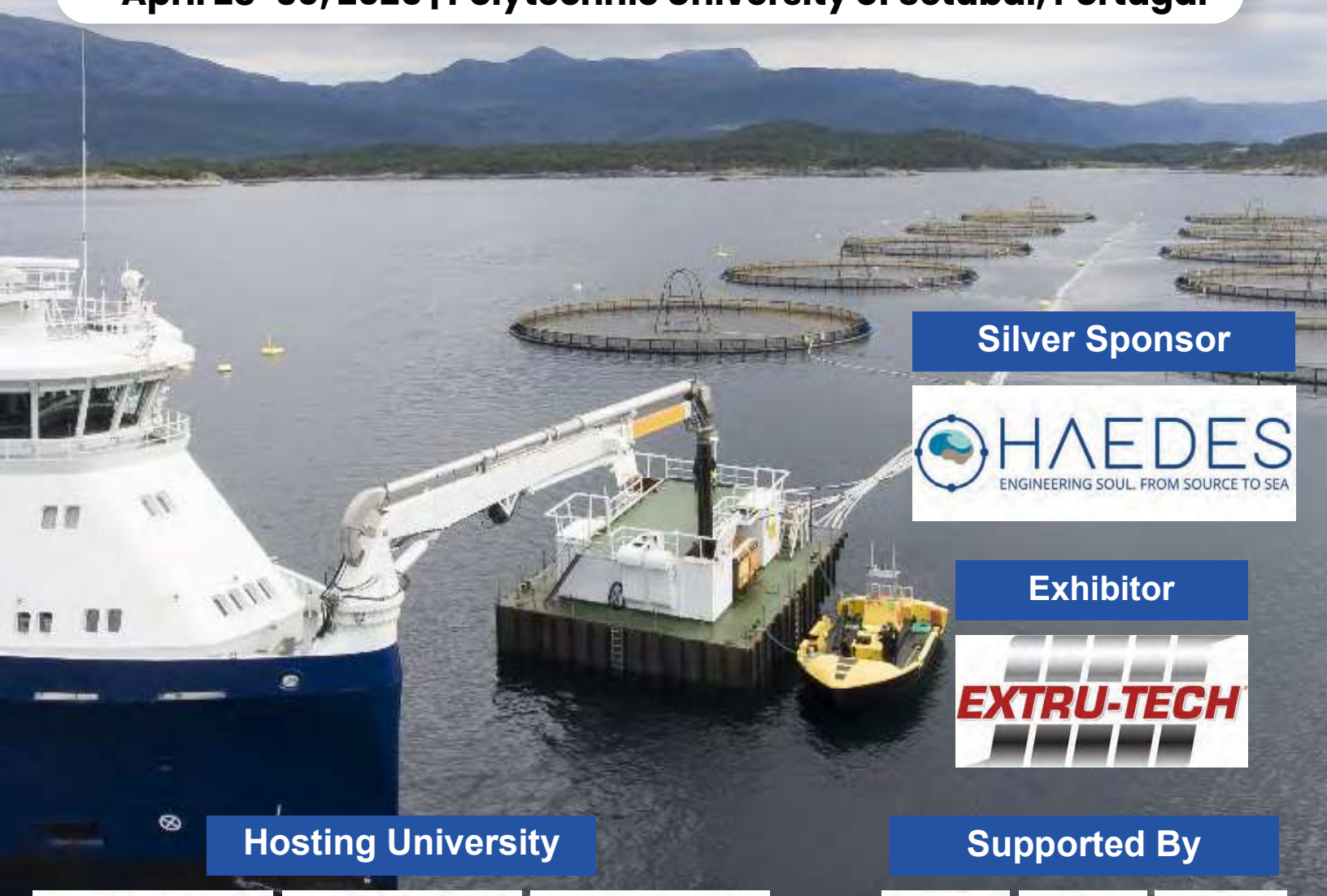

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Offshore the Future of Aquaculture

Paulo Serra Lopes, Mariculture Systems Ltd, Portugal

Context of the Aquaculture Industry in Portugal and Setúbal: Challenges and Opportunities

Antonio Correia, Aquanostra, Portugal

Larval culture of the tropical spiny lobster *Panulirus homarus*; a new candidate species for aquaculture in Oman

Mohamed Al Wahaibi*[1], Wenres3 G. Gallardo[2], Jupit M. Donoso[3], Najla Al-Mandhari[2] and Michel Claereboudt[2]

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Abstract

The tropical spiny lobster, Panulirus homarus, is the most important species among all existing lobster species in the Sultanate of Oman. Due to a decrease in supply from the wild and the associated increase in price, aquaculture has emerged as a viable option for lobster production. However, the aquaculture of the tropical spiny lobster is currently limited to the grow-out of wild caught juveniles. Although larval rearing techniques are being developed, several ecological aspects yet require further research. One crucial aspect is determining larval tolerance to starva3on during periods without feed, which may occur due to factors such as long-distance drifting, unpredictable egg hatching times or unsuccessful Artemia cyst hatching. Another key aspect is the effects of changes in culture temperature and salinity on the survival of early larval stages of Panulirus homarus were inves3gated. Larvae fed for one to four days only survived up to 14 days post-hatching, whereas those fed daily survived up to 20 days. Survival was highest at 24 °C and 33 ppt, while higher temperatures and salinity values resulted in shorter survival dura3ons. Spiny lobster larvae tend to migrate long distances in the ocean, during which they are exposed to fluctuations in temperature, salinity, and food availability. Although temperature varies depending on the geographical region of the species, identifying optimal water parameters and ensuring sufficient food availability could significantly enhance the successful cultivation of this species in captivity.

Palinurus elephas culture – fishery restoration and farming?

David J Fletcher

RAS Aquaculture Research Ltd., UK.

Abstract

The European spiny lobster, Palinurus elephas, once featured as an important commercial species in Wales. The fishery was destroyed during the 1970-1980s through excessive fishing pressure largely due to a dive fishery but also the introduction of tangle nets combined with weak management. While there are now some tentative indications of fishery recovery in Wales and England the possibility of full restoration to former population numbers is debatable.

Apart from Filippi et al (2024), there has been little published data on *P. elephas* culture since the early work of Kittaka et al (2001).

With EU support, research by RASAR commenced in 2013 and the project has subsequently been supported through private funding since 2015. This presentation will summarise main observations of P. elephas phyllosoma during culture and juvenile behaviour. Some reference will be made to recirculation aquaculture system (RAS) design, phyllosoma culture tanks, feeding and water quality requirements. Some key findings include:

High quality RAS technology is critical for maintaining conditions for optimal phyllosoma growth and survival. This is particularly related to having tight control over key water quality parameters, disinfection and maintenance of low levels of dissolved and fine particulate organics.

P. elephas readily breed in captivity but appropriate broodstock feeds still required.

The natural planktonic phyllosoma phase of 7- 8 months is significantly reduced under controlled culture conditions.

The larval cycle has been completed with the first juveniles produced in July 2019 and increased production in 2021.

Following larval settlement, pueruli and juvenile ongrowing growth and behaviour indicates real potential for large scale production of hatchery juveniles.

Communal juvenile culture does not appear to present an obstacle to acceptable production costs.

Juvenile ongrowing from settlement could be performed in stacked shallow trays up to 350 – 400mm depth.

The potential for commercial ongrowing directly for the seafood market needs should be evaluated.

Stable feed formulations have been developed for juvenile ongrowing.

Development of formulated phyllosoma feeds is considered critical for expanding production.

Molecular Insights into the Life History of the Ornate Lobster (*Panulirus ornatus*): A Breakthrough in Decapod Research

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Abstract

Most commercially significant decapods, such as penaeid prawns (*Litopenaeus vannamei* and *Penaeus monodon*), exhibit rapid larval development, making it challenging to study their life stages in detail. The ornate lobster (*Panulirus ornatus*), however, presents a unique opportunity for high-resolution life-history investigations due to its extended and complex developmental timeline. Eggs develop over a month, followed by up to four months of larval growth, producing some of the largest planktonic larvae among decapods.

Building on decades of research, the commercialization of *P. ornatus* hatchery technology by Ornatas in Townsville, Australia, has revolutionized our ability to study this species. Optimal environmental controls in hatchery systems have enabled the generation of transcriptomic libraries spanning 11 embryonic stages, 12 larval molt stages, late larval through juvenile stages, and 18 adult and sub-adult tissues. These data are consolidated into *CrustyBase.org*, a spatiotemporal atlas of gene expression that facilitates rapid exploration of developmental biology in *P. ornatus*.

This resource has driven breakthroughs in understanding sexual differentiation pathways, molecular mechanisms governing embryogenesis and metamorphosis, and key genes influencing behavior and metabolism. The ornate lobster is not just a valuable aquaculture species but also a model organism for decapod research, offering unprecedented insights into crustacean life history.

As a testament to the power of integrating molecular tools and aquaculture innovation, *P. ornatus* research is paving the way for advancements in both science and sustainable seafood production.

The Benefits and Pitfalls of Ozone Use in Marine Hatchery Systems

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Abstract:

Aquaculture production has grown exponentially over the past 36 years, increasing from 10 million tonnes in 1987 to over 131 million tonnes in 2023. This growth is predominantly driven by commodity aquaculture species with relatively simple lifecycles. The top ten aquaculture species include carp, brown and red seaweed, marine shrimp/prawns, oysters, tilapia, catfish, clams/cockles, salmon/trout, and other freshwater fishes.

Conversely, high-value fisheries have experienced significant declines, driven by overfishing, insufficient regulatory protections, environmental changes, and anthropogenic impacts. While aquaculture holds immense potential for high-value species, their production is often constrained by the complex biological requirements of their larval and juvenile stages. Meeting these requirements is critical for successful culture practices and the commercialization of new species.

Key parameters for successful aquaculture include temperature, salinity, pH, dissolved oxygen, ammonia/nitrite levels, water clarity, and waste removal. However, ozone treatment has emerged as a pivotal factor influencing and being influenced by many of these parameters. In recent years, ozone has been instrumental in enabling the culture of challenging marine larvae. Since its application in the culture of spiny lobsters in 2006, ozone has remained a cornerstone in hatchery technology and disease suppression.

This presentation will explore the foundational applications of ozone in marine systems, drawing on nearly two decades of experience. It will highlight the benefits of ozone in enhancing larval survival and system health, while also addressing potential pitfalls to ensure its sustainable and effective use.

The science behind artificial intelligence powered European Lobster production.

Carly Daniels[1], Asbjørn Drengstig[1]

[1]*Norwegian Lobster Farm, Stavanger, Norway*

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Abstract

The Norwegian Lobster Farm (NLF) is a pioneering company, that created and runs the world's first land-based lobster farm, to produces a novel product, the plate sized BabyBlue^{TM} lobster for a high-end market. Gathering data on production and lobsters is essential to improve knowledge and understanding, and NLF have decades of expertise which have fed into current operations. Most recently research has focussed on helping to inform the sophisticated roboticized technologies, by providing links to the background biological information relating to the facility specific growth and survival rates of lobsters. Research considerations include, growth rates, moulting frequencies, survival, feed availability and welfare.

Conserving the European Black Lobster (Homarus gammarus) through Breeding, Research, and Community Engagement at the North Sea Oceanarium, Denmark

M. Riis

The North Sea Oceanarium, Willemoesvej 2 DK-9850 Hirtshals, Denmark.

