Compilation of Session Summaries

A compilation of the session summary reports received from the session chairs.
Not all the sessions have been reported and only simple editing has been made.

WORLD AQUACULTURE Society

eas european aquaculture society

Compiled by the EAS secretariat. October 2018

AQUA 2018 celebrated the fact that aquaculture is one of the most important food production industries in the world. Aquaculture is the most efficient producer of high-quality food and contributes to global health and wealth. Aquaculture respects the environment, creates employment and offers significant investment opportunities.

AQUA 2018 took place from August 25-29 in the beautiful French city of Montpellier and comprised a scientific conference, world press day, trade exhibition, industry forums, workshops, student events and receptions. The event highlighted the latest aquaculture research and innovation to underpin continued growth of this exciting food production sector.

It was attended by 3003 participants from 109 countries.

The AQUA events are co-organised by the European Aquaculture Society (EAS) and the World Aquaculture Society (WAS) and are held every six years. Past events were held in Nice (2000), Florence (2006) and Prague (2012).

KEY FIGURES:

Participants	3003
Countries	109
Trade show booths	175
Oral Sessions	81
Oral presentations	800
Poster sections	17
Poster presentations	317
Industry sessions	10
Pre- and post- event tour participants	126

Next EAS and WAS events:

WAS events www.was.org

- LACQUA 2018 - Bogota, Colombia - October 23-26
- AQUACULTURE 2019 - New Orleans, Louisiana, USA - March 7-11
- ASIAN PACIFIC AQUACULTURE 2019 - Chennai, India - June 19 – 22
- LACQUA 2019 - San Jose, Costa Rica - November 19-22
- AQUACULTURE AMERICA 2020 - Honolulu, Hawaii, USA - February 9-12
- WORLD AQUACULTURE 2020 – Singapore - June 8 – 12

EAS events www.aquaeas.eu

- AQUACULTURE EUROPE 2019 - Berlin, Germany - October 7-10
- AQUACULTURE EUROPE 2020 - Cork, Ireland - September 29 – October 2

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Contents

Adaptation to climate change and ocean acidification

Chair: Lynne Falconer (University of Stirling, UK)

Aquatic products are rich in protein, essential fatty acids, vitamins and minerals, and play an important role in food and nutrition security. Wild fish stocks have long been overexploited, so aquaculture is considered the primary method of meeting the growing demand for aquatic products. However, climate change and ocean acidification may impact production so there is a need to consider how the industry may be affected and investigate potential adaptation methods. This was the focus of the "Adaptation to climate change and ocean acidification" session.

The session included ten oral presentations, but unfortunately there were four no-shows which meant there were only six presentations on the day. This disrupted the flow of the session, but it was still well attended with over 40 attendees throughout the morning. There were a good range of presentations from research groups across the world and topics covered fish, shellfish and aquatic plants.

The first presentation was given by Lynne Falconer and highlighted work from the EU H2020 ClimeFish project, assessing implications of changing sea temperatures for salmon aquaculture. Key points were the need to consider multiple spatial scales for impact assessment and adaptation planning, but also the challenges in using global and regional scale models to assess local scale impact. Joao Ferreira then presented results from CERES, another EU H2020 project, and showed a range of modelling approaches being used to assess impact of different climate change scenarios on shellfish aquaculture. This included models focusing on individuals to determine implications for growth and then upscaling to population level and how this can be informative for aquaculture management.

Staying with shellfish, Thomas Guyondet then presented a modelling approach used to explore the interactions between shellfish culture and the ecosystem to identify potential impacts of climate change. This presentation highlighted how models can be used to explore different scenarios and combinations of climate, physical environment and aquaculture drivers. Following this, Gregor Reid presented results from an extensive review of the potential for aquaculture to adapt to climate changes. This talk highlighted the potential range of adaptation measures but also knowledge gaps and areas in need of more research. Doris Soto then presented an assessment of salmon farming vulnerability to climate change in southern Chile. The semi-quantitative approach explored different management scenarios and combined exposure (risks), sensitivity (economic and social dependence) and adaptive capacity to determine vulnerability and show how this can be used to plan and manage aquaculture given the changing climate. Finally, Ik Kyo Chung gave the last presentation of the session which focused on the use of seaweed as mitigation and adaptation measures based on experiences from several projects.

One of the key themes throughout all presentations was the need for more research into the impacts of climate change and ocean acidification which can then be used to inform adaptation measures. **While progress has been made there are still many unknowns, particularly around multiple climate drivers and the combination of effects.** If aquaculture is to maximise its contribution to food and nutrition security, then both short and long-term plans require more information on how climate change may affect the sector.

Agriculture/Aquaculture circular co-production and eco-intensification

Chair: Lionel Dabbadie (CIRAD, France)

The session started with presentations of a broad scope: the concept of Nutritious Pond, "based on ecological principal where by manipulating the composition of formulated pond diets the metabolic wastes resulting from nutrient inputs (feed, fertilizer, carbohydrates) become a balanced fertiliser stimulating the natural productivity of the pond", the efficient use of resources in desert aquaculture (a related presentation was given during the FAO special session on agroecology and Integrated Agriculture-Aquaculture held on Saturday, August 25), two presentations on the Irish approach to support freshwater aquaculture and one value chain analysis of aquaculture industry in Tanzania.

The second part of the session was more technical, dealing the relationships between the Pacific oyster surrounding species and the disease risk, the production of Artemia using wine wastes and several presentations on aquaponic systems. These last one dealing more specifically with microbial aspects, growth performance and commercial acceptance and aquaponics development issues (Italy-Slovenia-Islands)

Antimicrobials in Aquafeeds, Prebiotics and Probiotics

Chair: Peter Bossier (Ghent University, Belgium)

The session contained two meta-analysis papers on the use of probiotics and prophylactic health products (PHP) in aquaculture. The first paper had a focus on probiotic in shrimp. While the second meta-analysis study had a wider perspective.

In the first shrimp study, a wide variety of experimental designs were detected, which is a source of heterogeneity that affects the results and reduces the consistency of the findings. However, the meta-analysis allowed to identify certain components of the experimental designs that could affect the probiotic effect on shrimp farming. This, in turn it allowed to define guidelines to standardize the experimental designs of future trials. Some of these guidelines are that: (1) there are more chances of finding beneficial effects on shrimp farm indicators by including probiotics in the feed; (2) probiotic viability should be maintained during all the trial; (3) trials should focus on the use probiotics with more than one strain (4) increasing the numbers of animals can improve the success of probiotics use and (5) trials designed as experimental growth models can be useful to assess the effectiveness of the probiotic to induce enzyme such as amylase, lipase, protease and gut probiotic colonization.

The second meta-analysis paper indicated that a significant proportion of published studies lacked proper study design. Furthermore, few studies have been independently substantiated under farm-conditions, effectively omitting critical key genotype-environment challenges from most of this body of work. The authors anticipated that this systematic review will help researchers better design experimental and field trials for the proper assessment of the effectiveness and cost benefit of PHPs. It will also support decision making for the use of PHPs in aquaculture

A particular research paper, effectiveness and cost benefit of PHPs on shrimp (*L. vannamei*) health and production performance during (i) extended nursing and (ii) post-treatment, during pond grow-out to harvest. Five individual and combination PHP treatments (in-feed probiotic, in-feed prebiotic, in-feed synbiotic, water probiotic and combined in-feed prebiotic and water probiotic) were evaluated against a "no-treatment" control and a biofloc system as a potentially low-cost alternative. Preliminary findings indicate significantly enhanced growth outcomes for the biofloc and water probiotic treatments ($p < 0.05$) which could significantly reduce grow-out time and disease exposure.

Another paper reported on the use of *Saccharomyces cerevisiae* fermentation product (SCFP; Diamond V Original XPTM). In fish and shrimp, SCFP reduces intestinal load of Vibrio sp., E. coli O20:H42, Bacilli MS030A1_FO2 like, Pseudomonas fluorescens YC0357-like, and increases numbers of beneficial bacteria as has been reported for probiotics and prebiotics.

In another study the focus was on the isolation of probiotics from the local environment. Use of bacteria isolated from the host itself or from its rearing environment has become essential in efforts to increase efficacy. For bacterial disease control strategies, studies indicate that green-water from saline-tolerant tilapias and their skin extracts are capable of inhibiting pathogenic Vibrio spp. in shrimp. For 2 isolated Bacillus strains growth was not significantly affected, survival was improved with the probiont supplementation, yet phenoloxidase and bactericidal activity were enhanced with the dietary application of the probionts. Moreover, both isolates showed protection to the shrimp against *V. harveyi* infection.

With a focus on Tilapia a study was presented assessing the impact of a commercial probiotic, Sanolife PRO-F, on water quality, growth performance, blood profiles and intestinal morphometry of monosex Nile tilapia in Egypt. Application of Sanolife PRO-F at 0.1-0.2 g kg-1 diet might have beneficial effects on growth, immunity, stress responses, gut health and function and water quality of farmed Nile tilapia.

Finally, a talk was presented illustrating a strategy of protective bacteria' selection, for application in seafood, especially for prevention of risk associated to the lethal bacteria *Listeria monocytogenes* for histamine-producing bacteria and for spoiling bacteria. It was found that certain Carnobacteria has the potential to limit the development of Listeria.

In conclusion, this session has shown that probiotic strains can be isolated and screened effectively, even from local sources. At experimental scale the effectiveness of these probiotics can be demonstrated. Mega analysis demonstrates that experimental design is not always optimal and the probiotic applications should be based on a formulation of multiple strains. In addition, effectiveness should be demonstrated on field scale where environmental interference is larger.

Aquaculture and prospective

Chair: Denis Lacroix (Ifremer DS / Scientific watch and Prospective, France)

This session proposed a reflection on the long-term challenges in aquaculture when considering 3 global scenarios: (1) Awareness of crisis and pro-action; (2) Tensions and turbulences; (3) Priority to technology in a globally fluid trade.

The 7 selected countries represent 80% of the world aquaculture production: India, China, Vietnam, Norway, Egypt, Greece and Brazil. Each national expert had to identify the figures of 4 components of the national sector in each scenario (i.e. productions, markets, politics, sites availability and inputs) and to propose a level of total production at the horizon 2040. Table 1 summarizes the key data and key words of the 7 presentations.

Country Criteria	**INDIA**	**CHINA**	**Vietnam**	**Norway**	**Egypt**	**Greece**	**Brazil**	**(Total)**
Prod 2016	6,5	51,4	3,53	1,3	1,4	0,12	0,8	**65,05**
Main species	Carps Panga	Carps Nb spp.	Panga Tilapia	Salmon	Tilapia Carps	Seabass Seabream	Tilapia Tambaqui	
Consu/hab/an	6	40	37	35	20	15	9	(kg/h/yr)
Main Problems	-markets -fry -feed	-impacts -markets -quality	-technos -markets -quality	-parasite -image	-fry -salt -techno	-sites -impacts	-dev plan -reliability -image	
Scenario 1	17,5	65	8	3,3	5,2	0,3	1,5	**100**
Scenario 2	12	55	5	2,2	3	0,2	1	**78**
Scenario 3	25	85	6,5	16	6	0,15	3	**141**
Average	**18**	**68**	**6,5**	**7,2**	**4,7**	**0,2**	**1,8**	**106**

Table 1: Facts and figures for aquaculture in 7 countries at the horizon 2040 according to 3 given scenarios (in million metric tons)

If the ratio of the contribution of the 7 countries to the world total would remain stable (80%), then, **the average production of 106 Million tons (MoT) would give a total of 132 MoT for the world aquaculture production in 2040, that is to say an increase of 47 MoT** when compared to the estimated production in 2018 (85 MoT). The range of production in 2040 is quite broad as, in the crisis scenario (2), aquaculture is declining, and in the most optimistic scenario (3), aquaculture increases up to 66% of 2018 production. India a second major impact on results, after China.

The debate started on the issue of the capacity of world aquaculture to match the increase of the demand in aquatic products. Indeed, this demand is a result of the increase of the aquatic food consumption (from 20 to 30 kg/capita/year) and of the human population expansion (from 7,3 to 8,5 billion people), which entails in a demand of a supplementary **45 MoT**.

During the previous decades, aquaculture increases by 24 MoT in a 10 years period, which involves that an extrapolation to the year 2040 should supply additional **53 MoT**.

Those three figures coincide approximately by 2040: the demand (**45 MoT**), the trend extrapolation (**53 MoT**) and the extrapolated done by the 7 countries (**47 MoT**).

Therefore, the issue is less a problem of quantity than a more global issue related to:

1. the limits of inputs (space, feed, skilled people...)
2. the control of externalities (pollution, eutrophication, biodiversity erosion...)
3. the promotion of a positive and credible image of aquaculture on the long term
4. the capacity of adaptation to the global change to come, notably salinization

The debate highlighted an interesting opportunity for aquaculture, related to the sea level rise and the lack of freshwater supply in the large delta areas. Salinization of those zones offers the possibility to develop brackish water aquaculture in former rice fields. **The example of Egypt aquaculture evolution is remarkable**: from 1990 to 2017, this sector has shifted from 0.1 to 1.4 MoT with very simple means. Egyptian fish is now the cheapest source of proteins in the whole Middle East and North African country (MENA); the consumption is about 20 kg/capita/year (for 100 million Egyptians), which is twice the fish consumption in the MENA countries.