Overfishing and inadequate protection have endangered the European black lobster population (Homarus gammarus) in the coastal stone reefs off Hirtshals, Denmark. The North Sea Oceanarium, an EAZA and DAZA-accredited zoological facility that attracts approximately 195,000 visitors annually, is dedicated to advancing research and conservation efforts to protect this vital species.

At the Oceanarium, we are actively engaged in breeding and releasing lobsters back into the wild, enhancing our understanding of the species, educating the public, and involving researchers and students in our conservation initiatives. Our project aims to expand knowledge about lobsters, provide educational outreach through programs for visitors and school children, and support the protection of the natural black lobster population. Ultimately, the project seeks to promote sustainable lobster fishing practices.

In our specially designed facilities, fertilized egg-bearing female lobsters are brought in from the wild to hatch their eggs. The larvae are carefully nurtured through their early life stages until they reach a size that significantly improves their chances of survival in the wild. Once mature, the lobsters are released onto stone reefs outside Hirtshals in the Skagerrak.

Numerous efforts have been made to assess the success of catch-release programs and their impact on population dynamics. As part of this project, we will monitor the released lobsters over time to understand their performance and settlement in the wild. In collaboration with the Port of Hirtshals, we have identified a 150-meter section of the harbor outer pier as a suitable habitat for juvenile European lobsters and a convenient site for monitoring their progress. Here, we will conduct dives, install cameras, and deploy 3D-printed concrete structures to track the released lobsters' survival and behaviour.

This presentation will provide an overview of the Oceanarium's breeding and conservation efforts, including the facility setup and practical methods employed. I will also discuss the various release techniques used in the project.

Project Summary to Date:

- Survival rates within the breeding facility have increased significantly.
- Over 20,000 lobsters have been released onto stone reefs off Hirtshals since 2020.
- The facility has been used by researchers and students for studies and development.
- The project has contributed to new legislation that protects lobsters during their breeding season in the Skagerrak.

Acknowledgements: The project is supported by DTU Aqua, the Port of Hirtshals, Aalborg University (AAU), the local fisheries association, local restaurants, and tourism organizations.

European Lobster farm scale up powered by artificial intelligence.

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Abstract

The Norwegian Lobster Farm (NLF) is a pioneering company, that created and runs the world's first land-based lobster farm, to produces a novel product, the plate sized BabyBlue^{TM} lobster for a high-end market. Having started in Kvitsøy in 1999 and now producing from their facility in Finnøy in Rogaland, Norway, the next step for NLF is expanding their operations into a sustainability driven facility. A facility which is run by AI that uses sophisticated roboticized technologies in both hatchery and on-growing. The use of advanced technologies such as robotics, computer vision and AI allows NLF to produce a high quality, sustainable lobster in a cost-effective way. Learning from the company's aquaculture research (automation, feed development, breeding, temperature control and animal welfare) over the decades, the new facility will take production to the next level, allowing the production of 30 tonnes per annum. The new facility will move away from traditional heating methods (used in RAS) and the facility will use a fascinating and innovative approach to improve the sustainability, reduce cost and lower environmental impact, by promoting a circular economy. This will be done by utilising the low-grade waste heat from the data centre industry. On top of this NLF strives to help support the wild lobster stocks through releasing approximately 10% of their hatched lobster juveniles back into the wild, to support the local threatened stocks.

Effect of *Artemia* prey size, type of prey and V-UV irradiation on survival and growth performance of European lobster larvae

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Abstract:

Gradual declines in European lobster fisheries have supported restocking initiatives and release of juveniles from aquaculture. Inconsistent but low survival rates to post-larvae are typically reported in aquaculture with cannibalism, nutrition and water quality being key elements (Hinchliffe et al., 2022; Goncalves et al., 2022a; Lund 2025). If an optimal feed exists is unknown but pelagic lobster larvae (stage I-III) are opportunistic feeders and prey on a range of potential feed sources size including zooplankton, conspecifics and even formulated feeds of various sizes. Formulated feeds and frozen - thawed feeds may negatively impact water quality (Goncalves et al., 2023, authors personal observations) and typically live feeds are preferred. Alive brine shrimp nauplii (*Artemia*) is a common feed due to ease of use, although alive adult *Artemia* in larval studies on American lobster has proven to be superior (Conklin 1995).

In this study we report a series of tests on effects of prey type, size of *Artemia* and use of Vacuum UV (V-UV) water irradiation on survival and performance of lobster larvae to post-larvae. A first test evaluated alive *Artemia* adults (~4.7-7.2 mm); newly hatched alive *Artemia* nauplii (~0.3 mm); alive rotifers *Brachionus plicatilis* (< 60 μm) or a mixture of the 3 alive feeds in communal rearing tanks while a similar effect of feeding *Artemia* nauplii or *Artemia* adults was tested in individual up-flow rearing units. In a subsequent communal experiment the effect of frozen *Artemia* adults with or without V-UV treatment was tested against alive *Artemia nauplii.*

Results revealed significant positive influence on post larval survival and time to reach post larvae stage by use of alive adult *Artemia* as compared with *Artemia* nauplii or rotifers. A mix of the 3 prey types did not have an additive positive effect. The combined use of alive *Artemia* and individual rearing compartments increased survival rate significantly and was significantly highest with use of adult *Artemia*. The comparison of frozen- thawed adult *Artemia* and alive *Artemia* nauplii revealed that the size of prey did not increase growth or survival to post larvae, but that water V-UV irradiation had significantly positive effects on survival including water UV transmittance (UVT); turbidity and total bacteria count. In conclusion; the use of alive adult *Artemia* or frozen-thawed adult *Artemia* in combination with V-UV improved larval survival in communal rearing systems with cannibalism still being a major factor. Future research should address explanations for the obtained observations.

Advances in the management of cannibalism in the Ornate Rock Lobster *Panulirus ornatus*

Quinn P. Fitzgibbon[1]*, Andrew J. Trotter[1], Tara R. Kelly[1], Alan D. Henderson[2], Dean R. Giosio[2], Jennifer Blair[3], Gregory G. Smith[1]

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Abstract:

The development of larval rearing techniques has enabled the commercial farming of the ornate rock lobster. However, low survival rates during juvenile culture remain a significant bottleneck in production. Cannibalism, the primary cause of mortality, occurs most frequently during and shortly after moulting, when lobsters are "soft-shelled" and highly vulnerable. Providing effective protection from conspecific attacks during this critical period is essential to reducing cannibalism. This study highlights recent advances in managing cannibalism by exploring its underlying mechanisms and developing innovative culture systems to mitigate this destructive behaviour. Behavioural studies on chemoreception, particularly olfaction, reveal that *P. ornatus* juveniles can distinguish between moulting and non-moulting conspecifics. Their responses vary based on their own moult stage and their relationship to the moulting individual. Notably, lobster activity changes up to one hour before a cannibalism event, indicating that this behaviour is premeditated and likely driven by chemical cues released by the moulting lobster. Additional research has identified specific chemical cues associated with moulting, which could potentially be used to disrupt this behaviour in culture settings. Efforts to improve culture systems have explored both communal and individual approaches. In communal systems, stocking density significantly impacts juvenile survival, while factors such as animal size and the availability of hiding structures have limited influence. This study also presents a novel tank design that separates vulnerable pre-moult lobsters from potential cannibalistic conspecifics by leveraging behaviourally driven segregation based on feed attraction.

Variation in Reproductive Traits of the Mud Crab (*Scylla olivacea*) Across the Indo-Pacific: Implications for Aquaculture and Sustainable Fisheries Management

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Abstract

The commercially valuable mud crab (*Scylla olivacea*) faces increasing pressure from anthropogenic stressors in the Indo-Pacific region. This study investigates potential regional differences in key reproductive traits of *S. olivacea* populations from the Indian and Pacific Oceans to inform sustainable management strategies. Crabs were collected monthly from five sites across both oceans (April 2022 - May 2023) and analyzed for sex ratio, size at first maturity, fecundity, and gonadosomatic index (GSI). Crabs from the Indian Ocean (Ranong province) exhibited smaller body size and lower values for most reproductive parameters compared to the Pacific Ocean (Pattani province). Notably, fecundity was significantly lower in Ranong (1.03×10^6 eggs) compared to Pattani (1.49×10^6 eggs). Positive relationships were found between body size metrics and ovary weight, and mature females were present year-round at both locations. Peak abundance occurred in November, followed by a decline in July. GSI levels displayed seasonal variation, with peaks in April and June for both regions. High GSI levels were recorded in April and June for Ranong province (3.05 ± 1.97 to 10.97 ± 1.96) and February and June for Pattani province (3.19 ± 1.72 to 10.52 ± 1.71). The estimated sizes at maturity (M_{50}) for female/male of *S. olivacea* varied across locations with smaller sizes observed from the Indian Ocean viz., 78.0/83.1 mm, 64.0/79.2 mm and 81.9/80.6 mm in the provinces of Ranong, Satun and Trang, respectively and 92.3/93.2 mm and 96.9/96.8 mm in Pattani and Suratthani, respectively. The sex ratio also indicated variations across region, with male:female ratios of 1:0.92, 1:0.78, 1:0.77 and 1:1 in the provinces of Pattani, Ranong, Satun and Trang. These findings suggest that the oceanic region significantly influences the reproductive characteristics of *S. olivacea*. This study highlights the importance of localized management strategies that consider regional variations in reproductive ecology to ensure the sustainable use of mud crab resources either for fisheries and aquaculture purposes in the Indo-Pacific.

Microbial flocculation : Exploring the avenue in green and smart aquafarming

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Abstract:

The intensification in aquaculture is highly required to resort to high production from a limited space to avoid overexploitation of natural resources like land and water. Such technologies which have limited resource usage and ecofriendly nature have huge potential to revolutionize the aquaculture. Biofloc technology (BFT) is one of such technologies which resorts on minimal water exchange and supports high density fish farming which is based on the microbial flocculation. For sustainable production and productivity, the technology developed should be eco-friendly catering to the green technology concept. The microbial flocculation based fish farming ensures efficient nutrient utilization, biosecurity and economic sustainability to the aqua ventures. The basic principle behind the microbial flocculation is that the waste generated in the system will be assimilated by heterotrophic microbial floc in-situ, which in turn will reduce the nitrogenous metabolites generated in the system. The nitrogenous metabolites are converted at an accelerated pace than the regular nitrification process. For microbial flocculation to happen in the culture unit, one must provide conducive environment for flocculation. The microbial floc is nothing but in-situ protein which has vast potential to contribute to the protein requirement of cultured organisms. The microbial contains 32-38% protein and will serve as an excellent source of nutrition to the farmed organisms and also can be produced in large quantities to be utilized in fish feed as a dietary protein ingredient. In addition, the in-situ microbial floc has proved to enhance digestive enzyme activity, nutrient utilization, stress amelioration and also promote growth and reduce feed conversion ratio. The carrying capacity of the microbial floc based in-situ culture unit can be vary between 25-40 Kg per cubic meter depending on the management measures. The microbial floc will assimilate the nitrogenous metabolites from the feed waste and faecal matter which will be utilized for further growth and flocculation, hence there is limited water exchange only which ensures biosecurity. The in-situ microbial floc based farming for tilapia was standardized by evaluating the stocking density, various carbon source, bioflocculating agents and evaluated various responses like growth, immunity, disease resistance, nutrient utilization and stress response. It was proved that microbial floc enhances immune response, disease resistance, and antioxidant status of fish under culture. The carcass quality of fish in in-situ microbial floc based system indicated that the carcass quality parameters like color, texture and sensory evaluation attributes were enhanced in fish reared in microbial floc based environment. Our studies also proved that the microbial floc based system can enhance the gonadal development in fish through the presence of bioactive compounds accumulated by the flocculating organisms. It is mentioned in many studies that biofloc contains probiotic bacteria, immunostimulants, exogenous enzymes, pigments, essential fatty acids, amino acids, vitamins and minerals which might enhance the gonadal response and gamete quality.