Numerous other countries could take advantage of this constraint, notably when large deltas suffer from freshwater shortage, which entails into greater risks of subsidence, salt intrusion and sea level rise. The solution is a long-term zoning and planning of territories to adapt aquaculture in terms of species (from fresh to brackish water) and space (from the coast to the hinterland). **Then, the prospective could fully play its role** in the enlightenment of potential strategic choices through several contrasted scenarios. The next step would be the modelling and all the disciplines used in aquaculture, from the selection of adapted species and strains to the social acceptability of a transition which will became inescapable in the future.

The representative of China identified 3 successive "E" as priorities for aquaculture over the last 3 decades: Economy, Environment, Ecosystems. After discussion, it was suggested to mention a 4th "E" for our decade: **Education (and Ethics as well)** in order to show the necessity to involve societies into the development of this sector, since school. Indeed aquaculture has to be recognized by actors and consumers as a responsible activity in terms of inputs as in terms of impacts on environment, within the frame of the Sustainable development goals (SDGs). Those SDGs will probably be strengthened with time, integrating an increasing number of indicators and digital control systems. If aquaculture, notably in research and in technology, would anticipate this evolution, it would gain much in terms of image, credibility and example.

Aquaculture in Iran

Chair: Hossein Ali Abdolhay (SHILAT – Iran Fisheries Organisation, Iran)

This short session provided an overview of aquaculture development in Iran, followed by a discussion between those present on cooperation and opportunities for foreign companies to do business.

Aquariology - Role of Public Aquaria

Chair: Nicolas Hirel (Montpellier Marenostrum Aquarium, France)

The session took the theme “Tight links between aquaculture and aquarium” and was comprised of two sub-sessions, the second proving an excellent case study.

1- Differences and similarities between aquaculture and aquariology

Aquaculture and modern aquaria show few differences in their practices but share indeed a lot of similarities. While aquaculture breeds large amounts of animals of a similar size and species for food consumption, aquaria display a wide diversity of species, even from aquaculture, of different size in a same volume, for educating people.

But they both run large water volumes in indoor recirculated systems and need to maintain optimal water quality for their animals (with emphasis for transparency in aquaria).

Aquariology and aquaculture work to solve every day very similar issues such as:

- zootechnical aspects (nutrition, reproduction, pathology ...),
- water treatment solutions,
- administrative constraints,
- economic sustainability,
- building and equipment pathologies in comparable aggressive conditions,

Since a long time, the aquarium industry also benefits from aquaculture experience for breeding their collection (mainly marine species).

The general public is more and more sensitive to the ecological debate and the animal welfare cause in both industries.

Aquarium and aquaculture staff often share the same curriculum and many technicians, engineers, scientists work alternatively or at the same time in both sectors. In France, the new training trends are around 7 main topics:

- Raise or breed aquatic animals for aquaculture, aquarium, education, leisure and conservation,
- Adopt an ethical behaviour on environment,
- Identify and conduct in autonomy experimental projects,
- Communication skills to deliver knowledge to professionals, schools and general public,
- Manage projects and work in a team or alone,
- Create and manage a company,
- Prepare and submit licensing/permit that comply with French laws on aquarium trade or public aquaria.

2- Collection and conservation of gametes from the aquarium livestock using aquaculture techniques with emphasis on an emblematic aquarium species: the Sawfish

The Sawfish Assisted Reproduction Program aims to assist the reproduction in captivity of this emblematic species, in accordance to the IUCN Sawfish Conservation Strategy, in it’s 7th objective : “*Ensure that captive sawfishes are handled, studied, displayed, and (where legal) transported according to the highest standards with a view to contributing to their recovery. “*

As for aquaculture species, the main general issues for breeding are:

- Get as much as possible information on their natural life cycle and maturity period,
- Provide the animals the best husbandry conditions to perform their natural life cycle,

- Get access to the individuals in safe conditions for staff and animal,
- Involve every knowledge, know-how and qualified person,
- Share information to the whole community.

Large Elasmobranch reproduction in captivity is an issue regarding population viability, conservation and the image perceived by the general public. In many facilities the animals are displayed in non “specific species tanks” mixing species with different size and often different optimum temperature ranges. This is considered as the main obstacle for successful reproduction in aquarium.

Elasmobranchs are known for their late and low fecundity: “The bigger they are the less they breed”.

However, significant results of natural breeding in few species of sharks (*Carcharhinus plumbeus, C. melanopteus, Stegostoma facsiatum*, catsharks, …), rays (*Aetobatus ocellatus, dasyatids, rhinobathoids*) and many other egg laying species are currently observed.

For larger species, knowledge on elasmobranch reproduction improves step by step on endocrinology, anatomy and life cycle. Limited and scarce success on assisted reproduction via insemination was already obtained on very few viviparous and oviparous species (*Notorhynchus, Stegostoma, Chiloscyllium, Scyliorhinus, Raja*). But research continues on *Carcharhinus plumbeus* and *Carcharias taurus*.

In order to progress in the Sawfish Assisted Reproduction Program, the aquarium industry should “*Continue development of captive breeding programs and increase exchange of information with the scientific community about the life history, physiology, and biology of captive sawfishes ».*

Thus, the Industry Forum participants agreed on the following summary statements:

- Adapt if possible the water parameters to the wild conditions (may be the key issue with multi species displays with different water parameters optimum),
- Find a means to check female reproductive period,
- Train their animals to be close enough for safe examination under soft/flash anaesthesia,

- Collect Sawfish sperm as it can be considered now as successful, on *Carcharias Taurus* another large specie of elasmobranch.

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Assessment and mitigation of environmental impact

Chair: Thomas Guyondet (Gulf Fisheries Centre, New Brunswick, Canada)

This session comprised 12 presentations that covered a very wide range of topics going from the detection of toxicants in farmed fish to the use of biofilms as indicator of fish farm waste dispersion. Although this wide range of topics prevents from drawing general conclusions about this session contents, two topics were covered by multiple presentations and generated more active discussions.

The first outstanding topic was the **application of the life cycle approach**. This method provides a framework to integrate and compare all aspects of the production cycle using a common measurement unit (nutrient, energy…). This type of analysis constitutes an interesting tool to identify weaknesses in the production and help improve its overall environmental efficiency. However, the applications presented were limited to closed production systems (aquaponics, ponds) and the method might prove more difficult to apply to open systems.

The second topic that focused most of the attention was **microplastics**. Concerns are growing regarding the presence of microplastics in aquaculture products (fish and shellfish). A message that came out of the session is that research is still needed to refine the methods of detection in the environment and in the products as well as to understand their effects on the cultured species. Aquaculture operations themselves can contribute to this type of pollution, the reduction of which should be included, if not already, in the industry best practices.

These two topics should be considered for dedicated sessions during future aquaculture conferences.

Biodiversity, Conservation, Alien Species

Chairs: Fabrice Teletchea (University of Lorraine, France) and Matthias Halwart (FAO)

The aim of this session was to give an overview of the aquaculture production in the World and discussing some challenges in the coming years. Overall, seven talks were given (the last one from Sergeevna *et al.* was cancelled).

The two first presentations give an overall picture of the aquaculture development in the past decades. Based on the FAO database, Teletchea and Beisel demonstrated clearly how the global volume of aquaculture production of finfish has tremendously increased, particularly since the 1980s. This strong rise relied partly on the domestication of a growing number of marine, diadromous and freshwater fish species; yet the production is heavily skewed towards the farming of a low number of species. The leading species (by volume) represents almost 11% of the global volume. In three (Americas, Europe and Oceania) of the five main regions considered by the FAO, the Atlantic salmon *Salmo salar* is by far the leading species. This study demonstrates that the industry, except in Asia, is probably focusing more on more on the production of a low number of species globally. This questions the sustainability of such a development, such as the introduction of few species across the wold and the possible biological and ecological consequences. Then, Halwart *et al.* provided an overview of the key findings in the Report on The State of the World's Aquatic Genetic Resources for Food and Agriculture performed by the FAO. This report represents the first ever, country-driven, global assessment of aquatic genetic resources (AqGR) for food and agriculture, and is now available on line (www.fao.org/aquatic-genetic-resources). This report highlights that current data on aquaculture production does not fully reflect the broad diversity of AqGR in use and identifies a need to record information at a genetic level (e.g. as "farmed types") as well as at the species level. The Report also identifies that some degree of genetic management is applied in 60% of species reported under culture but recognises aquaculture's continuing dependency on wild stocks, emphasizing the interconnectivity between ecosystem conservation, sustainable fisheries and aquaculture development. The presentation concludes by identifying possible next steps, including recommendations to assess, explore and develop mechanisms to monitor the status and trends of AqGR, including through the establishment of a global information system and a registry of farmed types and stocks of wild relatives.

The third presentation focused on the ecological carrying capacity of the ecosystem and the economic potential of expanded bivalve shellfish aquaculture. Based on an integrated modelling approach in conjunction with laboratory and field efforts, Byron *et al.* explored fundamental drivers to the modelled production potentials. Such sustainable approaches to aquaculture are essential for improving the way in which coastal zone resources are utilized so that they are not in conflict with other usages and user groups. This work will help inform on-going management and policy discussions about sustainable coastal aquaculture development. The fourth presentation explored what could be the consequences of global warming for the species common in European and Norwegian aquaculture today. Bergh *et al.* discussed that fish farms could have to be relocated and farming technologies and/or species modified in order to reduce the undesirable effects of higher temperatures, such as compromise of the immune system leading to increased disease problems (francisellosis, vibriosis, furunculosis), or more numerous parasites (salmon lice).

The three other presentations focused on specific aspects of one or two species: Pacific cupped oyster, *Crassostrea gigas*, and the Portuguese cupped oyster, *C. angulata* (Lapègue *et al.*), African river prawn *Macrobrachium vollenhovenii* and giant freshwater prawn *M. rosenbergii* (Savaya-Alkalay *et al.*), and Bonefish Albula vulpes (Mejri *et al.*). Lapègue et al. described the history of domestication of these two introduced oysters in Europe and then suggested that these semi-species are still evolving in the so-called "speciation grey zone". Furthermore, the recent reciprocal introgressions observed in contact zones in Portugal and France highlight the need to better characterize and potentially conserve those

genomic resources of importance for shellfish aquaculture. The aim of the presentation of Savaya-Alkalay *et al.* was to evaluate whether all-male populations of the introduced giant freshwater prawn will not be able to hybridize with the native African river prawn. According to their results, the reproductive barrier between these two species is both pre- and post-zygotic and thus they suggest that all-male *M. rosenbergii* can be safely and sustainably used as an aquaculture species in areas where *M. vollenhovenii* naturally occurs, and as a bio-control agent in Africa, where schistosomiasis is a major health concern.

In the last presentation, Mejri *et al.* aimed to describe, for the first time, the oocytes development, lipid characteristics, and reproductive hormones in wild bonefish during the reproductive season in different tidal flat pre-spawn aggregations locations in Grand Bahama Island, Bahamas. Their results not only serve as a benchmark for determining the nutrient requirements, and hormonal status of broodstock to produce high quality eggs from bonefish captive broodstock but also will help establish a meaningful management practices for this species.

Cage Culture

Chair: Hans Bjelland (SINTEF, Norway)

This session covered advances in salmon cage culture technology, spanning assessments of antifouling coatings, effects of shielding skirts on water quality, technologies to monitor behaviour and physical states in farmed fish, and design of autonomous robots for use in and around cages. The session was well attended, with time for responses from the audience between presentations.

As salmon farming has grown to a large industry, its requirements for precision and control of its processes increase. Technology plays an important role in achieving this, exemplified by the presentations of the session that also highlighted knowledge needs. New technology might introduce new challenges and the complex interactions between technology, fish and the environment must be studied to avoid problems and to optimise production.

A range of new methods and technologies are becoming more available and mature, enabling solutions for observing the aquaculture system, interpreting, supporting decisions and, finally, more autonomously carrying out operations. This is expected to increase precision, make operations more robust and improve sustainability.

Communication to Society

Chair: Mark Flaherty (University of Victoria, Canada)

This session took place on Sunday August 26 from 11:20 to12:40, and then resumed after the lunch break from 14:30 to 15:10. The first part of the session was very well attended, and all four of the scheduled talks were presented. The session covered a wide range of issues from global initiatives to empirical studies of community attitudes towards aquaculture development and consumer preferences.