The BFT development need to have a suitable inoculum which contain semi moist pond soil as source of heterotrophic bacteria which can be enriched by supplying suitable ammonium and carbon source and provided with aeration will help them to flourish in the system. It has also been studied that the incorporation of a suitable bioflocculating agent including natural polymers like chitosan or cationic starch, the quality of biofloc produced will be enhanced in the culture system which in turn consumed by the fish will act as nutraceuticals for them. Our study also proved that biofloc can be produced ex-situ also by using a suitable bioreactor. The process optimization studies indicated that the quality of biofloc in terms of crude protein, crude lipid and floc volume can be enhanced by providing parameters such as extended sludge retention time, intermittent aeration and usage of bioflocculating agent along with glucose or jaggery as carbon source. The biofloc produced from the reactor is in semi moist form which need to be dried in controlled conditions and can be powdered and stored for 90 days in air tight condition. Our research also proved that the biofloc powder produced in the bioreactor can be utilized for preparing inoculum with a small quantity of 15 mg for 200 L inoculum along with 200 gm fermented jaggery and will be useful for the farmers to develop quality biofloc forming bacterial consortia in an easy manner. There was a considerable reduction in feed conversion ratio (FCR) at 0.84: 1 which indicate the profitability of adopting BFT in the culture system. The alternate day starvation and feeding by farmers towards the end of culture period was also found to be cost effective. The bioactive compounds and their quantification and the correlation with bio-growth parameters of fish reared in BFT system will give more impetus on the concept of "waste to wealth". It can also lead to another tagline in research "health from waste" through efficient utilization of bioactive compounds present in the fish rearing unit. The future research thrust is mainly focused on customized inoculum for different agroclimatic conditions, species specific biofloc product development, microbial management through optimized products in reactor. The extraction and quantification of possible bioactive compounds through controlled production of biofloc in ex-situ mode in a biofloc reactor can give many products valuable for various industries. The future thrust has to be on development of technology which will add value to the farmed fish through modified environment using microbial management which in turn will be beneficial for the human nutrition in various ways. The development of value added fish directly from farm will be a much necessary process, when future fish production is concerned.

Trade-off between fisheries utilization and environmental protection in lakes of China

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Abstract

China is the largest freshwater aquaculture producer in the world, and almost all freshwater bodies including ponds, lakes and reservoirs are used for aquaculture. Lakes, amounting to 34% of the total freshwater surface area in China, are important resources both for fisheries and for other uses. Many species are stocked into lakes to increase production. The most common species stocked are the major Chinese carps, i.e. silver carp, bighead carp, grass carp and black carp. In recent years, a trade-off between fisheries utilization and environmental protection has been applied in some lakes. High valued species such as mandarin fish, mitten crab, yellow catfish and culters are stocked into lakes. However, the stocking of mandarin fish and mitten crab perhaps are the most successful because the two species received systematic research for stock enhancement. The basic idea of this trade-off is to decrease the effect of intensive culture on lake environment while keeping economic benefits of fish farmers with lower production but higher value of stocked species. In this paper, the culture-based fisheries in lakes are generally introduced, with special reference to mandarin fish and mitten crab stocking in lakes in China. The stocking rate of mandarin fish is determined by food consumption, which is mainly related to water temperature and fish size, and prey fish productivity which is related to production/biomass ratio. The bioenergetics model of mandarin fish is established to predict the growth and consumption in stocked lakes. Impact of stocked mandarin fish on wild mandarin fish populations is assessed. The stocking model of mitten crab in lakes is also established based on macrophyte, benthos and secchi transparency.

Environmental effect on oyster growth in the Sado Estuary (Portugal)

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Abstract

Oyster aquaculture farming offers a viable and sustainable method to meet the growing demand in the bivalve market. With increasing oyster demand in many countries, determining optimal growing conditions and ensuring high survival rates during cultivation are crucial for enhancing system productivity. The Sado estuary in Portugal provides natural conditions conducive to oyster production. This study aims to determine the effect of environmental conditions on the growth rate of triploid Crassostrea gigas oysters in the Sado estuary using floating cylindrical baskets in earth ponds. Two sets of baskets were prepared, one with 100 oysters per basket (initial average mass 3-7 g) and another with 40 oysters per basket (initial average mass 19-30 g). The cultivation employed floating cylindrical basket technology, operating with a rotation regime according to tides in an extensive production mode. Data was collected over two consecutive years (June to December) to assess environmental conditions through water quality monitoring. Monthly biometric parameters of 25 randomly selected living oysters were analyzed, and mortality rates were recorded during sampling campaigns. Growth rates for individual baskets were calculated using the biomass of living oysters (n=25). The highest growth rates were observed during the warm period from June to October. Oysters with an initial mass of 3-7g exhibited a growth rate of 0.39±0.02 g/oyster.day, while those with an initial mass of 19-30g showed a growth rate of 0.49±0.03 g/oyster.day. These growth rates in the Sado estuary demonstrate the exceptional conditions for oyster farming.

The secondary sexual characteristics of female *Procambarus clarkii*: Application in the accurate identification and selection of mature female crayfish

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Abstract:

The selection of mature parents is an important step in the intensive breeding of *Procambarus clarkii* seeds, and the rapid identification of mature parents is key to the selection process. In this study, the secondary sexual characteristics of female *P. clarkii* and their variation patterns were explored through regular sampling in ponds, and a rapid identification method for mature females is proposed. The results showed that the weight, cephalothorax length, annulus ventralis length, body width, white patch coverage (WC) on the uropod, and ratio of uropod content weight to weight (WW) of female *P. clarkii* changed significantly during ovarian development. The random forest model revealed that white patches on the uropod were secondary sexual characteristics of female *P. clarkii*. The ovarian maturity status of female *P. clarkii* was identified by the variation pattern of white patches on the uropod (distribution shape, coverage, and density of white patches), particularly white patch coverage. White patches waxed and waned during ovarian development and oviposition. Specifically, white patches were absent from the uropod of female *P. clarkii* at ovarian stages 1 to 3; visible on the uropod at ovarian stage 4 (WC < 30%); WC 30–45% occurred at ovarian stage 5; WC > 45% occurred at ovarian stage 6; and white patches disappeared from the uropod of female *P. clarkii* at ovarian stage 7. The accuracy of identifying mature female *P. clarkii* (ovarian stage 6) based on the variation pattern of white patches was 86.36%. This study indicates that the observation of white patch changes on the uropod could be an effective method for the rapid identification of mature female *P. clarkii*, providing valuable insights for the artificial intensive breeding of *P. clarkii*.

Shape your body: early-life environment shapes claw bilateral asymmetry in the European lobster (*Homarus gammarus*)

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Abstract

Developmental plasticity allows organisms to modify traits such as behaviour, physiology, and morphology in response to varying ecological conditions. This ability is crucial for survival and adaptation, as it enables organisms to cope with environmental challenges throughout their lives. Understanding the mechanisms underlying developmental plasticity, particularly how environmental and ontogenetic factors shape functional traits, is fundamental for both evolutionary biology and conservation efforts. In this study we investigated the effects of early-life environmental conditions on the development of claw asymmetry in juvenile European lobsters (*Homarus gammarus*, N=244), a functional trait essential for survival and ecological success. Juveniles were randomly divided between four different rearing conditions characterized by the presence or absence of physical enrichments (e.g., substrate and shelters), which were introduced at different developmental stages in separated groups to assess the timing and nature of their effect. Results revealed that exposure to substrate consistently promoted claw asymmetry, regardless of the timing of its introduction, while the 6th developmental stage emerged as the critical period for claw differentiation. By identifying the environmental factors that influence developmental outcomes in lobsters, and the timing of these effects, this study improves our understanding of developmental plasticity and offers valuable insights for optimizing conservation aquaculture and reintroduction strategies.

Does genetic bottlenecking undermine European lobster hatchery stocking?

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Abstract:

For many harvested taxa, aquaculture-based restoration and stock enhancement are under-studied and often overlooked tools in the creation and maintenance of sustainably productive fisheries. In species for which culture techniques are already viable, this arises primarily from a lack of suitable methods to discriminate released individuals from wild counterparts, and a history of poor genetic management that has led hatchery stocking programs to either lack formal impact assessment, or introduce damaging side-effects for target stocks in nature. Nevertheless, stocking ventures that can rapidly overcome a serious recruitment bottleneck in early lifestages while preserving genetic diversity retain significant potential for use in improving wild fisheries. As a slow-growing, high-value coastal species with high site fidelity, whose egg-bearing females are routinely captured by fishers, European lobster (*Homarus gammarus*) is uniquely well-suited to hatchery intervention, but stocking ventures are held back by information gaps relating to appropriate genetic management and the fate of released individuals. From communal culture batches initiated with equal sibling cohorts of pelagic larvae, we utilise a highly variable SNP genotyping tool to assess the parentage of offspring surviving to the post-larval juvenile phase typical of benthic restocking releases. We quantify biases in survival among sibling cohorts, and assess maternal, ecological and industrial factors for their association with variability in offspring fitness and signatures of genetic bottlenecking. We also use this same genotyping tool to appraise relatedness among fished lobsters in areas with and without stocking releases, to assess whether current hatchery ventures are causing inbreeding depression and associated reductions in long-term adaptive fitness, or whether aquaculture enhancement can be expanded without significant risk to the genetic diversity of UK lobsters and the sustainability of their fisheries. We lastly assess the viability of our genotyping tool to identify hatchery individuals among admixed stocks, and appraise whether it provides the feedback to holistically assess the value of juvenile releases, which could present a paradigm shift in the use of hatchery stocking in sustainable lobster fisheries management.