It began with a presentation about a ecosystems ecology approach to regional planning for ocean food systems referred to as a "**Taxonomy of Seafood Systems**," that identifies first the structure of regional ocean food production systems to reveal the full diversity of modern fisheries and aquaculture production systems and their local to global value chains. It also describes partnership developments in support of training of an international training program for graduate students.

This was followed by an overview of the *Mr.Goodfish Programme*, which has been launched in France, Italy, and Spain. It aims to better manage seafood resources and to secure the sustainability of seafood stocks, by helping consumers to choose their seafood smartly. It endorses an exclusively positive approach and promotes the aquaculture and all sustainable fish production process to encourage new consumption patterns.

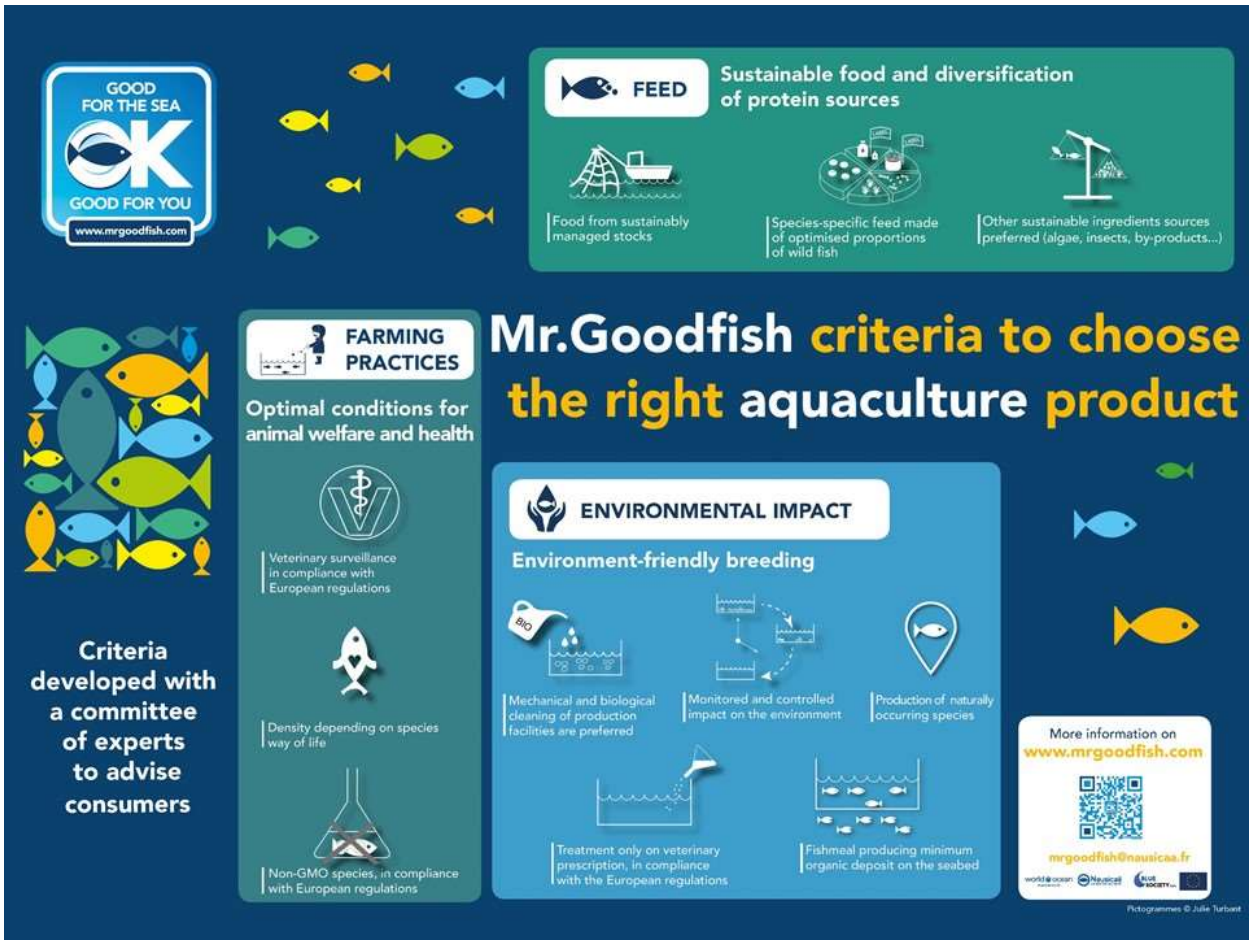


Photo: The Mr Goodfish programme in France. An example of a Public Aquarium informing consumers about the sustainability of fish from fisheries and aquaculture.

The next paper discussed how lack of social acceptance and legitimacy can be a constraining factor for further growth in the aquaculture industry. Even though the industry is seen as an important global producer of food, the industry faces critiques and challenges with social acceptance from the public, consumers, markets, and policy makers. It argued that to improve the industry's social acceptance, we need a more nuanced debate about aquaculture.

The final paper reported the results of a study undertaken in small coastal communities on Canada's Pacific (west) and Atlantic (east) coasts that investigated awareness of aquaculture, and the issues that people associate with its development. It highlighted the similarities, but mostly differences in perceptions between respondents on the two coasts.

In the second section of this session only one of the two scheduled papers were presented. This section had the misfortune of being double-booked for the same room as a technical session on tilapia production. This created some confusion, and also resulted in there being a very mixed audience in terms of their interests. The chair of the tilapia session graciously allowed our speaker to make his presentation first, as one of the tilapia speakers had not shown up. The final paper in the session examined the effect of information on consumer preferences for organic aquaculture production in the EU. The results showed a preference for organic labeled fish products among the majority of consumers.

Development, Welfare and Poverty Alleviation

Chair: Mark Flaherty (University of Victoria, Canada)

This session took place August 29, from 14:00 to 15:40, which was the last session on the last day of the conference. As might be expected attendance was relatively low. The three papers focused on aquaculture and poverty alleviation drawing upon recent experiences in Cote D'Ivoire and Guinea, Bolivia and Nigeria.

The first paper outlined how the national government back in the 1990s had set up the "Direction Nationale de la Pisciculture" in order to promote the integration fish farming into the rural households, as the basis of the national aquaculture sectoral policy. It then examined what the impact has been and reported that urban markets drain the higher quality fish produced in most places through a value chain managed mostly by women. Consequently, local distribution is made up of small size fish which face difficult competition from imported fish. It was also reported that the value chain suffers from information and coordination difficulties.

Despite these positive signals, the development has been sometimes difficult and faces numerous challenges: at a macro level, it hasn't affected the increase in imported fish.

The next paper presented the results of a study undertaken to investigate the contribution of family based small-scale farming of Tambaqui to household incomes and food security in Bolivia. A holistic value chain analysis was designed and conducted that incorporated horizontal linkages (gender, food security, poverty analysis, and socio-political context). Principle findings point to an aquaculture system that has a low environmental impact, and which has considerable potential for alleviating poverty and improving food security in rural communities. Opportunities and barriers to expanding the adoption of aquaculture, as well as for improving productivity and ensuring sustainability were outlined.

The final presentation reported the results of a study to examine the constraints to aquaculture production in Nigeria. The findings indicated that the major constraint to catfish production in the state

is high cost of feed, which is sourced externally. Other problems include inadequate finance, and lack of encouragement from government.

Emerging Diseases & Diagnostics

Chair: Benjamin H. Beck (U.S. Department of Agriculture, Aquatic Animal Health Research Unit, Auburn, Alabama USA)

Aquaculture is the fastest growing sector of animal agriculture; however, sustainable expansion and intensification of aquaculture is severely hampered by issues related to disease. Irrespective of cultured species, diseases can severely threaten the sustainability and efficiency of aquaculture operations. The "Emerging Diseases and Diagnostics" session focused on both new/emerging pathogens and age-old pathogens that are affecting new host species. Broadly, the session emphasized a clear need to: bridge knowledge gaps related to host:pathogen dynamics and microbial pathogenesis, prioritize the development and validation of new approaches for the detection of outbreaks before they start, heighten biosecurity and surveillance measures to prevent or minimize epizootics, continue to pursue new insight into antimicrobial resistance and alternatives to antibiotics.

The session included 16 oral presentations, with no cancellations or "no-shows" which fostered continuity and led to an engaging Q&A dialogue following each talk. The session was well attended and averaged approximately 50 attendees for each talk. There was a diverse array of topics covered from research groups across the world (France, United Kingdom, Philippines, USA, China, New Zealand, South Korea, and Vietnam). Topics covered both freshwater and marine finfish along with shrimp and oysters; and pathogens of bacterial, parasitic, and viral origin.

For the diagnostics component of the session, Cara Brosnahan highlighted work on the development of a viability PCR technique to more accurately ascertain pathogen levels colonizing an infected host or in the aquatic milieu. This technology showed great potential to revolutionize diagnostic capabilities by eliminating unwanted contributions of nucleic acid signal from dead bacterial cells, which will allow more accurate quantification and improve the quality of downstream approaches such as the use of next generation sequencing platforms. In this same vein of novel and robust detection methods, Chen Su showed the utility and sensitivity of a small, high-throughput, and portable system (for use in the lab or on the pond bank) for the rapid detection of Tilapia Lake Virus, a debilitating pathogen of tilapia that is rapidly spreading throughout the globe. Attendees also learned from Monica Campas that magnetic beads were found to greatly improve the detection of Ostreid Herpesvirus in oyster homogenates and seawater, an approach that could potentially be applied to streamline the detection of other problematic pathogens of fish and shellfish. Switching gears to the host side of the equation, Brian Quinn discussed the usage of clinical chemistry analysis to profile the alterations of serum biomarkers in the context of exposure to a sea lice therapeutant which revealed perturbations in the serum compartment linked to potential liver, kidney, and hematological dysfunction.

Later in the morning, the session shifted to topics related to bacterial pathogens with discussion on determinants of virulence and host:pathogen interactions. Two consecutive talks were delivered on Aeromonads, the first by Andrew Desbois where a transposon mutant library generated by their group for *Aeromonas salmonicida* allowed for the identification of a suite of genes that allowed this pathogen to exhibit enhanced growth in mucus. Continuing with this theme, Benjamin Beck showed recent data on the importance of iron dynamics in the context of *Aeromonas hydrophila* virulence and the impacts of nutritional status on mediating disease outcomes following experimental challenge with this pathogen. Alain Le Breton discussed the distribution, host selectivity, and diversity of *Tenacibaculum*

species that are negatively impacting marine finfish species. This talk offered important new insight on the bacterial players involved, and detailed the most common clinical signs and symptoms, and how they have rapidly evolved over time as new isolates have emerged. Nora Navarro-Gonzalez monitored over a hundred *Yersinia ruckeri* isolates for a plasmid encoding resistance to colistin, one of the last lines of defence to treat antibiotic resistant Gram-negative bacteria in humans. In contrast to the situation in Asia characterized by liberal colistin use in intensive production settings, in France only a single isolate from 1985 was found bearing the resistance plasmid. Later in the session, Stella Paret characterized the susceptibility of Red tilapia to *Streptococcus agalactiae* using an elegant challenge model and offered discussion on the impacts of this bacterium on the industry in Vietnam.

Viruses were next on the docket, where Jean-Christophe Avarre walked the audience through the usage of next generation sequencing to characterize the genomic diversity of Cyprinid herpesvirus 3, which pointed to the existence of previously unrecognized mixed infections and the existence of two predominant viral lineages and a third group of highly divergent atypical samples. Relatedly, the attendees heard about the emergence of Spring Viremia of Carp Virus (SVCV) in common carp and largemouth bass in South Korea. Seongdo Lee spoke on the phylogenetic results of his work that the SVCV isolates were members of the Asian clade and subsequent challenge models showed that carp experienced substantial mortality following injection and immersion exposures.

Shrimp diseases took front and centre for several presentations with two focused on *Vibrio parahaemolyticus* strains that bear toxin producing plasmids and bring about large-scale mortality in shrimp; a disease termed acute hepatopancreatic necrosis disease (AHPND). Through a battery of pathogenicity tests Edgar Amar demonstrated the mortality patterns and histopathological lesions for different isolates from the Philippines, where AHPND has recently made landfall. Dr. Xuan Dong followed up with a profound description of the toxin plasmids that cause AHPND with discussion on their promiscuity, as he showed the attendees that these lethal genetic elements can be rapidly transferred to other *Vibrio* bacteria. Jie Huang touched also touched upon AHPND and confirmed and extended the epizootic potential of this pathogen and then covered other new bacterial, viral, and parasitic threats to shrimp. He spent the latter half of his informative talk covering biosecurity practices featuring different levels of stringency termed biosecurity grades, which was useful for anyone working with aquatic animal husbandry and culture. Building upon this momentum, Anton Immink switched gears to discuss health/farm management apps that hinge upon data sharing between farms to alert each other in a given region to new threats to shrimp operations, which can foster increased trust and value amongst producers—a together we are stronger—mentality with farmers in a region. The importance of data was also evident in a talk by Brit Hjeltnes regarding the temporal and spatial patterns of disease outbreaks in salmonids across Norway.