Into the Wild: A New Approach to the Aquaculture Production of Brown Trout (Salmo trutta L.) to Promote Restocking Success

[Note: Oral Communication]

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Abstract

The brown trout (Salmo trutta L.) is one of the most iconic native species from European river ecosystems, being highly sought after by recreational fishing activities (e.g., fly fishing). This species has a significant potential to attract anglers and related investment to the main fishing grounds, which are usually located in poorly developed areas and away from main city centers. Due to its environmental and socioeconomic value, this species is often targeted by actions to enhance the abundance and condition of trout populations, such as the restocking of wild populations with fish from aquaculture facilities. However, most fish come from fish farms using traditional production methods such as high densities in the tanks, use of commercial food and standardized feeding methods, lack of environmental stimulus, and domestication of breeding stocks, which usually results in poor fitness and very low survival rates after release. This consequently leads to reduced success of these management actions. To contribute to solving these problems and enhancing the success of restocking actions for the recovery and sustainable enhancement of wild trout populations, we propose a novel approach to the production of this species, by testing and implementing a new protocol that aims to produce wild-reared trout. These fish come from wild breeders and are produced with the least human contact in conditions that mimic their natural habitat and contribute to their increased well-being and fitness. Taking advantage of a recently remodeled and re-equipped aquaculture facility, located in Central Portugal (Posto Aquícola de Campelo, Figueiró dos Vinhos), we are rearing trout in low densities (10–20 trout/m3), like the ones observed in natural habitats, using live food (larvae and insects), and subjected to environmental stimuli such as refuges, and water and flow variability, equivalent to those observed in local streams. Accompanied by a set of scientifically-oriented studies aiming to validate the contribution of this wild-rearing procedure to promote differences in growth, survival, refuge and predatory behaviour, muscle proximal composition and redox potential, among other biological and ecological parameters of these trout, this approach will contribute to optimize the success of future restocking actions, promoting the sustainable enhancement of wild trout populations, and, thus, increasing the interest of restocked fishing grounds for angling activities and associated incomes.

Bridging Conservation and Fisheries: Restorative Aquaculture in Tasmania

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Abstract

Restorative aquaculture has long been employed to address challenges of biodiversity loss and sustainable fisheries. At the University of Tasmania's Institute for Marine and Antarctic Studies (IMAS), we have recently commenced a diverse range of restorative aquaculture projects that highlight the increasing need for this approach. Comprehensive ex situ breeding programs have been established for two critically endangered marine species; the red handfish (*Thymichthys politus*) and the Maugean skate (*Zearaja maugeana*). These initiatives are essential for the persistence of both species, which are now known from single locations in Tasmania and face alarming population declines due to habitat degradation and other anthropogenic pressures.

Likewise, we have recently commenced fisheries enhancement projects tackle key issues such as genetic diversity and bolster recruitment. Efforts to restore sand flathead (*Platycephalus bassensis*) populations in southern Tasmania involve introducing genetically robust individuals from northern populations, countering the effects of size-selective fishing that has reduced growth potential in local stocks. Similarly, research on southern rock lobsters (*Jasus edwardsii*) focuses on refining puerulus collection, transportation, and on-growing techniques to enhance wild populations sustainably while aligning with industry needs.

Habitat restoration initiatives provide critical support for ecosystems and the species and resources they sustain. Restoration of giant kelp forests (*Macrocystis pyrifera*) addresses the near-total collapse of this critical habitat along Tasmania's east coast due to ocean warming and overgrazing by sea urchins. IMAS's project includes replanting aquaculture produced giant kelp, coupled removal of invasive sea urchins and competing seaweeds, and lobster reintroductions, creating a multi-faceted strategy for ecosystem recovery. Additionally, seagrass (*Zostera and Heterozostera*) restoration trials employ novel aquaculture techniques, including seed propagation, to rehabilitate these essential habitats, which serve as nurseries for a profuse assemblage of species. Together, these initiatives highlight the potential of restorative aquaculture to promote ecological resilience, socio-economic benefits, and sustainable marine resource management.

Recent Models of the Hydroelastic Behaviour of Floating Flexible Net Cages for Offshore Aquaculture

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Abstract

Offshore aquaculture is increasingly vital to compensate for shrinking wild fish catches and the demands of a rising global population. Therefore, Researchers are developing a range of floating, flexible net-type fish cage designs suitable for use in open, wave-exposed waters for the dynamic analysis which has an important influence on the cage system available for fish farming and wave forces.

Flexible nets are cost-efficient, environmentally friendly, and do not damage the marine ecosystem. Elastic floaters under lateral pressure coupled with fish cages play a vital role in aquaculture systems, particularly their hydro-elastic response, which significantly affects the dynamic loads on the cage's joints, mooring lines, and netting. Also, they offer several benefits: structural stability, economic advantages, and the potential for diverse functionalities in harsh marine environments with waves and currents. From an engineering perspective, the key hydroelastic analysis involves examining the vertical motions and accelerations of the elastic floater on the effect of lateral pressure plays an important role in the aquaculture system to study its bucking limit in harsh wave conditions. Hence, an important aspect of modeling offshore aquaculture fish cages is understanding the effects of lateral pressure on the elastic circular floater through analytical study.

Here, the abstract of the presentation deals with the theoretical mode developments on the moored floating flexible net cages and hydroelastic response of elastic floaters under lateral pressure. The mathematical formulations and solution techniques along with wave-induced forces, motion response, and mooring forces on the floating flexible cylindrical fish cages are presented. The latest contribution to the present is the formulation of an elastic floater under lateral pressure in the Cartesian coordinate and cylindrical coordinate system under the action of incident waves over finite water depth, whilst, the elastic circular floater is modeled as a curved beam equation represented by the Euler–Bernoulli beam theory with axial stiffness. The theoretical solution is determined by applying matched asymptotic expansion and the impact of lateral pressure on the hydroelastic response in terms of vertical acceleration and displacements are analyzed. In addition, the analytical results are compared with boundary element analysis (BEM) model simulations, and the model results demonstrate good agreement with those of the BEM. This analysis and formulation will provide valuable insights for the further development of large floating fish farms in offshore aquaculture under environmental conditions.

Healthy Fish for Healthy People: Global Veterinary Efforts to Support Responsible Growth of Aquaculture”

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Abstract

As world aquaculture is steadily growing and overtaking terrestrial protein production, it is becoming clear that responsible and sustainable use of aquatic resources is a must. Global expansion of aquaculture is prone to catastrophic crashes due to emerging and re-emerging diseases. Overuse of antibiotics with and without veterinary supervision poses a serious problem to human health due to emergence of multi-drug resistances. All of the above comes together in one health approach, in which major pillar is identified to be disease prevention, control and possible eradication through biosecurity approaches that are in accordance with International standards and National legislations, and with utilization of veterinary workforce. As plenary sepaker, Dr Palić will provide insights on how aquatic veterinarians are tackling different challenges and work toward sustainable increase of aquacultured animal protein to feed growing human population.

Revolutionizing Aquaculture Health Monitoring with AI-Powered Diagnostics

Presenter name Ihor Feoktistov

Affiliation Leven Vision B.V., The Netherlands

Abstract

The aquaculture industry is vital for meeting the global demand for seafood, yet it faces ongoing challenges in maintaining healthy aquatic environments and preventing disease outbreaks. Traditional methods for detecting microparasites and pathogens are often slow and labor-intensive, limiting timely interventions and impacting productivity and sustainability.

Leven Vision introduces an AI-powered diagnostic approach designed to enhance health monitoring in aquaculture. This presentation will explore how advanced artificial intelligence and imaging technologies can automate the detection and identification of harmful microorganisms in water and fish samples.

We will discuss the potential applications of AI diagnostics in various aquaculture settings, share insights from recent research and pilot studies, and explore opportunities for collaboration. Participants will be encouraged to engage in interactive demonstration of the technology.

PARASITES AND HEALTH CONDITION OF MARINE RESOURCES IN A FRAMEWORK OF GLOBAL CHANGE: cases of study in the Catalan coast (NW Mediterranean)

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Abstract

Marine fishery resources represent a significant percentage of the global economy, and understanding the current status and health of natural populations is crucial for their sustainable management. Parasites are key organisms because they can regulate host population dynamics and influence community structures. They are usually in equilibrium with their hosts and are transmitted through food webs to complete their life cycles. However, fluctuation in environmental conditions can directly affect the parasitic load which could become dangerous for the hosts and even be transmitted to humans causing zoonosis. Together with a researcher team from Institute of Marine Sciences (ICM-CSIC) in Spain, we are combining different expertise areas (parasitology, histopathology, ecotoxicology, marine litter assessment, population dynamics and fishery science) to evaluate the current status and health of three species commercially exploited in the north-western Mediterranean fisheries: the European hake *Merluccius merluccius*, the purple dye murex *Bolinus brandaris* and the deep-water rose shrimp *Parapenaeus longirostris*. Study area includes different fishing ports with different levels of anthropogenic impact, covering from north to south of the Catalan coast. Preliminary results indicated that macroparasites and biomarkers in *M. merluccius* are homogeneous along the Catalan coast despite founding higher plastic pollution in heavily urbanized areas, i.e. Barcelona. Moreover, hake presented a good condition and the *Anisakis* spp. (zoonotic) prevalence was very low (4%). Regarding *B. brandaris* from the Ebre Delta which populations have been decreasing in recent years, three new trematode species were recorded infecting this gastropod. Despite that none were zoonotic, one of them castrates the host and affects its survival and growth. Prevalence of this parasite was relatively high (15%) and could have negative effects at population level. Knowledge on shrimp diseases is very scarce for *P. longirostris*, a species favoured by the increase in temperature and salinity. A

preliminary study indicated the presence of cottony diseases caused by a microsporidian that affects its musculature. Although it is not zoonotic or dangerous for consumers, it renders the shrimp unmarketable. Ciliates were present in their gills and, despite being harmless, highly anthropic areas such as Barcelona exhibited a higher prevalence and abundance indicating their potential as a bioindicator. These study cases demonstrate the importance of investigating parasites and pathologies affecting the marine resources to identify potential damage on host, populations and local economy.

Effects of microplastics on blue mussel (*Mytilus edulis*)

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Abstract

About 460 million tons of plastics were produced in 2024 and the production could reach more than one billion tons by 2050. In the environment, plastics can be biodegraded or degraded by physical processes, resulting in smaller and smaller pieces, *i.e.* microplastics. For example, they are susceptible to UV radiation, changing their surface area and their reactivity, and leading to the releases of potentially toxic compounds into the water or the sorption of environmental organic pollutants, such as Polycyclic Aromatic Hydrocarbons (PAH). The microplastic ubiquity has been demonstrated by scientists, particularly in marine ecosystems. All levels of the trophic chain are exposed to these particles and can be affected, especially filter-feeders, such as mussels. Currently, new materials, namely biobased and biodegradable plastics, are developed to replace petrochemical plastics.

In this context, the aim of this presentation is to shed a bit of light on the effect of micro-fragments of polylactic acid, a biosourced and biodegradable plastic, on the blue mussel (*Mytilus edulis*). The effects of polyethylene microbeads on the same species will be also presented, taking into account two potential influencing factors: aging and PAH sorption.

Two separate laboratory exposures were conducted. On one hand, mussels were exposed to two doses of PLA fragments at environmental concentrations, 10 and 100 µg/L. On the other hand, other mussels were exposed to polyethylene microbeads at 10 µg/L. Some of them were irradiated for 1000 h in an accelerated aging chamber or not, and some of them were added in a solution of 4 PAH to mimic a sorption or not. After an 8-day exposure in 20-L tanks filled with artificial seawater, a battery of biomarkers was measured in dissected organs to assess neurotoxicity, immunotoxicity and oxidative stress. Lipidomic analyses were performed using flow injection analysis coupled to high resolution mass spectrometry on lipid extracts to assess potential impairments.

The combination of artificial aging and PAH sorption factors for microplastic exposure showed effects on the mussels with evidence of oxidative stress and neurotoxicity that were organ-dependent. The mantle, usually not analyzed in ecotoxicological studies, seemed to be an interesting organ to monitor the biochemical effects of microplastics. No marked influence of ageing or PAH sorption was highlighted by lipidomics, but glycerophospholipids, important structural lipids of biological membranes, seemed to be the most perturbed lipid category in individuals exposed to PLA microplastics. Biochemical and lipidomic approaches are complementary tools in the environmental risk assessment.

Vertical FISH Project – Impact of *Anisakis* spp. infection levels on the European Hake (*Merluccius merluccius*) fillet quality

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Abstract

The increasing prevalence of *Anisakis* spp. in commercial fish species represents a growing concern for seafood safety and quality. This study aimed to evaluate the impact of different levels of *Anisakis* spp. infection on the muscle quality of European hake (*Merluccius merluccius*), and the influence of seasonal dynamics on fillet quality parameters. European hake samples (n=30 per season/region) were collected from two geographical regions (SI-Southeast Ireland and BB-Bay of Biscay) across four seasons. Our findings revealed winter-specific patterns with decreased lightness (L*= 45.64 ± 0.47 SI; 49.63 ± 0.52 BB), redness (a*= -0.69 ± 0.12 SI; -0.83 ± 0.16 BB), and yellowness (b*= -4.36 ± 0.10 SI; -3.82 ± 0.18 BB), alongside altered protein and lipid profiles (lipid levels: 0.60 ± 0.04% SI; 0.68 ± 0.03% BB), compared to other seasons. Winter samples exhibited increased cohesiveness and decreased hardness and chewiness, coinciding with higher protein content and lower lipid levels (0.60 ± 0.04% SI; 0.68 ± 0.03% BB). Our findings advance the understanding of seasonal parasite-host relationships and their effects on fish quality parameters, supporting the development of evidence-based quality control measures in the fishing industry. These results are especially relevant for species exhibiting significant seasonal fluctuations in *Anisakis* spp. infection levels, enabling the implementation of targeted safety protocols throughout the seafood supply chain.

Keywords: Seafood quality; Anisakids; Parasite; Seasonality; Organoleptic quality; Food safety

Development of oral vaccines for aquaculture using spore-surface-display technology

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Abstract

Oral vaccines are highly demanded by the aquaculture sector to allow mass delivery of antigens. Despite this, most commercially available vaccines are injectable, being labor-intensive, expensive, and require individual handling of fish. One possible strategy to create injection-free vaccine delivery vehicles is the use of bacterial spores, extremely resistant structures with wide biotechnological applications. Bacterial spores, particularly those of *Bacillus subtilis,* are promising delivery vehicles of different molecules through surface display technology. The extreme resistance of *B. subtilis* spores, which guarantees passage through the harsh gut environment without losing characteristics, is the basis for their oral applications. Spores' direct incorporation into animal feed, circumventing further protection processes, such as encapsulation, together with their simple production and long shelf-life without the need for refrigeration, are also attractive characteristics from the industrial point of view. Adding to this "needle-free" and "refrigeration-free" potential, *B. subtilis* spores adjuvant properties and contribution to GALT development, **increase their potential as oral delivery systems of antigens.**

In this work, we displayed at the surface of *B. subtilis* spores, antigens from different problematic aquaculture pathogens (e.g., *Vibrio* spp., *Photobacterium damselae, Edwrdsiella tarda, Aeromonas hydrophila)*. The developed Sporovaccines were first tested by immersion in zebrafish larvae (*Danio rerio*). When previously treated with the antigens- carrying spores, zebrafish survival upon a bacterial challenge with each pathogen, increased up to 90% depending on the pathogen targeted. Further, when added to commercial feed and used to orally vaccinate European seabass juveniles, Sporovaccines increased fish survival from 60 to 86%. We then evaluated the effect on the expression of immune-related genes by using an epithelial gut cell line from rainbow trout (*Oncorhynchus mykiss*) (RTgutGC cell line). Transcription effects were evaluated by real-time quantitative PCR analysis of immune-related genes (e.g., TNF-α, IL-1β, IL-8, COX-2, Hsp70, Casp3a2). Sporovaccines significantly induced the transcription of the pro-inflammatory cytokine IL-1β and pro-inflammatory chemokine IL-8, whereas control spores (not carrying antigens) decreased the expression of Casp3a2, a caspase involved in the apoptotic death cascade. Our results indicate that *B. subtilis* spores can effectively be used as carriers for massive delivery of antigens in fish.

The feasibility of agricultural wastes on optimizing water quality and natural bait by regulating microbial loop

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Abstract

Effective screening feed substitutes for improving water quality in aquaculture systems has become a trending research topic. Organic detritus addition markedly improved the water quality, especially soluble reactive phosphorus and ammonium. Sugar cane bagasse induced core microbes to mediate nutrients transformation and recycling, which facilitated the primary productivity based on their positive relationships. This further reduced the available nutrients in the water and built a mutually beneficial microbial loop. In addition, sugar cane bagasse addition increased the abundance of genes involved in amino acids biosynthesis pathways, photosynthesis, and carbon fixation. These results led to energy transfer to higher trophic levels. The addition of corn cob powder had a better effect than sugar cane bagasse in terms of lower nitrogen levels and a higher fish growth rate. However, low temperatures and carbon accumulation jointly drive the anaerobic decomposition, resulting in unhealthy microbial loops. In contrast to the direct consumption of fish feed, organic detritus can induce more natural bait to provide food for fish by regulating the microbial loop. Furthermore, field simulation experiment in aquaculture ponds was conducted by adding different proportions (0%, 20%, 40% and 60%) of bagasse to fish feed for combined feeding. The addition of 60% bagasse significantly reduced the levels of various forms of nitrogen and phosphorus in the water. In the treatments without addition and with 20% bagasse added, nitrogen and phosphorus levels remained relatively high, ultimately stimulating the abundant reproduction of algae. Bacterial growth was limited due to insufficient supply of organic carbon, and the growth of fish relied more on the components of the feed. With the addition of 60% bagasse, the high organic carbon and low nitrogen and phosphorus levels could not support the growth of phytoplankton, bacteria, and zooplankton. Adding 40% bagasse achieved a balanced level of carbon, nitrogen, and phosphorus, establishing a healthy and stable microbial loop structure (including phytoplankton, bacteria, and zooplankton). Most nutrients were converted into plankton, which then became natural food for fish, ensuring complete nutrient utilization. This is beneficial for both water quality improvement and fish reproduction. Therefore, adding a moderate proportion of bagasse to the feed can maximize the effects of water quality improvement, fish reproduction, and even the quality of fish meat.

Improving Marine Finfish Seedstock Production: A US Department of Agriculture/Harbor Branch Oceanographic Institute Collaborative Project

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Abstract:

Marine finfish species are highly prized and sought after in the United States. The coastline of the United States has been estimated as 153,646 kilometers, which includes the Hawaiian Islands and Alaska. Despite the large area and expansive Exclusive Economic Zone (EEZ), the United States continues to import approximately 85% of its seafood leading to a seafood trade deficit reported in 2023 to be $20.3 billion (€18.5 billion).

In 2001, The U.S. Department of Agriculture's Agricultural Research Service (ARS) initiated a program to develop technologies for rearing marine finfish in inland low-salinity environments to help alleviate this deficit. In 2004, the program began evaluating Florida pompano, *Trachinotus carolinus,* a high-value species.

Following an interruption from 2011-2019, the Collaboration was reestablished between ARS and Harbor Branch and retooled this collaboration to focus on establishing technologies for improving Marine Finfish Seedstock Production.

The advances gained over the period 2019-2024 include all life stages that range from egg to market. Areas of research include production, economics, marketing, physiology, larviculture, disease resistance, reproduction, energy utilization, nutrient dynamics, metabolism, internal and external microbiomes, genomics, transcriptomic and larval adaptation to low salinity. Overarching goals include:

1. Developing year-round spawning strategies for captive broodstock and larviculture methods for seed production of marine finfish.
2. Developing methods for genetic improvement of warm water marine finfish for optimum production efficiency.
3. Increasing the understanding of fish physiology and enhance production efficiency through improved management strategies.

Special emphasis during this period of research has focused on establishing a marker selected breeding program with Florida pompano and Red Drum, *Sciaenops oscellatus*.

Bridging Ecosystems: Aquaculture's Role in the Spread of Marine Non-Indigenous Species

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Abstract

Non-indigenous species (NIS) represent an increasingly significant and widespread ecological challenge on a global scale. Activities associated with aquaculture play a pivotal role as critical and often underestimated vectors facilitating their introduction in marine ecosystems. Whether through intentional introductions for economic or environmental purposes, or as unintentional hitchhikers of other organisms, these species find new habitats in which they thrive. Furthermore, aquaculture systems themselves can serve as artificial substrates that not only support their establishment but also facilitate their secondary spread. Besides threatening native biodiversity, they also have negative economic impacts on the industry by affecting cultivated species and infrastructures.

The Sado estuary, located in southwest Portugal, is the second largest estuarine system in the country and is facing ecological challenges due to the rapid growth of the aquaculture industry. The occurrence of NIS was investigated by scrapping four random replicates in two artificial systems, namely one oyster aquaculture and one fish farm, in 2021. An area of 20 × 20 cm of artificial substrates available at each location was sampled to collect the fouling communities. Samples were preserved in ethanol and posteriorly identified in the laboratory to the lowest feasible taxonomic level. Species were classified as NIS, cryptogenic or native, based on a range of expert criteria. High abundances of *Molgula manhattensis* and *Microcosmus squamiger* were detected in both aquacultures, both considered as potential invasive ascidians. A higher number of NIS were identified in the oyster farm. However, the samples exhibited less variability among them. In the oyster aquaculture facility, workers have reported production losses and other economic impacts caused by the presence of these species.

Efforts to manage and control the spread of NIS in aquaculture facilities are fundamental for maintaining both the economic viability of the industry and the ecological integrity of the Sado estuary. Researchers and aquaculture operators in the region need to explore several strategies to prevent the introduction and spread of these species, including improved biosecurity measures and especially the implementation of regular monitoring programs. However, the challenges remain considerable, requiring continued collaboration between scientists, policymakers, and industry stakeholders to safeguard the long-term health of the estuary's ecosystems and the sustainability of its aquaculture operations. Due to the difficulty, and in some cases the impossibility, of controlling NIS once they are established in new marine ecosystems, forecasting, and avoiding their spread remains a key challenge for the scientific community in this field of research.

Introducing CADMUS to HACCP

Profesor Honorario Roy D. Palmer GradCertMgt

Seafood Consumers Association; Universidad Tecnológica del Mar de Tamaulipas Bicentenario

Abstract

The World Trade Organisation (WTO) describes illicit trade in food and food fraud as "the buying and selling of products to be eaten, drunk, or grown that are not what they are claimed to be; that fail to comply with health and other regulations (e.g., on quality); and that are smuggled or otherwise produced or traded outside the legitimate market framework." ("Illicit Trade in Food and Food Fraud")

For far too long industry and governments have allowed bad practices to evolve and escalate and by raising them it should make everyone think about how everyone can play a part in continuous improvement and making seafood not only the best protein but the best industry creating wonderful experiences for seafood consumers.

By exposing these fraudulent matters, we can all be aware and promote improved processes and push each other to improve, creating the best outcomes for the seafood consumer along with everyone in the seafood supply chain.

Sadly, seafood fraud is simply everywhere (Lawrence et al.). Such fraud is as old as the trade itself, mind you WTO state "There has never been a country nor an agri-food system which has been free of food fraud".