Collectively, this session offered profound new insight into the diverse strategies that pathogens employ to colonize their finfish and shellfish hosts and to emphasize the notion that we must continue to “run in order to stay in place” as pathogens evolve or new pathogens emerge.

Escapees – causes, consequences and prevention

Chair: Sten Karlsson (Norwegian Institute for Nature Research (NINA), Trondheim, Norway)

This session covered the state-of-the-art knowledge of escapees of farmed fish, focusing mainly on the consequences. Six abstracts were selected for oral presentations. Four talks presented results from research on genetic introgression of escaped farmed salmon in wild Atlantic salmon, one talk presented

morphological differences between farmed and wild sea bream in Turkey, and one talk presented a multivariate fitness model for genetic introgression of domesticated species into their wild counterpart.

Gilthead sea bream is an important aquaculture species in Turkey, and we learned that wild sea bream from different populations had different morphology, and wild sea bream showed clear differences in morphology compared to farmed sea bream, measured from 10 different landmarks on the fish to characterize the body shape. The morphological differences between wild and farmed sea bream was suggested to make it possible to identify escaped farmed sea bream from wild sea bream and to monitor possible genetic introgression from changes in morphology in the wild sea bream.

Atlantic salmon aquaculture has grown rapidly and has unfortunately become a threat to wild Atlantic salmon due to escapees and genetic introgression. The magnitude of genetic introgression is wide spread and has been identified in about half of the wild salmon populations in Norway with as much as 50% of the genome in some populations being of farmed origin. In this session we also learned that from a large escape event in Newfoundland, hybridisation occurred at a large scale in many wild salmon populations, with a decrease in the proportion of farmed-wild hybrids due to natural selection as the fish grew older, but also that farmed genetic introgression is accumulating in the populations. Escaped farmed salmon has been identified as the largest current threat to wild salmon populations, and monitoring programs show that escapees may be found all along the coast of Norway. The level of genetic introgression varies, and is best explained by local farming intensity, and that large salmon rivers have less introgression compared to small rivers. About 60 salmon populations are being stocked in Norway annually. Only locally caught salmon are being used as broodfish, but salmon genetically introgressed from escaped farmed salmon has, up until recently, not been possible to distinguish from salmon of pure wild origin. Consequently, broodfish of some degree of farmed ancestry have been used and offspring from these have been stocked into wild populations, with subsequent effects on the recipient populations. The developed molecular genetic methods for tracing and quantifying farmed genetic introgression has made it possible to study possible changes in important life history traits linked to fitness of the wild populations. In a study comprising 62 Norwegian salmon populations and more than 4000 individuals, a clear change in age at maturity (sea age) and size of the adult returning salmon was observed from farmed genetic introgression. This effect is different between sexes and between populations typically harbouring small- and large-sized salmon, and between salmon populations of different phylogenetic origin.

Domesticated aquaculture species are subjected to both artificial directional selection for commercially important traits and unintentional domestication selection. A common view is that domesticated species eventually will become so different from their wild origin that they will not successfully interbreed with their wild conspecific, and that introgressed populations will, through natural selection, return to fitness optimum when further introgression has stopped. This view is likely to be too simplistic and a multivariate model was presented, suggesting that escapees of domesticated species will impose considerable migration load in the foreseeable future.

Expanding Aquaculture within the Planetary Boundaries

Chairs: Max Troell (Beijer Institute of Ecological Economics, Sweden) and Michael Phillips (Worldfish)

Presenters: Patrik Henriksson, Dave Little, Simon Bush, Ben Belton

The departure for this session is a global food system that is a main driver of humanity but now approaching limits to many earth system processes, being described under the Planetary Boundary framework. Aquacultures future role in the overall food portfolio is still uncertain and will depend on

the direction it develops. Aquaculture has the potential to contribute positively to our ability to navigate our food system safely within the planetary boundaries. The framework has exclusively been linked to agricultures impacts when quantifying the food systems role and, thus, seafood including aquaculture has played only a minor role. This is not surprising considering the dominance of the agriculture sector, and its large contribution to impacts on key planetary boundaries related to climate change, land use change, biodiversity loss, freshwater availability and ocean acidification. However, aquaculture is an emergent sector and will grow and increase its role in the global food portfolio - enabling new options for how impacts from the food system can be altered. Already more than 20% of animal protein originates from seafood - contributing to food and nutrition security around the globe.

The planetary boundary framework is useful from another perspective when discussing aquaculture's future. The way we approach some of the earth system limits will have consequences for aquacultures potential to grow. Climate change will result in many direct and indirect effects that will lead to significant structural changes of the aquaculture industry. Thus, if aquaculture can contribute to reducing pressure on planetary boundaries it will widen its own window for growth.

The session consisted of four presentations that addressed the planetary boundary concept from different perspectives.

First out was **Patrik Henriksson** who's presentation "*Aquaculture's potential role as sustainable protein source*" had a large focus on how lifecycle assessment can present the basis for understanding environmental impacts at a system level and that this methodology increasingly is used for relating production to planetary boundary relevant impacts. He cautioned against misuse of the methodology and how this could lead the development in the aquaculture in the wrong direction, citing recent analyses of carbon footprints of seafood and livestock production, underpinned by inadequate data. Recent research from the Stockholm Resilience Centre (SRC) and WorldFish also show that the environmental consequences of different aquaculture systems and intensities are dynamic and the implications of such differences need to be better understood.

David Little talked about "*Locating sustainable consumption living within planetary boundaries debate*" and argued that consumption of seafood has to be a core part of understanding how a growing aquaculture sector can fit within planetary boundaries. Consumption is a key element of 'sustainable intensification' for which a broader value chain approach is most powerful. This helps us understand that many issues cannot be addressed on the farm alone, such as how the nutritional value of aquaculture products are distributed (export, domestic market) and where reduction of wastes can be targeted (on farm, during processing, through meal preparation). Addressing how fish contributes to diets will be strongly context specific, and its nutritional value compared to substitutes highly variable. Although often aggregated as 'fish', the species, size, stage in the life cycle, season, production system all greatly impact on both the global environmental impact of 'fish' and its human nutritional value. Changing patterns of fish consumption and , particularly, a shift from wild to farmed stocks may be expected to have important impacts on its nutritional impact and contribution to balanced diets. Small wild fish especially if consumed whole, for example, are often relatively rich in micronutrients compared to fillets of larger cultured species. Retaining a diversity of farmed species maybe desirable and/or maintaining production systems that are based on polycultures of both stocked and wild species. This concept might usefully be extrapolated to the system level where 'sharing' of food system space (fish/rice in the water, fruit vegetables on retaining dikes) gives optimal nutritional benefits. The major factors impacting on the planetary boundary and fish consumption dynamic is urbanization and the associated changing food cultures that are occurring. Lower trophic species may give way to higher impact species and the favored format purchased may change. Just as some studies suggest Chinese consumers are moving towards carnivorous species, so the preference for fish marketed live or

increasing demand for ready-to eat formats will have implications for both the planetary boundaries and nutrition.

The presentation by **Simon Bush** "*Operationalising aquaculture improvements – moving from innovations to common practice*" introduced more complexity to the planetary boundary framework by adding a social dimension based on the "Doughnut economy". The main argument was that while the planetary boundary framework allows to understand the status of production systems like aquaculture, it does not enable us to understand why change is not made in spite of the message that the framework gives. There is a need to move beyond measuring status and claims of willingness to change, and instead focus on the everyday practices of those in the food system. Doing so enables a clearer understanding of where change can occur. So called "practice based governance" can potentially lead to changes throughout the aquaculture food system: changing consumer practices, incentivizing retail support to producer improvement, or harnessing shared risk practices to foster area based management strategies.

Ben Belton continued talking under "*Economic and social dimensions of aquaculture growth*" and argued that changes in demand in developing countries will drive the future sustainability profile of global aquaculture. Moreover, aquaculture may make contributions to domestic food security and rural economies that are not captured fully by planetary boundaries metrics. He urged for understanding interlinked environmental, social, economic impacts beyond the farm and throughout value chain. Doing so will, however, require more and better data collected in a systematic manner, and more deliberate methodological integration of life cycle, value chain, and economy-wide impact analysis approaches. Overall, the biggest environmental sustainability gains are likely to come from improved feed use efficiency, which is better for both the farmer and the environment. However, this raises the question of whether the most environmentally efficient models will be socially optimal or desirable, if they require highly capital and technology intensive value chains with highly concentrated ownership structures that potentially generate limited economic spillovers to local economies.

The subsequent panel discussion focused on some pre-determined questions and also allowed the audience to participate with providing feedback on those questions.

A: What do you see being the main challenge for/limits to growth of aquaculture?

- Feed resources will be key as well as food safety issues
- Climate change with its direct and indirect effects will be challenging aquaculture development
- China's aquaculture development will have an impact on other countries ability to increase aquaculture.
- The lack of a social license to operate – based on the ongoing misinformation around aquaculture products and production.
- The relatively limited number of species, which in turn limit the diversity of ways in which fish can be consumed. A higher diversity of species results in more fish being eaten overall. The consequence of not having this diversity is that fish becomes more 'substitutable' with other proteins, such as chicken.

B: Is the planetary boundary framework suitable for discussing limits to aquaculture growth?

- Planetary boundaries framework is one out of many frameworks

- Large impact on many of the planetary boundaries comes from food systems and aquaculture is still only a small part of this. Still fish is usually excluded from many food policies.
- The planetary boundary framework aligns well with LCA impact categories
- The planetary boundaries framework is a great means of communication and advocacy, but it does not provide any guidance on how change can occur to staying within the 'safezone' of the donut. This is where social science perspectives can help – by helping to understand how change and transition processes can be steered and governed.
- The social dimension of the planetary boundary framework is also limited to status indicators rather than process indicators related to the capacity of the industry to solve problems, create innovation and ultimately lead the aquaculture industry to more sustainable production.

C: What is the planetary boundary framework covering, i.e. what is relevant (or not) and what is missing out from an aquaculture perspective?

- A systematic approach to understanding how food systems should be governed – so seeing fish as food along a chain from consumption to production rather than fish as a production system alone (as the planetary boundary framework tends to frame it).
- Understanding social processes that limit or enable change towards any of the indicators outlined by the planetary boundary framework

D: What key technologies and management measures show potential for increasing aquaculture growth sustainably?

- Technological advances in more sustainable energy systems
- Feed development will be key.
- New platforms like e.g. Amazon, Alibaba, enable increased understanding about connectivity and ability to steer both producers and consumers.
- Closed systems will be important
- Spatial management systems, information systems and transparency
- Shifting to a food systems approach – wherein we create new linkages between farmed fish consumers and producers.
- Linkages in the food system will be integrated through new transparent informational flows into the future, creating greater levels of trust in farmed fish food production.
- Going beyond farm level assessments to embed production in wider landscapes – and so developing assessment methodologies (state or market-based) that can assist this.

FISHBOOST – Boosting European Aquaculture by Advanced Selective Breeding

Chair: Anna Sonnesson (Nofima, Norway)

This session presented results from the EU funded project FISHBOOST.

The importance of ensuring genetic variability when establishing selection programmes in aquaculture. *B. Villanueva, M. Saura, A. Caballero, E. Santiago, E. Morales, A. Fernández, J. Fernández, S. Cabaleiro, P. Martínez, A. Millán, C. Palaiokostas, M. Kocour, R. Houston, M. Prchal, L. Bargelloni, K.Tzokas.* Genotyped populations of common carp, European seabass, gilthead beabream and turbot were used in this study. Effective population sizes of all but one of the five studied populations had reduced during the last five generations, i.e. in the time that they have probably been under strong domestication and selection pressure. This shows the importance of maintaining inbreeding when running the breeding programmes.

Genomic selection analyses results on common carp, European seabass, gilthead beabream and turbot. *A.K. Sonesson, C. Palaiokostas, R.D. Houston, B. Dagnachew, M.L. Aslam, T.H.E. Meuwissen.* In five studied populations of common carp, European seabass, gilthead sea bream and turbot, genomic selection resulted in 10-22 percent points higher selection accuracies than the pedigree based BLUP method. Within-family genomic selection resulted in 1-3 percent point lower selection accuracies than the between-family genomic selection. The within-family genomic selection was not sensitive to low SNP marker density. Use of Bayesian method resulted in 1-3 percent points higher accuracies than the BLUP models.

Mapping, sequencing and functional annotation of a QTL region affecting resistance to koi herpesvirus in common carp. *R.D. Houston, C. Palaiokostas, D. Robledo, T. Vesely, M. Prchal, D. Pokorova, V. Piackova, L. Pojezdal, M. Kocour.* In a common carp population, the heritability of overall survival (0/1) to Koi Herpes Virus was estimated to be 0.61. Significant QTL were mapped on LG44. Genomic prediction accuracy outperformed pedigree, but there was a substantial reduction in accuracy with distant relationship between training and validation sets (~30 % lower). The Trim25 gene was suggested as functional gene for this trait.