In today's world it is a flourishing, systemic, intentional activity that threatens public health/food safety, the environment, seafood integrity and the conservation of endangered species. It also severely impacts the economy of communities dependent on seafood, seafood authenticity and the integrity of the global seafood supply chain. Yet we hardly discuss it. We do not train specifically to address it. Enter CADMUS – coincidentally a name with a rich background in Greek mythology symbolising knowledge, civilisation and the spread of literacy. Very relevant in the aim of educating and put an end to seafood fraud!

In just the same way as we know Hazzard Analysis Critical Control Points as HACCP then we should consider CADMUS as an addition to the first step of HACCP when a hazard analysis is conducted. If we made the first step "Determine if any biological, chemical, or physical property, if not controlled, can cause a safety **and/or CADMUS** hazards; identify the preventive measures to control these hazards."

This would mean that these issues are top of mind for everyone in the chain. It would form a part of the training and would be entrenched into making everyone feel safe and build consumer trust.

Fish welfare: ensure well-being or reduce suffering?

Billo Heinzpeter Studer

Iindependent author at think.fish, Italy

Abstract

Twenty years ago, fish welfare was still a foreign concept because it was assumed that fishes do not feel pain. Then, pioneers in research and the **aquaculture** industry began to improve the animals' living conditions. Eventually, certification schemes and retailers began to adopt the idea. The welfare of farmed fishes has become almost a matter of course. However, the result is rather mediocre. All efforts so far have at best reduced the suffering of some farmed aquatic animals, but have not led to their well-being.

It is not due to a lack of will on the part of farmers who want to do better. It's simply because most of the species farmed today are not capable of experiencing welfare in captivity, even under improved conditions. The welfare potential of the 87 species that have so far been assessed in the fair-fish database is very low, with a few exceptions.

One of the problems of fish farming is the large number of more than 350 species involved, most of which are not fully understood in terms of their needs and behaviour. Land animal husbandry includes 20, at most 30 species, and none of them are predators. On the other hand, many farmed fish species are carnivorous, especially species that are in demand in Western markets. The industry will have ever greater problems meeting the increasing demands for good treatment of animals with such a wide variety of species. *Would it not be wiser to focus research and development on the few species that show promising animal welfare potential, such as African catfish and Nile tilapia, and perhaps two or three other species later on.*

The diversity of supply at the counter and on the menu has always been ensured by **fisheries**. Restoring this role is another good reason to enforce sustainable fishing practices and manage fish stocks so that they can fully recover. While sustainable fishing has become popular over the last 25 years, animal welfare in fisheries was only of interest to some idealists until two international research projects were recently launched.

Talking about animal welfare in fisheries sounds like an oxymoron. Let's rather talk about the best possible reduction of suffering, which means that we look for fishing gear and methods that hold the fish captive for the shortest possible time, do the least harm possible, and allow each fish to be stunned and killed immediately or released back into the water in good condition.

In fisheries, we are confronted with a variety of fishing gear and methods, some of which are associated with long and/or enormous suffering and with little potential for reducing suffering through improvements. *Would it not be wiser to focus research and development on those fishing gears and methods that show promising potential for little suffering, such as handlines, pole-and-line, short longlines, trolling, encircling nets,* used by small-scale fisheries, which bring 60% of the world's catch to the plate and could deliver even more with less competition from industrial fisheries.

EFFECTS OF REPLACING FISH OIL AND FISHMEAL WITH MICROBIAL DIETS ON SALMON GROWTH, LIPID COMPOSITION AND GENE EXPRESSION

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The continuous growth of aquaculture places a growing demand on alternative sources for fish oil (FO) and fishmeal (FM) in aquafeeds. Certain microorganisms provide a potential sustainable replacement for FO and FM due to their content of omega-3 long-chain polyunsaturated fatty acids, which are essential for fish health. Salmon feeding trials were conducted to determine the effects of replacing FO and FM with oil and biomass from different microorganisms. The first trial replaced FO with a microbial oil (MO) derived from *Schizochytrium*. The second reduced FO and replaced FM with algal biomass (AB) derived from *Pavlova*. These diets provided a unique opportunity to determine how dietary DHA, EPA and phytosterols influence lipid metabolism and physiological pathways in salmonids. Growth was unaffected when microbial products replaced dietary fish oil and fishmeal; however, lipid profiles were altered. With MO, linoleic acid and α-linolenic acid were present in low proportions, and DHA was present in very high proportions in the cellular membrane, especially in muscle tissue. In addition to cholesterol in muscle tissue, cholestanol, campesterol, stigmasterol, dinosterol and 24-methylpavlovol were detected in salmon. With AB, DHA was present in high proportions in tissues of all dietary treatments, especially in cellular membranes. Stable isotope data indicated a direct integration of EPA and DHA and not biosynthesis from its precursor ALA. Growth performance, lipid class composition, phospholipid fatty acid composition, and compound specific stable isotope analysis all suggest that salmon grown on microbial-based diets digested and utilized nutrients well, and directly incorporated critically important fatty acids into their tissues.

Protein Alternatives from Circular Bioeconomy for Aquafeeds

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Abstract

The adoption of protein sources from the circular economy offers a promising pathway to achieving sustainable resource management and ensuring food security. Unlike traditional linear models of production and consumption, which often lead to resource depletion, environmental degradation, and food waste, the circular economy prioritizes the reuse, recycling, and regeneration of resources, thereby minimizing waste and maximizing value. This approach is especially critical for addressing the growing global demand for protein in the aquaculture feed sector.

Globally, a significant amount of biomass from the agrifood sector is wasted along the value chain, yet it can be converted into high-value proteins. This includes both marine and terrestrial by-products from food processing. Furthermore, innovative technologies such as insect farming, algae cultivation, and fermentation processes enable the transformation of organic waste into high-quality protein sources. By incorporating these methods into closed-loop systems, resource efficiency is enhanced, and waste generation is reduced.

Technological advancements are paving the way for the production of a diverse range of protein sources with high nutritional value and functional properties, facilitating the large-scale provision of safe and nutritious feedstuffs. Nevertheless, to unlock the full potential of circular protein production systems, several challenges must be addressed, including consumer acceptance, market adoption, regulatory hurdles, and environmental considerations like the energy intensity of production processes.

White grape marc extracts as potential modulators of European seabass growth, immune status and disease resistance

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Abstract

The intensification of aquaculture increases the vulnerability of farmed fish to infectious diseases. While antibiotics help manage these diseases effectively, their use raises environmental concerns and affects public perception of aquaculture. Moreover, the overuse of antibiotics promotes antimicrobial resistance (AMR) in pathogens, prompting strict regulations. In many countries, the preventive use of antibiotics is prohibited. Consequently, developing efficient and sustainable alternatives to antibiotics is an urgent need of the aquaculture sector. White grape marc extracts are rich in polyphenols, with antimicrobial and antioxidant capacity, and are an interesting alternative to replace conventional antibiotics. In this work, we assessed the potential of three white grape marc extracts (obtained with an alcohol -A, a glycol -G, and a ketone – K) as modulators of European seabass (*Dicentrarchus labrax*) growth, immune status, and disease resistance. We first evaluated the extracts' antimicrobial activity against several important aquaculture bacterial pathogens. A and G grape marc extracts inhibited the growth of *Vibrio vulnificus*, *V. harveyi*, *Tenacibaculum maritimum,* and *Photobacterium damselae* subps. *piscicida*, while K inhibited *V. harveyi* and *T. maritimum*. The three grape marc extracts were then used to prepare European seabass diets containing each extract (A, G, and K) incorporated at 450ppm of polyphenols (based on previous *in vivo* trials used to determine the ideal extract dose). Triplicated groups of European seabass juveniles were fed each diet for 42 days and compared to a control group fed a control diet (CTR) without extract supplementation. There were no differences between dietary treatments in all growth parameters assessed, namely final body weight, weight gain, and daily growth index. Feed intake and feed efficiency was similar across all dietary treatments. Protein efficiency ratio was higher in fish fed the PG diet compared to fish fed the A and K diets, but again not statistically different from the CTR diet. Also, no significant differences were found in the hepatosomatic and visceral index. Catalase activity was higher in fish fed the G diet compared to those fed the A and K diets, although no significant difference was observed when compared to the control group. Fish fed the G diet had the highest absolute values of superoxide dismutase, glutathione reductase and glutathione peroxidase activities, although not statistically different. The feeding trial was followed by a bacterial-challenge trial with V. *harveyi*, or with PBS (non-challenged fish; negative control). Challenged fish had a mortality rate between 67% to 83%, while non-challenged fish (PBS) had 100% survival. Although there were no significant differences in all dietary groups when compared to the control, fish fed G and K diets managed to resist better to the infection *with V. harveyi*, having higher survival

rates. Grape mark extracts are potential alternatives to antibiotics in aquaculture. This work was funded by the European Union´s Horizon 2020 Research and Innovation program under grant agreement No 101036768 - NeoGiANT.

Discovering the Antioxidant Potential of Halophyte Plants

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Abstract

Halophyte plants are part of the plant kingdom. They are capable to growth and reproduce in saline, cold, hot, light and high drought-prone environments. These abilities are important for enabling the plants to bioremediate the soils, removing elements such as nitrogen and phosphorous, protect estuarine environments, and be cultivated in integrated systems with aquaculture. Due to their growth in harsh environments, these plants develop the ability to deal with reactive oxygen species (ROS) through various antioxidant systems, involving antioxidant enzymes and bioactive secondary metabolites, such as phenolic compounds. Different methodologies can be applied to extract different bioactive compounds. In this study, an ultrasound-based methodology (30 minutes at 40 kHz) was used with three different solvents (ethyl acetate, methanol at 70% (v/v) and water) of varying polarities to select the best solvent for extracting antioxidant compounds, such as phenolic compounds and flavonoids. Different parts of the halophyte plants (leaves and stems) were used for this evaluation. Our results show that the leaves have a higher content of antioxidants and proteins. When comparing the different extraction solvents, water was generally the best solvent to extract proteins, where the highest concentration was detected in aqueous extract of leaves of *Inula crithmoides* (339.0±2.25 mg/g DW) and the lowest value was detected in aqueous extract from stem of *Suaeda vera* (5.31±0.70 mg/g DW). On the other hand, methanol at 70% (v/v) was the most effective solvent for antioxidants. As example, the highest value obtained in ABTS was observed in leaves of *Halimione Portulacoides* extracted with methanol 70% (v/v) (7.92±0.42 mg TE/g DW), in DPPH assay the higher value was detected in leaves of *Suaeda vera* extracted with water (v/v) (9.01±0.78 µg TE/g DW). In respect to phenolic compounds the highest value in TPC assay was obtained in leaves of *Salicornia ramosissima* extracted with ethyl acetate (8.87±0.18 mg GAE/g DW). The flavonoids were also quantified, and the higher quantity was detected in methanolic extract of leaves of *Inula crithmoides* (47.27±14.22 mg QE/g DW). In short, this research supports the potential of halophytes as sources of antioxidant compounds for applications in the food and pharmaceutical sectors.