A closer look at turbot genome reveals a genetic component of parasite resistance: new tools for selection. *P. Martínez, F. Maroso, M. Saura, A. Fernández, A. Blanco, M. Hermida, S. Cabaleiro, A. Doeschl-Wilson, O. Anacleto, R. Houston, A. Millán, J. Fernández, L. Bargelloni, G. dalla Rovere, M.A. Toro, M.J. Carabaño, C. Bouza, B. Villanueva.* In turbot, 18,000 SNPs used to construct a highly dense genetic map used to anchor and refine the turbot genome assembly. Moderate but significant heritability were found for resilience and resistance, and a high genetic correlation between them. Significant association was found for resilience especially at LG19 (13 SNP), 9 Mb explained 33% of the total genetic variance. Suggested functional genes were *DMBT1*, *MARCH8, PLEK* and *TRIM16.*

Use of DNA pooling in genomic selection for a disease trait in Atlantic salmon. *B. Dagnachew, A. K. Sonesson, T.H.E. Meuwissen.* In a large dataset (7000 individuals) of Atlantic salmon, DNA pooling of extreme phenotypes (dead/alive) was tested to be used as a training population for genomic selection. Individual genotyping of all individuals resulted in selection accuracy of 0.718, and when 10, 100 and 200 pools per phenotypic groups were created, selection accuracies were 0.574, 0.623 and 0.692, respectively. When extreme families were pooled, accuracies were somewhat lower.

Successful realized selection response for fillet yield in rainbow trout (*Oncorhynchus mykiss). M. Vandeputte, J. Bugeon, A. Bestin, A. Desgranges, S. Courant, J-M Allamellou, A.S. Tyran, F. Allal, M.*

Dupont-Nivet, P. Haffray. Fillet yield was improved by 0.5-0.7% after one generation of selection. Both sib selection for headless gutted carcass weight and/or ultrasound measurements for fillet yield on candidates were suggested as selection criteria. The selection was correlated with reduced viscera%, and no decrease of head size was seen after one generation of selection. Selection for improved fillet yield is now applied in French trout breeding programs.

Potential for genetic improvement of the main slaughter yields in common carp with in vivo morphological predictors. *M. Prchal, J. Bugeon, M. Vandeputte, A. Kause, A. Vergnet, J. Zhao, D. Gela, L. Genestout, A. Bestin, P. Haffray, M. Kocour.* Heritability estimates of real and predicted slaughter yields were high (~0.5). Real and predicted (ultrasound and external morphological predictors) slaughter yields were strongly genetically correlated (r_g = 0.84 – 0.88). Predicted headless carcass yield was suggested as an efficient selection trait. Selected predictors could also be used as indirect selection criteria for slaughter yields improvement. The expected genetic progress per generation on fillet yield using predicted yield might result in better response than the expected gain obtained by sib selection. Overall, the results suggested a high potential of non-invasive genetic improvement of edible parts yields through selective breeding in common carp.

Optimal schemes for advancing selective breeding to the next level for the main species of European aquaculture. *B. Villanueva, S. García-Ballesteros, J. Fernández.* Software has been developed to optimise designs of breeding programmes. Population and industry specific cases were presented for rainbow trout, turbot, and gilthead seabream. The cases included designs where genomic selection for a disease resistance trait was added to selection for growth only and where indicator traits were used to select for Feed Conversion Ratio. Also, one case was presented where mating designs were optimised.

Cost-benefit analysis of a breeding program for Atlantic salmon. *K. Janssen, H. Saatkamp, H. Komen.* This study presents a case in Atlantic salmon, where economic values of important traits was estimated and used in a simulation program to perform a cost-benefit analysis of selective breeding. One of the traits was a disease resistance trait (lice resistance), which was modelled as the epidemiological term R0, i.e. the number of secondary infections produced by one infected individual. The other traits were different production efficiency traits.

Food Safety

Chair: Türker Bodur (Akdeniz University, Turkey)

Requests for 10 oral presentations were made prior to the session and ordered according to their subjects. Unfortunately, five of the ten presentations were cancelled before the conference and only three were submitted to speakers' preparation before the actual session started.

The opening presentation was made by Melony Sellars about RNAi Antivirals for Shrimp Aquaculture. The second and third presenting authors did not come to the session and with very few participants in the audience and no questions arising from the first presentation, the session was put on hold until the scheduled time for Mohamed Mahmoud's (Germany): Status Update on Malodor Formation and Accumulation Sources in Aquaculture and an interesting presentation by Anis Somani on the advantages deepchilling of shrimp to close the session.

It was unfortunate to have such low attendance. This prevented the presentation and discussion of some of the session posters during the period when scheduled presentations did not actually take place.

Future of Aquaculture Value Chains

Chairs: Olivier M. Joffre (WORLDFISH, Malaysia) and Ben Belton (Michigan State University, USA)

This session arose from a special issue of the journal Aquaculture, on Emerging Trends in Aquaculture Value Chains, co-edited by session contributors Bush, Little and Belton, and including papers from session organizers Joffre and Belton. The special issue brought together the largest collection of research on aquaculture value chains compiled to date, comprising 19 individual papers. Contrary to much recent research on aquaculture value chains, papers in the special issue highlight collectively how the expansion of aquaculture has resulted highly diverse configurations of production for consumption in the global South and underline the greater attention to neglected value chain segments and categories of actor, modes of production, regulation, and innovation, and patterns of access to benefits. This session was organized to showcase papers outlining key themes from the special issue, to stimulate interest in and debate over the future of aquaculture value chains and to identify priorities for future research. Two papers not featured in the special issue, but with complementary themes (Toonen; Verreth), were included in the session.

The introductory paper, *Emerging Trends in Aquaculture Value Chain Research, presented by* Simon Bush offered an overview of key five themes emerging from the special issue, namely: (1) multi-polarity; (2) diversity and scale; (3) dynamics of transformation; (4) performance and equity; (5) technical and institutional innovation. Two conclusions emerge. First, there is a clear need for research on neglected value chain segments and categories of actor, modes of production, regulation, and innovation, and access to both market and non-market benefits. Second, there is a need for more rigorous and diverse research on value chains to better understand the diversity and impact of aquaculture in order to contribute to the sustainable expansion of the sector as a fundamental component of the global food system.

David Little's paper, titled *Sustainable Intensification of Aquaculture - Lessons from Value Chain Actors*, focused on how progress towards sustainable intensification (SI) has been achieved by actors in aquaculture value chains, up- and downstream of the farm. Numerous examples were given of how a diverse array of private sector actors have progressed towards more sustainable outcomes. Barriers to innovation, the impacts of certifiers and standards and trends towards consolidation and/or specialisation in the sector were evaluated. The relative importance of local and introduced technologies in progressing SI were examined, and priorities for key research, development and policy actions were discussed

Hilde Toonen presented a conceptual introduction to *The Aquaculture Governance Index* – an tool under development by an ongoing project implemented by the Monterrey Bay Seafood watch and Wageningen University. The project has introduced a set of Aquaculture Governance Indicators (AGIs) which aims to identify potential gaps in existing governance systems and provide guidance to the organisation and regulation of aquaculture improvement in any given country. The AGIs are based on four governance dimensions on three levels: (1) the performance of legislation and prescriptive codes and standards; (2) collaborative arrangements between public and private actors; (3) capabilities of these actors to engage in governance are assessed. The AGIs provide a framework for moving beyond the performance of production to assess the capacity of public and private rules and actors to organise the identification, assessment, and responses to a range of sustainability challenges.

In keeping with the theme of multi-polarity, Johan Verreth's presentation on *Feeding Europe Farmed Fish* analyzed whether Europe will be able to maintain enough imports of farmed fish in the face of growing competition with other international markets, but reviewing trade production, trade and consumption data for Europe and three Southeast Asian countries (Bangladesh, Thailand and Vietnam). Four important trends emerged. (1) Aquaculture production and consumption in the EU has stagnated

over the last decade, but boomed in Southeast Asia. (2) Europe's consumption of seafood has levelled off, while consumption in Southeast Asia has continued to expand for both the rich and the poor. (3) The share of farmed fish exported from Thailand and Vietnam to Europe is declining. (4) The EU will continue to become more dependent on seafood imports from other parts of the world to maintain its current level of fish consumption, just as it is losing market share to emerging domestic markets and new export markets such as China. To maintain aquaculture based consumption into the future Europe will either have to expand production, or trade agreements will be required to capture enough fish in an ever more competitive global market

Highlighting another theme from the special issue, Ben Belton presented on *The Quiet Revolution in Aquaculture Value Chains.* The presentation identified seven key trends in the transformation of Asian aquaculture value chains. (1) Urbanisation has stimulated demand for fish as wages rise and diets diversify. (2) Growth of fish supply has been enabled by the growth of non-farm enterprises. (3) Farms and supporting businesses have merged in a largely 'immanent' or 'unplanned' way, supported by the provision of public infrastructure. (4) Value chains have undergone rapid technological change in all segments as they have modernized. (5) Structural changes have occurred throughout the chain as farms and related firms have proliferated and become more specialized. (6) Product differentiation has occurred over time in line with the product cycle, as species become commoditized, prices have fallen, and new 'niche' species have been introduced as alternatives. This process has resulted in farmed fish becoming accessible to greater numbers of low income consumers.

Olivier Joffre completed the session with a paper on *Value Chain Innovation Research in Aquaculture*, taking up another of the special issue's key themes. The presentation showed that there is limited systematic knowledge of how innovation has been approached in the aquaculture literature - and analyzed different approaches to innovation used in aquaculture development with a specific focus on value chains, to identify gaps in aquaculture innovation research and discover potential complementarities between different approaches to innovation. One hundred publications on innovation were selected from the aquaculture literature using a systematic review methodology. Most of these (61%) focused on *Transfer of Technology* driven approaches. Other value chain research focused mainly on analysis of regulatory frameworks and quality standards. Integrating elements of *Farming Systems*, *Inclusive Innovation* and *New Product Development* approaches would help to operationalize value chain research to provide specific outcomes for poverty alleviation.

Genome Regulation and Manipulation

Chair: Atle Bones (NTNU, Norway)

The session covered a range of topics and approaches from targeted gene editing to radiation inactivation of maternal nuclear genomes. Genetic approaches in fish were at the center of the session which also included talks on marine algae and shrimps.

Novel technologies now open for transgene-free editing of genomes. This will leave no "alien" or foreign DNA in the edited organism and as such should be dealt with as a non-GMO. In the next few years it must be expected that genome editing techniques using either ribonucleoproteins or episome based approaches will be developed and used which will challenge present day regulatory system for GMOs. The outcome of such genome editing would be more targeted and represent smaller/fewer genetic changes than a traditional mutagenesis by radiation of chemical methods.

Expression of double stranded DNA in enteric bacteria to silence virus genes and prevent virus infections was shown to be a promising principle for virus control in shrimps and the approach should be of interest also for other species/organisms.

Interest in lipid metabolism of species used in aquaculture is high and spans from gene expression studies to characterize endogenous transcriptional activity to the utilization of gene editing for functional studies of endogenous desaturases and elongases.

Breeding programs might benefit from the use of gynogenesis/androgenesis where only the genetic material from one parent is transferred and might also expose recessive alleles. Genetic effects of the treatment to produce such lines were discussed.

Expression of transgene material to increase growth is a tempting approach and might increase efficiency and output from cultivation. One principle that has been discussed and experimented with for some time is overexpressing growth hormones. In Europe such fish expressing a transgene growth hormone will be considered GMO and strictly regulated if approved for commercial use.

DNA methylation has a role in epigenetic regulation of gene expression. Temperature stress in rainbow trout had only small effect on the epigenetic modifications but a more pronounced effect of longer exposure and Δtemp should not be ruled out. Another study reported the expression patterns of methyltransferase genes during gametogenesis and pointed to a role of epigenetics mechanisms during gametogenesis.

Hatchery Technologies, broodstock management, larvae and juvenile management

Chairs: Maria Celia Portella (Aquaculture Center, Brazil) and Isabel Represas (INVE Aquaculture, Belgium).

Sponsor: INVE Aquaculture

The first part of the session "Hatchery Technologies and Broodstock Management" was chaired by Dr. Portella and included the presentation of 8 papers covering several topics, among them biotechnology, artificial intelligence, cryopreservation, gamete quality and daily rhythms for *in vitro* fertilization in fish.

The session was opened by a presentation from Dr. Jean-Jacques Lareyre, from INRA, that set the scene by describing an innovative biotechnology for germ stem cells transplantation that could be implemented in fish farms to conserve and regenerate the genetic characteristics of selected populations in fish. The study demonstrated the efficiency of the method and its practical application.

The second presentation was given in Russian, with translation to English. Dr. G.G. Matishov presented an overview of Russian aquaculture and the experience of the Southern Scientific Center of the Russian Academy of Sciences in the development of biotechnologies and new technical methods for introduction of so-iuy mullet, pike-pearch, pike and vimba into the aquaculture of South Russia.

Artificial intelligence was the subject of the next presentation. Dr. Valérie Robitaille, from Xpertsea Solutions Inc., presented new technology to generate accurate and reliable data to count and measure small aquatic organisms. An artificial intelligence approach using machine learning and computer vision was developed to accurately predict the number of prawn post-larvae in a production setting with > 97% of accuracy and 2.1% SD. According to the author, manual counting error estimation is about 20%.

Other algorithms can be developed to predict other species, considering color, size, shape, heterogeneity etc.

The results of cryopreservation of wels catfish sperm were then presented from a lab scale trial, considering different glucose-based extenders and cryopreservation of large volume of sperm (4 mL straw and 10 mL cryotube). The authors concluded that 6% fructose extender and 10% methanol cryoprotectant was the most suitable freezing media for wels catfish sperm and the application of 10 Ml cryotube was successful. The next step will be to reproduce the propagation technology in fish farms.

The next three presentations dealt with gamete quality, basic information to establish captive production commercially viable. Maria Fernández-Mígues presented the preliminary results on her attempt to identify genes and maternal factors involved in embryonic development of Atlantic cod. Conventional egg quality indicators (fertilization rate, normal cleavage pattern, egg mortality) and differential expression of the stage-specific genomic markers will be compared to understand the function of the temporal transcriptome activity during cod embryogenesis and its relation to egg quality and maternal effect.

Lumpfish is a new species of commercial interest in Europe mainly for biological control of sealice and more research are needed for closed lifecycle management. In this presentation, Dr. Samuel Pountney described the reproductive development in lumpfish and the effects of holding temperature during the spawning season on productivity and gamete quality of captive lumpfish broodstock. The authors concluded that to assure viable gametes (oocytes and milt), captive lumpfish broodstock must be held at temperatures below 10 °C during the spawning season. The study is the first step in understanding environmental optima regulating reproductive development in the species and to go forward, adjusting rearing conditions for commercial rearing programs.

Another new species for aquaculture diversification in Europe and Canada was the focus of investigation presented by Dr. José Beirão. Eggs of spotted wolffish (*Anarhichas minor*) obtained in three hatcheries (two in Norway and one in Canada) were analyzed regarding different egg quality parameters as well as the biochemical composition of the stripped eggs. The data were compared with egg development, hatching and larvae survival. The authors argue that the data obtained will help to build evaluation schemes that can be used to select rearing protocols, breeders and gametes for in vitro fertilization, as well as to develop broodstock feeds for spotted wolffish.

The final presentation was related to the daily rhythm of *in v*itro fertilization in fish. After an introduction on the physiological functions that exhibit rhythmicity regulated by a biological clock that keeps track of time, Dr. Juan Fernando Paredes presented evidences of the existence of daily *in vitro* fertilization rhythms in zebrafish and in Senegalese sole (*Solea senegalensis*). Maximum success was achieved around the specie-specific natural spawning time (diurnal or nocturnal for zebrafish and sole, respectively), indicating that the time of the day should be considered when establishing protocols for *in vitro* fertilization in broodstock fish farming.

Isabel Represas chaired the second part of the session, where 8 papers were presented out of the 9 submitted. The first presentation in the afternoon session was given by Sherezade Carrillo, talking about the combined effect of daily thermocycles and light spectrum during early development of fish, looking at hatching rate, larval growth, feeding activity and mortality. The results revealed the best performance was observed when environmental conditions are similar to wild conditions, constant temperature and red lighting conditions affected negatively the larval development.

The gap in the program created by the no-show of her next planned presentation was covered by a **stimulating group discussion about the technology or innovation that has the most potential to change aquaculture.**

The participants were very cooperative and enthusiastic with the subject and the outcome of the discussion can be summarized as follows:

- Digital technology will play a big role in the future of fish hatcheries.
- Data collection will go up and help farmers to increase predictability and efficiency.
- Monitoring all parameters of farming in relation to the environment will make the fish farming industry more predictable, regardless of disease outbreaks, health risks and other threats.
- The introduction of stricter biosecurity and health management strategies will allow the further expansion in production.

Getting back to the programme, in the next presentation, Dr. Elin Kjorsvik was talking about the extensive work in Functional Development of Lumpfish Larvae in relation to growth and diet and the results obtained using different feeding regimes.

Dr. Luis Conceiçao then presented high-performance microdiets, explaining that nutrition is always a matter of balance. High-tech microdiets are thus a balance of nutritional requirements, digestibility, bioavailability, leaching, floatability and dispersion.

The impact of post-ovulatory ageing on the development of diploid and triploid Atlantic Salmon was the paper presented by M. Clarkson. He pointed out that investigating a range of egg quality parameters may highlight particular biomarkers that could be used as real-time indicators to determine the potential of egg populations.

Aquaculture livestock insurance was the subject of the next presentation. Cedric Audor show the importance of being covered for the farmers to guarantee the future of their business. Aquaculture insurance is not something we can afford to ignore. It will guarantee the future income and ensure the long-term survival of the business.

The next two presentations focused on the recent advances in larval rearing, the innovations on Artemia technologies and on live food.

The presentation was covering new concepts of optimized use of live food and early weaning diets, the impact of the use of immunostimulants during early stages, and new concepts that aim to control the environment by means of microbial management to boost the intrinsic potential of the fish larvae to a maximum during the early phases. The effect of the different strategies on survival, growth and subsequent fry quality in terms of deformities and robustness.

The final presentation was giving by Luis Andre Sampaio talking about the effect of stocking density on production of Juvenile flounder.

Immunology and Pathology

Chair: Nerea Roher Armentia (Autonomous University of Barcelona, Spain)

The Immunology Session had a vast participation with 23 oral presentations. The talks aroused much interest and there was room for discussion with several questions from the audience. Presenters came from different research groups, all over Europe mainly but also from Asia, and focused on a wide range of species from invertebrates to finfish. Research themes addressed issues such as trained immunity, diet supplementation or immune response against parasites, using a broad range of methodologies including genomics and proteomics.

More than half of them focused on trained immunity as emerging concept that explain very well the immune response in invertebrates since invertebrates have evolved defence systems only based on innate immune mechanisms. Trained immunity is based on epigenetic mechanisms including DNA methylation and histone modification. Moreover, in some species trained immunity seems to be transgenerational and based on epigenetic molecular marks. Other research in antiviral response in oyster showed that protection could last until 4 months. This fact opens the door to think about the possibility to develop vaccines for invertebrates such as molluscs or crustaceans. Trained immunity has also been described in finfish (turbot and zebrafish) but the effects on survival after infection needs to be further studied.

Other issues, such as the description of macrophage response in Nile tilapia, the gills cell response or the HPA axis responses in gnotobiotic larvae were relevant. Different researchers pointed out that activation of the immune system has an energetic cost and that the supplementation of diets is a strategy to cope with this.

Overall, this session was a real success and demonstrated the increasing focus on trained immunity as a way to control infections in invertebrates and to improve health status in finfish. There is clearly a lot more research required in all scientific fields to develop tools based on the knowledge of the immune system mechanisms. All of these will help developing the immunostimulation, the survival and thus the production of different species.

Integrated Multi-Trophic Aquaculture

Chair: Thierry Chopin (University of New Brunswick, Canada)

The Integrated Multi-Trophic Aquaculture (IMTA) session, originally planned as a one-day session, had to be extended to 1.5 days due to the number of abstract submissions, which is a sign of the vitality of this innovative aquaculture practice and its evolution. The session took place in one of the large rooms of the Corum Conference Centre and was attended at full capacity.

There were 23 presentations from 15 countries: 5 from Portugal, 3 from Canada, 3 from France and 1 from each of Malta, Sweden, Norway, Israel, Madagascar, Bangladesh, Indonesia, Greece, Oman, Spain, the USA and South Africa.

The examples of IMTA systems described in these different presentations illustrated very well the flexibility of the IMTA concept. The different combinations of organisms included marine fed fish and invertebrate species (salmon, sable fish, seabream, seabass, meagre, red drum and abalone), freshwater fed fish species (carp, roach, perch and catfish), marine macroalgae (brown, red and green seaweeds), halophytes (sea knotgrass, sea purslane and saltwort), terrestrial plants (rice, tomatoes and *Azolla* ferns) freshwater microalgae (phytoplankton and periphyton), bacteria, suspension-feeding and

deposit-feeding invertebrates (mussels, oysters, sea cucumbers, sea urchins and polychaetes), detritivore fish (grey mullet) and omnivorous/vegetarian fish (giant gourami).

It is important to remember that IMTA was never conceived to be only the cultivation of salmon, kelps and blue mussels, in temperate waters, and within the limits of existing finfish aquaculture sites. That is how it started in Canada, in order to be able to conduct experiments at sea, within the limitations of the regulations presently in place. This is only one of the many variations on the IMTA central theme, just like in the music of J.S. Bach.

These examples show that IMTA can be applied worldwide to open-water (cages, rafts and long-line systems) or land-based systems [earthen ponds, recirculating aquaculture systems (RAS), tanks and agri-aquaculture systems], marine or freshwater systems (aquaponics), and temperate or tropical systems.

IMTA fits into circular economy thinking very well. We have to stop seeing nutrients as wastes or by-products, and consider them as co-products, useful for the cultivation of other crops in more efficient and responsible food production systems, while bioremediation of coastal nutrification takes place.

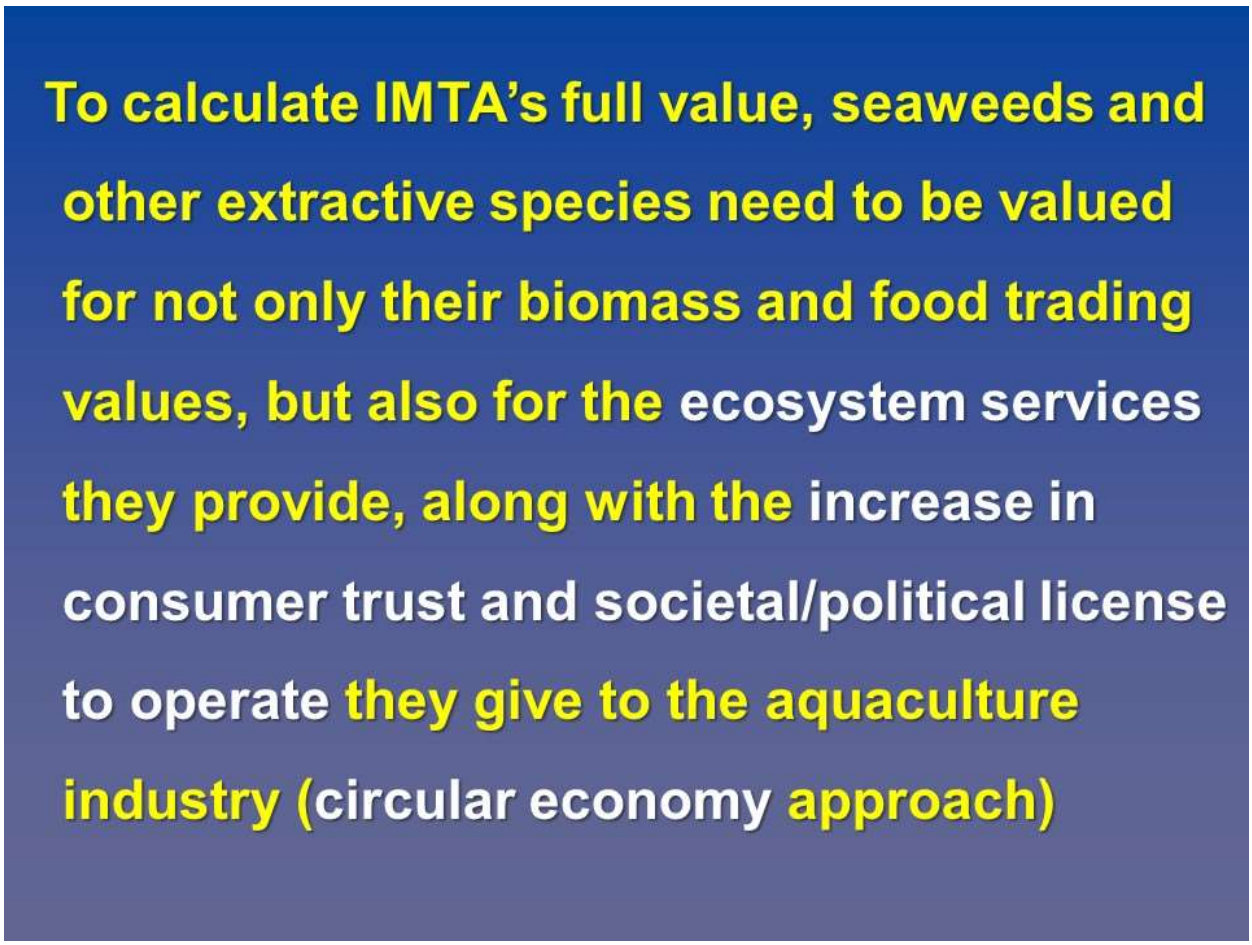
Because different nutrients (small particulate organic nutrients, large particulate organic nutrients, dissolved inorganic nutrients) need to be recaptured, different spatial and temporal strategies should be designed. This means that the different components of an IMTA system do not, necessarily, have to be right at the same location (e.g. within relatively small finfish sites), but that entire bays/coastal areas/regions could be the units of IMTA management, within an Integrated Coastal Area Management (ICAM) strategy. The “Integrated” in IMTA should be understood as cultivation in proximity, not considering absolute distances, but rather connectivity in terms of ecosystemic functionalities at the ICAM scale.