Assessment of fatty acid metabolism in European lobster (*Homarus gammarus*) larvae and postlarvae: a pathway to optimized larval nutrition

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Abstract

Fatty acid (FA) metabolism is critical for the early development of *Homarus gammarus*, influencing growth, metamorphosis, and survival. This study investigated the lipid and FA composition of *H. gammarus* larvae and postlarvae, their capacity to incorporate radiolabeled FAs ([1-14C]-FAs) into lipid classes, and their ability to transform these substrates via elongation and desaturation processes. Larvae (stages I-III) and postlarvae (stage IV) were incubated with six [1-14C]-FAs, including free (LA, 18:2n-6; ALA, 18:3n-3; ARA, 20:4n-6; EPA, 20:5n-3, and DHA, 22:6n-3) and phosphatidylethanolamine-bound (PE-ARA) substrates.

Larval and postlarval FA profiles closely resembled those provided by the krill-based diet and those reported in *H. gammarus* eggs (Rosa et al., 2005). They exhibited high levels of EPA (19.8–21.3%) and DHA (17.3–18.8%). Notably, the DHA/EPA ratio (0.9) was considerably lower than that observed in many marine fish larvae (>1) (Izquierdo, 1996), underscoring the crucial role of EPA in lobster early development. Subtle yet statistically significant stage-specific changes were observed in the FA composition. EPA levels increased during stages I–III, while DHA levels declined. These findings suggest that while EPA is retained, DHA may suffer ß-oxidation for energy production.

Radiolabeled FA incorporation revealed that stage I larvae preferentially retained n-3 FAs, particularly EPA and ALA, while stage IV postlarvae favored C18 PUFAs (ALA and LA), potentially linked to hepatopancreas development (Mourente, 1996). ARA from PE-ARA was the least incorporated substrate, suggesting limited enzymatic capacity to de-acylate phospholipid-bound FAs, a constraint that may affect larval survival in hatcheries.

Polar lipids, particularly phosphatidylcholine (PC) and phosphatidylethanolamine (PE), the most abundant lipid classes in the body composition of *H. gammarus* early stages (Gonçalves et al., 2022), were the dominant esterification targets. Neutral lipid incorporation, predominantly into triacylglycerols (TAG), peaked in stages III, potentially reflecting energy demands in preparation

for metamorphosis (Limbourn and Nichols, 2009). Less than 16% of incorporated radioactivity was recovered as free fatty acids Transformation capacity for tested substrates (LA, ALA, and EPA) also peaked in stage III. Desaturation activity, albeit low, enabled ARA synthesis from LA and EPA synthesis from both ALA and LA, demonstrating the activity of ω5 and ω6

desaturases in lobster larvae as demonstrated for other crustacea (Kabeya et al., 2018). DHA synthesis was not so clear.

These findings highlight stage-specific lipid metabolism and requirements in *H. gammarus*, particularly the increasing EPA and decreasing DHA levels during larval development. The apparent inability to hydrolyze phospholipid-bound FAs and to synthesize DHA underscores metabolic constraints, informing strategies to optimize larval diets and improve hatchery survival.

Formulation of Sustainable Fish Feed for Aquaponics: Utilizing Poultry Droppings to Enhance Nutritional Efficiency and Environmental Sustainability

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Abstract

Aquaponics, a sustainable farming technique combining aquaculture and hydroponics, is a closed-loop system. However, it often faces challenges in efficiently and cost-effectively formulating fish feed that meets the nutritional needs of aquatic organisms as well as plants while minimizing the environmental impact. One such challenge is the dependency on traditional fish meal, which raises concerns regarding ecosystem sustainability. The use of alternative feed ingredients, such as poultry droppings, presents a promising solution. Poultry droppings are rich in essential nutrients like nitrogen, phosphorus, and potassium, making them an ideal candidate for recycling within aquaponic systems. This study aims to formulate a nutrient-dense and cost-effective superfeed combining fish meal and poultry droppings, perform proximate analysis to determine its nutritional composition and conduct a comprehensive analysis of the nutrient content in the fish feed. The feed formulation was done through careful selection and blending of ingredients, followed by processing steps such as drying, grinding, and pelletizing. Proximate analysis was conducted to determine the nutritional profile of the feed, including protein, fat, moisture, ash content, and mineral composition.

The results showed that the nutritional composition of fish feed samples varied based on ingredient quantities. Crude protein ranged from 30% to 34%, with higher protein levels in feeds containing increased quantities of fish meal and poultry droppings. Phosphorus levels varied from 0.036% to 0.212%, and potassium ranged from 0.57% to 0.83%. Higher poultry droppings increased ash content, reducing space for carbohydrate-rich ingredients like maize flour, which decreased carbohydrate levels. The study concludes that the formulated super feed, combining poultry droppings with fish meal and other nutrient sources, shows significant potential for enhancing the productivity of the plants along with the fish in aquaponics systems. Reducing dependency on traditional fish meal not only lowers feed costs but also supports environmental sustainability through the recycling of poultry waste. Future research should focus on long-term feeding trials to assess the impact of the formulated feed on fish and plant growth rates, and overall system productivity.

Vermi-Tea Production from Fish Waste in Vermicomposting Reactor for Enhanced Nutrient Recovery in Aquaponics System

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Abstract

The incorporation of vermi-tea reactor using fish waste offers a sustainable and efficient method for nutrient recovery and ammonia removal in aquaponics systems. This study explores the development and integration of a vermi-tea reactor designed with vertically stacked trays to transform fish sludge mixed with plant waste from the aquaponics system into nutrient-rich vermicompost and liquid biofertilizers, including vermiwash and vermi-tea. The reactor design was finalized using SolidWorks and fabricated with durable wooden trays with dimensions suitable for vermicomposting. Wood was chosen for its cost-effectiveness, and structural stability, and a two-layer plastic-paint coating was performed for resistance to decomposition during the composting process. The vertical design of the reactor optimizes space and facilitates the simultaneous production of solid vermicompost and liquid vermi-tea and vermi-wash while treating aquaponics waste. Key to its success is maintaining optimal conditions for *Eisenia fetida*, the earthworm species responsible for vermicomposting. An automated sensor system regulates temperature (25-30^{o}C) and humidity (50-70%), creating an environment conducive to efficient decomposition and nutrient cycling. The process yields vermicompost enriched with essential nutrients, including phosphorus (0.455%), organic carbon (21.74%), and manganese (494 ppm), outperforming traditional cow dung-based vermicompost, while maintaining comparable levels of nitrogen, potassium, iron, and magnesium.

The integration of the vermi-tea reactor into an aquaponics system demonstrates a closed-loop approach to recycling plant waste and fish sludge. This integration enhances resource use efficiency, reduces environmental impacts, and minimizes dependency on synthetic fertilizers in soilless farming, contributing to a more sustainable farming model. This innovative approach underscores the feasibility of integrating waste-utilizing techniques into aquaponics systems to address global challenges in sustainable food production and environmental conservation. Future research will focus on refining nutrient recovery processes and assessing long-term impacts on plant and fish productivity, to determine the scalability and commercial viability of this technology for broader agricultural applications.

Economic Challenges and Livelihood Resilience in the Baltic Fisheries Sector: The Impact of Feed and Aquaculture Market Shifts

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Abstract

The European fisheries sector has long been a dynamic and adaptive cornerstone of coastal livelihoods. However, environmental changes, aquaculture demands, and the evolving Common Fisheries Policy (CFP) pose significant challenges for the fishing community. This study examines the perspectives of Polish Baltic fishermen regarding the current landscape of their profession and market dynamics. Using a Likert scale questionnaire with 129 respondents from 17 coastal harbours and in-depth interviews with 28 participants. Key issues include livelihood security, government responsiveness, and adaptation strategies, revealing widespread dissatisfaction and significant disparities across regions, unit sizes, and employment statuses. The Kruskal-Wallis test further analysed these responses, exploring variations based on port location, employment status, and vessel size among respondents. Communities like Łeba and Wolin Island reported the highest dissatisfaction with CFP regulations and the lowest resilience. Large-scale fisheries (LSF) in full-time employment demonstrate greater resilience due to their ability to adapt to changes in target species and market demands but are undercut by limited quota allocations. Moreover, the market shift towards catching fish for feed to supply Scandinavian aquaculture farms, rather than for human consumption, has intensified this trend, further skewing economic benefits in favor of LSF. Meanwhile, small-scale fisheries (SSF) in part-time employment face greater financial challenges, including high operational costs and limited fishing opportunities leading to increased vulnerability and dissatisfaction. The consistently low resilience scores across all fishing groups highlight that the fisheries sector in Poland is increasingly hostile to its fishermen. With a likely unsustainable future within this sector, many fishermen are likely to abandon the profession in pursuit of better economic opportunities. Future research should assess if similar trends exist in other fishing communities globally to inform policies that balance sustainability and economic resilience.

What are the governance effects of artificial intelligence in aquaculture?

Presenter

Paul Robert VAN DER HEIJDEN

Affiliation

MatureDevelopment BV, The Netherlands

Abstract

Artificial intelligence (AI) is increasingly integrated into global industries and universities, as well as in the global aquaculture industry. As demand for sustainable and efficient food sources rise, food security and aquaculture face immense pressure to evolve. AI offers possible supportive tools to meet these challenges and (!) could put pressure on governance.

AI has already been applied in various ways, from optimising fish feeding, and monitoring water quality, to employing image recognition for fish population health. However, the integration of AI in aquaculture presents new influences and challenges. One such concern is the risk of overreliance on AI without understanding its limitations and its hallucinations, potentially leading to unintended consequences such as financial results, political/societal repercussions or increased negative environmental impacts. These factors highlight that integrated considerations need to be made to ensure that AI is used responsibly in aquaculture, balancing technological innovation with managerial human insights to support sustainable industry growth; creating leverage by AI.

Paul Robert, at Aquaculture Horizons, will report on six-month research by MatureDevelopment BV about governance aspects of AI in aquaculture and related organisations, answering the research question:

What are the governance effects of artificial intelligence in aquaculture?

Operationalising AI at scale in Aquaculture

Hans-Petter Dalen

Business Executive for AI in EMEA, IBM

Abstract

While the potential for AI in Aquaculture is significant, there are many considerations to make to operationalize use cases at scale. In this session, you will hear how IBM has successfully operationalized more than 6500 AI use cases. Through a risk and governance framework, IBM are operationalizing 200 or more AI use cases every quarter. The receipt is well known; People, Processes and Tools.

NEXUS: Streamlining Aquaculture Real Time Monitoring

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Abstract

With the growing need for continuous monitoring in aquatic environments, significant challenges arise such as limited access to data and real-time information, high acquisition and maintenance costs for instruments measuring metocean conditions, as well as the complexity of existing instrumentation systems. In aquaculture, there is a need for intelligent systems that optimize maintenance routines and provide farmers with effective management tools, especially in offshore aquaculture farms. Aquaculture activities require continuous monitoring and maintenance, which can be optimized through NEXUS – low cost, smart, secure and self-sufficient solution designed to facilitate the collection and analysis of oceanographic and environmental data with a user-friendly approach.

NEXUS consists of a monitoring network that collects *in-situ* data and transmits it via satellite, processed and accessible globally, in real time. It has applications in offshore environments, coastal areas, ports, inland waters and aquaculture farms. In addition to measuring wave physical parameters, NEXUS also integrates customizable water quality sensors (e.g. Temperature, Salinity, OD, pH, etc) tailored to different environments and objectives. These sensors can be placed both on buoys – for surface data collection – and on mooring systems, enabling vertical profiling of key parameters. The use of NEXUS serves as a risk management tool, preventing losses associated with adverse environmental conditions by tracking parameter variations over time and space.