Nothing says that only one company needs to be in charge, producing all the IMTA components. There may need to be several companies coordinating their activities within the ICAM.

“Multi-Trophic” refers to the incorporation of species from different trophic or nutritional levels in the same system. It is not enough to consider multiple species (like in polyculture); they have to be at multiple trophic levels, based on their complementary functions in the ecosystem. The co-cultured species should be more than just biofilters; they should also be harvestable crops of economic value or potential.

Moving IMTA along the Research & Development & Commercialization continuum will require profound regulatory and policy changes. The placement of the different components of an IMTA system, and the scale at which it will be managed, will certainly trigger changes to regulations, as they were designed without IMTA in mind in most countries. Regulations governing aquaculture are often designed with a single species/group of species in mind, just like fishery regulations, and can inhibit a more holistic approach by not considering species interactions and an ecosystem-based management approach.

The apathy for changes can be frustrating. We are still in the infancy of western IMTA (after all, we have been improving agriculture for centuries and it is still not perfect). Science and society need time to think and evolve. The adoption of IMTA will not happen overnight, especially in the western world, which presently prefers monocultures, linear processes and short-term profits. We will need patience, determination and persistence to get people to see the advantages of growing complementary species together, creating circular economy processes and seeking sustainability in the long term.



To calculate IMTA's full value, extractive species will need to be valued for not only their biomass and food trading values, but also for the ecosystem services they carry out, along with the increase in consumer trust and societal/political license to operate they provide the aquaculture industry. The value of the ecosystem services should be used as financial and regulatory incentive tools (e.g. nutrient trading credits). Moreover, the IMTA multi-crop diversification approach (fish, seaweeds and invertebrates) could be an economic risk mitigation and management option to address pending climate change and coastal acidification impacts.

Presenters at the session agreed that there is no ultimate IMTA system to feed the world. Different climatic, environmental, biological, physical, chemical, economic, historical, societal, political and governance conditions, prevailing in the parts of the world where they operate, will lead to different choices in the design of the best suited IMTA systems. Species selection, combinations and proportions will be highly variable depending on the local conditions and biodiversity.

Presenters concurred that IMTA is a concept, not a formula. Being highly flexible and ever evolving, it cannot, consequently, be reduced to a short bureaucratic definition. After all, nobody is requesting a narrow definition for sustainable aquaculture or offshore/exposed/high energy aquaculture; why would we, then, attempt to provide a reductionistic definition of IMTA, indicating species, type and number of infrastructures, distances, etc. when, in fact, it is its versatility that makes IMTA remarkable.

Live Feeds

Mike Schwartz (Virginia Seafood AREC, USA)

The AQUA 2018 Live Feeds Session provided a robust dialog on emerging issues and trends in live feeds, as they apply in marine and freshwater larviculture. The thematic topic focused upon the ever-increasing demands for smaller and more nutritionally complete live feeds to support not only larviculture optimization, but also larviculture for emerging species with significant constraints to traditional live feeds.

More than half of the presentations, and most of the dialogs dealt specifically with the topic of copepods, identifying new culture techniques, new observations and insights, and discussing industrial R&D needs to advance industrial larviculture production. In short, the emerging species promoted by industry have larviculture live feeds requirements that cannot be met by current rotifer and Artemia practices.

While copepod nauplii have been shown to address most of these needs, there remains a dearth of copepod species to culture, and very little useable information towards industrial copepod production at the farm level. A synopsis conducted at the end of the session focused upon the need for accelerating integration of academic and industrial programming towards expediting new copepod technologies to the industry.

Note: EAS has a Thematic Group on Copepods. https://www.aquaeas.eu/groups-new/eas-thematic-groups

Marine Spatial Planning (Siting, area management, zoning and GIS)

Chair: José Aguilar-Manjarrez (FAO)

The session included 13 presentations from different regions and countries around the world (i.e. Belgium, Brazil, Europe, Germany, Indonesia, Italy, Turkey, Mayotte Island, Norway, Indonesia, the United Kingdom of Great Britain and Northern Ireland and the United States of America). The presentations addressed a wide range of subjects pertinent to the use of marine spatial planning in aquaculture, including advances in technology, gaps and future trends in marine spatial planning and the challenges and knowledge needs currently facing the aquaculture industry.

State of the art technology

Efforts to promote spatial planning under the ecosystem approach to aquaculture (EAA) and move aquaculture development towards improved sustainability were presented and key opportunities for the evolution of the EAA in the next decade were highlighted.

Assessments tools have been developed to understand how the aquaculture industry is managed and how shared natural resources are protected under a broader approach to management, commonly referred to as zonal aquaculture management or area management.

Spatial planning tools are being developed and tested to help stakeholders to better define acceptable impacts from aquaculture on coastal areas, drawing on expertise in biology, ecology, economics, sociology and computer science. Novel approaches to estimating ecological carrying capacity to plan the development of sustainable aquaculture are being developed, using a combination of models which together are used to understand the different components of a system such as a catchment, inner bay or an extended bay area. Coupling of farm, hydrodynamic and particle tracking models are also being implemented to estimate accumulation of solids on the seabed and assess associated benthic effects.

The application of these modelling approaches offers powerful methods to define *a priori* the scale and type of culture systems adapted to each site by screening a range of possible farm/site combinations.

Spatial technologies, like many other information technologies, are developing rapidly. Some of these technologies include advances in satellite remote sensing, aerial surveys, global positioning systems, geographic information systems, information and communications technology, and underwater and meteorology sensors. A good example of the application of spatial technologies in aquaculture is a project that is using drone-mounted cameras to monitor water quality in reservoirs, lakes and rivers in real-time for aquaculture management. This project will eventually help engineers to deploy water quality fixes.

Spatial technologies may also be applied in the field of disaster risk management (DRM) within the aquaculture sector. DRM requires interrelated actions and activities to ensure early warning, prevention, preparedness, response and recovery for a wide range of natural, technological and complex disasters that can impact aquaculture operations and livelihoods. A new publication that describes and provides guidelines for the application of spatial technologies for DRM in aquaculture is currently being drafted by FAO.

Advances are being made with the development of spatial planning tools that simulate scenarios and possible spatial overlaps with other marine activities, thereby helping stakeholders and decision-makers to analyse both conflicts and synergies among various coastal activities. Multi-use approaches have emerged to encourage spatial efficiency in the use of marine resources. These approaches mark a departure from the concept of singular, exclusive resource rights and a move towards the inclusive and synergistic sharing of resources and marine space among different sectors.

Gaps and/or future trends in marine spatial planning

A number of topics should be pursued in order to address gaps and future trends. Some of these are mentioned here.

- Disease is probably the main threat, and cause of disaster, to aquaculture all over the world and combatting disease requires spatial planning at all scales. The development and implementation of biosecurity, zoning and compartments and strategies for infected zones and disease-free zones is increasingly recognized by countries and industries as essential to the sustainable growth of aquaculture.
- The economic science of marine spatial planning is in its infancy and only a handful of studies in this area are cited. Other gaps that should be pursued are: innovative ways to identify needs and capacities for spatial planning at all levels of administration; and increase of capacity building in spatial analyses. Here, lessons could be learned from other disciplines and institutions that have been successful in reaching large audiences with low cost, effective solutions via the Internet and/or other mechanisms.
- Science-based tools are needed to inform the development and regulation of offshore marine aquaculture. Although much can be learned from nearshore aquaculture, moving offshore requires new scientific information and the refinement of models used for nearshore marine aquaculture.
- An area of active development is virtual reality. In a virtual reality, computer-driven simulation, the operator is immersed in a realistic multimedia presentation. Virtual reality systems are being used to test public perceptions of aquaculture by developing scenarios for coastal water uses (e.g. aquaculture, energy and leisure), and to inspect fish cages and moorings.

Challenges/knowledge needs for the industry
If it is to advance, the EAA will need to take into account climate change adaptation, visibility of small-scale producers, and ongoing developments related to the achievement of the Sustainable Development Goals. The expansion of value chains and the emergence of complementary planning approaches will ensure its continued relevance in the next decade.

The session underscored public perception as one of the current challenges to aquaculture expansion in Europe and North America. Consequently, there is a need to explore and better understand attitudes towards the aquaculture industry and the ways in which it interacts with other marine users.

Another significant barrier to aquaculture development is the complexity of the administrative processes required to obtain a license. New and flexible approaches are needed so that licensing and regulation become less costly and more transparent and efficient.

Decision-makers, faced with spatial data and output from spatial planning analyses, often lack a basic understanding of spatial planning technologies, including their limitations, strengths and the kinds of questions that can be addressed by them. This lack of understanding inhibits the use of these technologies for informed decision-making. Building a solid foundation for the use of spatial planning tools will require technical guidance, capacity building and promotion of spatial planning tools at decision-making and technical levels. Spatial data sharing within and across disciplines is also crucial, but only a small proportion of potentially useful information is actually shared. Despite some notable advances, there is still a need for facilitated data sharing agreements.

The spatial inventory of aquaculture at sub-national and especially at individual farm level, with attributes that include, at least, species, culture systems and production, are necessary to support spatial planning scenarios and better estimate the potential impacts of aquaculture on the environment and ecosystems.

Complementary presentations
Over 15 complementary presentations were made in other sessions. These highlighted the cross-cutting nature and multiple advantages of spatial planning in addressing aquaculture development. The range of topics included, *inter alia,* modelling the implications of climate change, such as changes in sea surface temperature, for strategic planning and management of aquaculture; new methodologies for spatial and temporal management of fisheries and aquaculture in coastal areas; spatial planning tools for the development of offshore oyster farming; a 3D hydrodynamic-biochemical model coupled with a kelp growth model to estimate the cultivation of kelp; spatial scenarios for the allocation of suitable aquaculture activities within marine protected areas; and hydrodynamic connectivity between shellfish farms.

Micro & Macro Algae Culture

Chairs: Aleksander Handå (SINTEF, Norway) and Eric Causse (Greensea, France).

Session sponsor: GREENSEA

Successful and predictable production of high-quality biomass are being targeted to make significant steps towards industrial land- and sea-based macroalgae cultivation world-wide. To achieve this, interdisciplinary knowledge platforms are being developed on production biology and technology for macroalgae cultivation over a wide range of climatic, ecological and physical conditions. Biological performance and environmental requirements for optimized chemical

composition and biomass production of selected algae species are being studied to obtain technological specifications and develop generic model and simulation tools for land- and sea-based farm systems and biomass production. The brown kelps *Saccharina latissima* and *Alaria esculenta*, the green algae *Ulva lactuta* and the red alga *Palmaria palmata* are currently being studied as promising species for industrial cultivation.

Ongoing projects delivers knowledge on seedling quality, tank- and sea-cultivation, nutrient mass-balances for waste-water treatment and IMTA, fouling and diseases and functional genetics of selected species. Growth models are being developed and coupled with 3D hydrodynamics-ecosystem models to estimate site-dependent biomass production. Conceptual studies are being done to enable efficient automated seeding, deployment and harvest. Drag forces are being measured in flume tank experiments and numerical models for simulation and visualization of farm designs in dynamic marine systems are being developed. Finally, potential impacts of industrial macroalgae cultivation on coastal ecosystems are being studied to develop decision-support to ensure good environmental management practices thereby securing sustainable industrial development.

Microbial and Marine Algae in Aquafeed

Chairs: Luisa Valente (CIIMAR, Portugal and Kjell Inge Reitan, NTNU Norway).

This session took place in Sully2 room that was clearly too small for the high number of attendees. So, many were standing or not even being able to get into the room, showing the great interest the topic has attracted.

The Microbial and Marine Algae in Aquafeed session joined two COFASP ERA-NET projects for the Cooperation in Fisheries, Aquaculture and Seafood Processing: “Microbial raw materials as source for protein and EPA and DHA for use in aquafeed – MICRO-Feed” coordinated by Kjell Reitan from Norway and “Improving Bio utilisation of Marine algae as sustainable feed ingredients to increase efficiency and quality of aquaculture production – Marinalgae4aqua” coordinated by Luisa Valente from Portugal (http://marinalgae4aqua.ciimar.up.pt/). The main target of both projects is focused on proposing new sustainable protein and lipid sources for aquafeeds either from heterotrophic microorganisms or from algae (micro- and macroalgae).