In aquaculture, the implementation of NEXUS presents an opportunity for rapid and accessible real-time monitoring, representing a breakthrough in efficiency and process optimization. Continuous knowledge of the aquaculture environment enables more efficient routines in feeding, water renewal and cleaning. Moreover, ongoing data collection and analysis allow for a deeper understanding of parameter evolution over time and space, ensuring that action is taken only, when necessary, in response to alert signals.

Incorporating image analysis, machine learning, and automation into aquaculture research

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Abstract

The application of state-of-the-art image analysis, machine learning, and automation is advancing aquaculture research by enabling the efficient collection and analysis of large, high-quality datasets. This presentation showcases a series of case studies that demonstrate the practical application of these technologies, highlighting their ability to address species-specific challenges and improve production outcomes.

The first case study looks at the development of an in-tank larval monitoring unit for tropical rock lobster (*Panulirus ornatus*), designed to track larval populations in real time. This system combines high-speed image capture and cloud-based IoT data reporting to provide continuous, remote monitoring of larval stock levels and behaviour.

For juvenile slipper lobsters (*Thenus australiensis*), an automated biomass estimation system has been implemented, utilizing image analysis to calculate size and weight non-invasively. This reduces stress on animals while improving accuracy and efficiency in grow-out operations.

Efforts to address traceability and mislabelling in seafood exports have led to the investigation of individual identification techniques for tropical rock lobsters based on unique dorsal shell patterns. These methods enable reliable fingerprinting for supply chain tracking, ensuring product authenticity for high-value markets, as well as being a useful tool for research in enabling more granular data collection.

By combining automation, advanced image processing, and machine learning, these technologies provide aquaculture researchers and industry with powerful tools to improve data accuracy, streamline operations, and address critical challenges in production systems. This work demonstrates the transformative potential of technological integration in advancing sustainable aquaculture practices.

How Do We Quantify Shell Quality in Oyster Aquaculture?

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Abstract

Oyster aquaculture, representing 38% of global bivalve production, faces increasing demand driven by diverse consumer preferences. The Australian industry, for instance, prioritizes key quality indicators that are either directly or indirectly linked to the shell. Market-driven attributes such as uniform size, consistent colouration, and aesthetically pleasing shape, coupled with robust shell strength to withstand the rigors of grading/shucking and the compressive forces encountered during freight, exert a profound influence on production yields and ultimately dictate market outcomes. Here, we introduce innovative methods for quantifying and integrating shell quality metrics, enabling more precise breeding and husbandry strategies to optimise production and improve sales performance.

We have developed, tested, and refined methods to quantify a range of Pacific oyster shell characteristics including colour, chalkiness, hardness, compressive strength, density, and shape. We applied chromatic quantization and 3D hue modelling to characterise shell colour, capturing variations across the greyscale spectrum. Differential luminescence analysis was used to characterise chalkiness by distinguishing between chalky and foliated inner surfaces. Ultrasonic contact impedance technology characterised shell hardness through rapid, non-destructive testing of the inner shell surface. Shell compressive strength was characterised using a modified Hounsfield tester, ensuring even load distribution at the shell base. Shell density was characterised through a simple and efficient densitometry method.

This novel quantification of shell characteristics provides a more precise dataset for a nuanced understanding of the multifaceted effects growing location, genetics, and husbandry practices have on the overall performance of Pacific oysters. The presentation will outline these refined shell quality quantification methods and present comparative results from growout experiments, highlighting effects of location, husbandry techniques, and genetic family lines on oysters.

A computer vision method to estimate ventilation rate of Atlantic salmon in sea fish farms

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Abstract

The growing demand for aquaculture production drives the need for innovative, intelligent tools to monitor and manage fish health effectively. While non-invasive video monitoring has become a common practice in finfish aquaculture, existing methods predominantly focus on assessing body condition or fish movement and are often developed and evaluated in controlled tank environments. This underscores the necessity for methods that can monitor physiological traits directly within the production environment of sea fish farms. To address this, we developed a computer vision method for monitoring ventilation rates from videos recorded in commercial sea pens. Our approach uses a fish head detection model, which classifies the mouth state as either open or closed using a convolutional neural network. This is followed with multiple objects tracking to create temporal sequences of fish swimming across the field of view of the underwater video camera to estimate ventilation rates. Extensively tested on real-world production videos from Atlantic salmon farms in Tasmania, Australia, the method achieved high accuracy in detecting open and closed mouths (95.8% and 93.2%, respectively) and demonstrated robust performance, with a Pearson correlation coefficient of 0.82 between predicted and manually assessed ventilation rates of 100 fish recorded in ten different sea pens. When the method was used to assess ventilation rates of four fish populations of which two showed signs of increased respiratory effort, the median ventilation rate proved to be a robust indicator of population-scale ventilation rates. By reliably identifying pens where fish show signs of respiratory distress, our method could reduce costs and animal handling associated with routine health checks by aiding the prioritisation of pens for inspections. This early detection capability not only improves operational efficiency, but also has a positive impact on fish health and welfare. By enabling quantitative and long-term monitoring of ventilation rate—a critical physiological trait linked to various environmental and health conditions—our method offers broad applicability and the potential to revolutionise fish health and welfare monitoring in finfish aquaculture.

Using computer vision to assess the gill health of farmed Atlantic salmon (*Salmo salar*)

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Abstract

Computer vision is emerging as a valuable tool for non-invasive, continuous monitoring of the health and welfare of farmed fish and may reduce the need for manual health inspections. Field trials, however, are needed to interpret the output of computer vision models and validate their use by industry. Freshwater baths, a commonly used treatment for amoebic gill disease (AGD), in farmed Atlantic salmon (*Salmo salar*), effectively reduce gill mucus and improve gill health. We tested the use of a computer vision model to assess the effects of freshwater baths on the ventilation rates of farmed Atlantic salmon. The computer vision method first detected fish heads and classified their mouth states as open or closed using a convolutional neural network. This was followed by a tracking-by-detection approach, which measured the frequency of mouth opening and closing to estimate fish ventilation rates. We hypothesised that exposure to freshwater treatments would significantly reduce ventilation rates. Ventilation rates of farmed salmon were calculated using the computer vision model from 53 pairs of videos filmed before and after fish were bathed in freshwater at commercial farms in Tasmania, Australia, between 21/11/2023 and 22/05/2024. Additional data on water temperature and dissolved oxygen levels were recorded at the pens. A multiple linear regression model was used to analyse associations between these variables. On average, median ventilation rates decreased significantly by 2.2 open-closed cycles per minute after the baths. This study demonstrates that computer vision monitoring of ventilation rates could be used to reduce manual monitoring of gill health and prioritise pens for freshwater bath treatments.

A novel AI system to automatically measure shrimp for selective breeding in aquaculture.

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Abstract

Aquaculture farming provides a sustainable solution to meet the growing food demands of modern society while mitigating overfishing and preserving marine ecosystems. Among farmed species, shrimp stands out as a sustainable choice due to its efficient feed-to-yield ratio compared to larger fishlike salmon. However, shrimp farming presents unique challenges, including the need to monitor numerous individuals to achieve production goals. This paper introduces an automated method for measuring shrimp size, an important factor for improving product quality and health management.

Our proposed system leverages deep learning techniques for precise and robust size measurements, aiding the genetic selection process. Traditional methods require extensive manual measurements, which can be prone to human error, but mainly limit the scalability of this process. From an industrial perspective, producing 4 kilograms of salmon requires monitoring a single individual while producing 4 kilograms of shrimp requires monitoring dozens of shrimps. Our system automates key measurements using a novel skeletal model tailored to shrimp. It predicts keypoints for 2D measurements, which are then transformed into 3D measurements using a regression model, achieving a mean error of only 0.09 cm. The estimation of the measurements of a shrimp from an image takes 173 milliseconds (0.173 seconds) per image.

Our AI systems also incorporate secondary models that mitigate human error by identifying potential inaccuracies in shrimp orientation (lateral or dorsal) and the presence of the rostrum. These systems significantly reduce annotation errors from 0.70% to 0.04% for orientation and from 6.37% to 0.52% for rostrum detection. Our method's reliability and automation enable the processing of thousands of individuals efficiently, improving genetic selection and reducing operational costs.

Our contributions are: (1) a robust 3D shrimp measurement system utilizing deep learning and a custom skeletal model, (2) AI detection systems to reduce human error in data collection, and (3) a regression estimator that enhances measurement precision. Compared to prior work, which achieved only 2D visual analysis with a mean error rate of 2.1 cm, our method delivers accurate 3D pose estimation with a significantly lower mean average error (0.39 cm). To our knowledge, this is the first 3D pose estimation system for shrimp, marking a significant advancement in aquaculture technology.

Development of a low-cost acquisition board with IoT support for aquaculture Monitoring

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Abstract

This paper focuses on aquaculture monitoring technologies, proposing the design and implementation of a system capable of collecting critical water quality data, including pH, temperature, Oxidation-Reduction Potential (ORP), and Dissolved Oxygen, among others. The study emphasizes integrating diverse sensor interfaces and communication protocols to enhance data accuracy, reliability, and real-time accessibility. The proposed system incorporates a range of sensor interfaces such as 4-20 mA, RS485, and analog (0V-10V) to ensure compatibility with different types of sensors and to facilitate precise data collection. The 4-20 mA interface is highly valued for its durability and ability to transmit signals over long distances with minimal loss, making it well-suited for large-scale aquaculture operations. RS485, a standard for serial communication widely used in industrial and aquaculture sensors, ensures reliable sensor connectivity and seamless data transfer. Meanwhile, the analog interface (0V-10V) provides a simple and cost-effective solution for integrating diverse sensors, facilitating easy calibration and maintenance. To enable real-time data transmission and remote monitoring, the system includes advanced communication protocols such as WiFi, Bluetooth, and LoRa. WiFi provides high-speed data transfer and is suitable for aquaculture facilities with established network infrastructure. Bluetooth, known for its low power consumption, is ideal for short-range communication with portable monitoring devices. LoRa (Long Range) technology, with its capability to transmit data over long distances with low power consumption, is particularly advantageous for remote aquaculture sites where traditional network infrastructure may be lacking. The integration of these communication protocols ensures that data collected from various sensors can be transmitted efficiently to a central monitoring system. This central system can process and analyze the data in real-time, providing aquaculture operators insights to optimize water quality and overall farm productivity. The ability to monitor parameters such as pH, temperature, Oxidation-Reduction Potential (ORP), and Dissolved Oxygen continuously allows for timely interventions to maintain optimal conditions for aquaculture species, thereby enhancing growth rates, health, and yield [1]. The study also emphasizes the importance of adopting low-power IoT protocols to streamline data collection and control processes. These protocols facilitate the collection of large amounts of data, which can be easily accessed and analyzed in real-time. This capability is crucial for developing a comprehensive understanding of aquaculture environments and for implementing effective management practices [2]. In conclusion, the integration of advanced sensor interfaces, like the one proposed, and communication protocols in aquaculture systems represents a significant step forward in the industry, enhancing the accuracy and reliability of water quality data and enabling real-time monitoring and control, leading to improved productivity and sustainability in aquaculture operations.

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