The global supply of fish oil is limited and cannot meet the future demands for aquaculture and human consumption. Aasen et al. from Norway presented the production of marine, heterotrophic microorganisms (thraustochytrids) for use as source of long-chain omega3 fatty acids in aquafeed and discussed ways of improving its productivities and nutritional value through manipulation of the cultivation conditions.

Pereira et al. from ALGAplus in Portugal reviewed the production of seaweed biomass focusing on availability and differentiation factors. The diversity of seaweed and of their chemical composition makes them potential ingredients in aquafeed. Some of the differentiation factors, such as amino acid profile, were compared with that of common ingredients (such as soya). Nevertheless, more research is needed particularly with seaweed obtained through cultivation (rather than wild harvested), with the possibility to improve its quality. The various applications of seaweeds, including extraction of bioactive factors for diverse markets was discussed.

Microalgae are natural primary producers of n-3 LC-PUFA and are widely used in aquaculture either for direct consumption or indirectly as live feed for fish larvae. Wang et al. from Norway evaluated the influence of environmental factors on the lipid content and fatty acid profiles of *P. tricornutum*,

Isochrysis aff. *galbana* clone T-Iso, *R. baltica* and *N. oceanica* cultivated by batch and semi-continuous culture to create a gradient in N limitation. The highest amount of lipids was found in *N. oceanica*, and the highest DHA productivity was found in T-Iso from batch culture. This study concluded that *N. oceanica* and T-Iso are promising microalgae strains for producing long-term alternative source of lipid and *n*-3 LC-PUFAs for fish feed.

Vadstein et al. also from Norway highlighted the need for microbes´ strain improvement as production organisms of DHA/EPA.

Valente et al. from Portugal presented different technological processes developed to improve the bio-utilisation of both macro- and microalgae in European sea bass *Dicentrarchus labrax* juveniles. Algae were submitted to physic and enzymatic treatments before drying. Both disruption methods clearly promoted cell disintegration and increased the soluble protein fraction. In a digestibility trial, *Chlorella* sp. showed higher protein digestibility values than *Tetraselmis* sp., only surpassed by *Nannochloropsis* sp. after enzymatic processing. In terms of seaweeds, *Gracilaria* sp. seems a better protein source than *Ulva* sp. to be incorporated in sea bass diets, irrespectively of processing, and can be further improved by physic processing.

Sevgili et al. from Turkey evaluated the incorporation of *Thraustochytrids, Phaeodactylum tricornutum* and *Nannochloropsis oculata* in diets for juvenile European sea bass.

The quality of feed ingredients is often assessed based on their nutrient composition and potential to support fish growth. Sørensen et al., from Norway evaluated the growth and intestinal health of Atlantic salmon fed with microalgae *Nannochloropsis* and *Tetraselmis* as replacements for fish meal or fish oil. Pre-extrusion of *Nannochloropsis* tended to have a positive effect on fish growth compared to the other algae-fed fish groups. Pre-extrusion of *Tetraselmis* significantly improved the antioxidant response based on the higher expression of the related genes in the liver.

Gong et al. from Norway evaluated the effect of feed additives on the utilization of microalgae *Nannochloropsis* sp. fed to Atlantic salmon *Salmo salar.* Nutrient digestibility values of microalgae-included feeds were lower compared to the reference feeds. The specific growth rate and feed conversion ratio of the fish did not suggest any positive influence of the additives.

It was concluded that there is a huge potential of both heterotrophic microbes and algae, both micro- and macroalgae, as sources of long-chain omega3 fatty acids and protein to incorporate in aquafeeds. But production costs and availability are still major problems to be addressed. Moreover, many algae have cells walls hard to digest by carnivorous fish, but new processing technologies can help improving the bio utilisation of such algae by fish.

Molluscs

Chairs: Aad Smaal (Wageningen University, Aquaculture and Fisheries Group, NL) and Marion Richard (UMR MARBEC, Ifremer, Sète, France).

In the two-day mollusc session, 29 presentations were given by participants from 12 countries including European countries, New-Zealand, USA and Canada. All papers except one about Abalone, dealt with Bivalves. The session was organized along the life cycle: (i) early life stages - oocytes, hatchery production and spat collectors -, (ii) culture techniques and how to handle environmental factors, (iii) pathogens, diseases and genomic selection, and (iv) interactions with the ecosystem and development of modelling tools.

Early life stages

There were 9 papers about reproduction, larval development and recruitment. In cockles atresia of oocytes was reported also before spawning; there was no difference between fished and non-fished sites. The cause of atresia is still unknown. In an offshore farm at the Basque coast reproductive cycle of mussels, flat and pacific oysters was examined as a basis for aquaculture development in the area. There was a low parasite prevalence and spawning periods were registered. In Mali Ston Bay (Croatia) flat oyster culture is under pressure due to lack of recruits. Hence a hatchery was set up and it was shown that recruitment in January resulted in harvest size oysters in next December, while April recruitment took loner time for harvest, till July in the next year. In a study from Iran it was demonstrated that pearl oyster larvae performed better with a diet that contained high levels of 18 C fatty acids such as in *Isochrisis*, compared to Chaetoceros. For *M galloprovincialis* gene expression during ontogeny was shown to be different in different development stages, suggesting gene expression regulation. Immune genes such as antimicrobial peptides suffer a decreased expression during metamorphosis. A Canadian study showed positive effects of underwater noise from vessels, in combination with sufficient pico-phytoplankton supply as being a settlement trigger for blue mussels. In the Thau lagoon, oyster pediveliger abundance was higher outside shellfish farms where also the nano and microphytoplankton quantities were larger. This is explained by top-down control in shellfish farms. A Dutch study showed changes in mussel seed provisioning for farming, from bottom dredging on wild beds to suspended seed mussel collectors. This is done to secure seed supply in years with failing bottom settlement, but also in response of pressure from NGO's to stop bottom disturbance in the Dutch Wadden Sea. At present ca 50 % supply is through collectors. In New Zealand there is also a need for a more secure seed supply for the greenshell culture. Research is focused on the spawning cycle in the wild and the retention of spat on ropes.

Culture techniques

There were 6 papers on different aspects of culture techniques. From Denmark a presentation was given about bottom culture rather than wild fisheries. The benefit turned out to be limited due to starfish predation but avoiding anoxia by transplantation looks promising. In a presentation from the US west coast the role of cementing scallops was addressed. Cementing has pros and cons and the relevance depends on site and timing. From the Baltic Sea results were presented about the consequences of starvation upon the general condition of blue mussels under low salinity; Authors recommended incorporation of water in body tissue as good quality indicator. Various papers were presented about cultivation factors that have an effect on bivalve growth, survival and taste such as local density (offshore culture along the Basque coast), inundation (for off bottom oyster culture in NL) and diet characteristics (for the taste of oysters).

Pathogens, diseases and genomic selection

Seven papers were presented about pathogens, diseases and genomic selection. A study form US Virginia showed that aerial exposure of oysters promoted Vibrio development. Authors recommended that growers harvest intertidal oysters as close to initial aerial exposure as possible. A model study on Vibrio infestation into oysters demonstrated the importance of haemolymph for initial colonisation and the septicaemic nature of the disease. Another Vibrio study dealt with the brown ring disease in Tapes. This study highlighted major genome differences between healthy and diseased individuals and provided information regarding the role of brown ring as part of the disease. Some paper highlighted that mass selection is usable to improve survival during summer mortality in oysters. Finally, a study was presented with a focus on genetic parameters of growth, morphologic, behavioural and immune traits in the European abalone.

Environmental interactions

Seven papers were presented about the relation between bivalve aquaculture and environmental factors. In the Thau lagoon, it was demonstrated that mortality of juvenile oysters stimulated development of picoplankton and ciliates due to tissue decay. Oyster juvenile filtration and mortality shifted the microbial food web structure toward a heterotrophic microbial system. In Canada, bivalve particle filtration was analyzed in relation to pumping rate; it was shown that particle retention in oysters was more efficient at higher pumping rates; for mussels there was no significant relation. Rejection of particles as pseudofaeces by mussel was tested with increasing levels of Chlorella in a controlled environment; at higher levels PSF production was lower, probably due to decreased filtration. A model for stock management in nurseries for the pacific oysters was presented with a focus on juvenile oysters in flupsys. The model is available online to optimize stock management. Another modelling study addressed the impact of climate change on mussel growth in the Adriatic expressed as time to reach commercial size, at various farm sites. Despite uncertainties in future temperature and chlorophyll values over the season a suitability index was presented for future culture areas. A model approach was presented to identify the role of bivalves in regulating eutrophication by reducing chlorophyll as an end-point indicator. This was compared with costs of other measures like retention of nutrient inputs. It is recommended to explicitly address the potential of bivalves in regulating water quality as they are more effective in ecosystem with diffuse nutrient inputs than other measures. The features of bivalves were presented by using the goods and services concept. It was shown that bivlaves have a broad spectrum of characteristics in addition to traditional aquaculture. This regards the use of bivalve reefs for coastal defence, the use of bivlaves for water quality control (nutrients, turbidity) and also socio-cultural services like local community actions for shellfish restoration. This paper was based on a novel book that will be available online through Springer later this year. A paper on remote sensing by satellites showed that this is a promising approach to identify food availability for bivalve culture, validated with mussel growth data from Dutch culture sites.

Evaluation

Attendance was on average 50 persons. Response from participants was in general positive. It was an extensive session for two full days. All submitted abstracts have been the accepted by the PCO for oral presentations, the moderators have not been involved in this process. On request of the author, one paper was turned into a poster (without timely adaptation of the oral program, so there was one gap). There were no other mollusc posters. It is recommended to also make use of the option to have a poster session in future conferences.

National Aquaculture Policies & Regulations

Chair: Giovanna Marino (ISPRA, Italy)

This session covered research topics in support of national policies to strengthen livelihoods and food security from aquaculture in African and Asian countries, as well as new technical tools and best practices to improve aquaculture policy and governance.

Rodriguez Yossa opened the session and presented the WorldFish Strategy 2017–2022 and the Sustainable Aquaculture Flagship to support the growth of aquaculture in African and Asian countries. The Flagship is organised into 3 main Research Clusters (Fish breed and genetic; Fish health, nutrition and feeds; aquaculture systems) and is working within the broader CGIAR RESEARCH PROGRAM ON FISH - AGRI-FOOD SYSTEMS (FISH). The project is carried out in collaboration with public and private partners and is focused to support aquaculture growth for income and nutrition in those African and Asian countries where fish is the most important animal-source food. The presentation was mainly focused on topics related to «*Fish Feeds and Nutrition Research* », which are expected to provide cost effective and sustainable aquafeeds for 2,5 million of farm households by 2022. Research topics include research on i) sustainable fish feed resources to produce sustainable aquafeeds with locally-available ingredients, ii) nutrient requirements of fish, mainly tilapia and carp iii) model of production efficiencies for pond management validated by farmers and BMP and iv) feed additives for fish health incorporated in feeds. Research in feeds and nutrition are in place in WorldFish Centers located in Malaysia, in Egypt and in Bangladesh.

Malcom Dickson presented the 5-years investment for USD24.5 million provided by the US Agency for International Development (USAID) to achieve inclusive aquaculture sector growth in Bangladesh using a market system approach. The USAID initiative is managed by WorldFish and is built on the impressive achievements of the project 2012-2017 USAID-WorldFish Aquaculture for Income and Nutrition (AIN) implemented in Bangladesh, that contributed to achieve: an increase of 60% in fish and 30% in shrimp production (thanks to the delivery of thousands millions of SPF shrimp seed, an increase of 102% in sales, the training of 130.000 farmers (55% of whom were women) who were trained by local services providers. The new USAID investment has adopted the market system as the main approach for its Global Food Security Strategy in Bangladesh i) to increase the productivity of aquaculture production systems; ii) to strengthen aquaculture market systems with particular attention to expanding opportunities for women and youth; iii) to increase awareness and adoption of nutrition-related behaviours. Previous projects on market system in Bangladesh have been implemented mainly for fisheries and agriculture and few for aquaculture. The MSA approach for aquaculture sector is currently implemented in twenty-one southern districts in Bangladesh, and progress so far were the identification of sectoral problems using stakeholder consultation workshops and development of grants for aquaculture sector. The Market System Approach is increasingly recognized as best practice for inclusive economic development, for facilitating market change by identifying and addressing the underlying issues causing poor performance in the market system, for stimulating co-investments by the private sector and for improving access to aquaculture input and services in Bangladesh as well as in other territories.

Moving to European countries, Trevor Telfer presented the speech on «*Tools, models and decision support systems for policy and governance* » developed as part of the EU H2020 TAPAS (Tools for Assessment and Planning of Aquaculture Sustainability) project which aims to support aquaculture development in Europe. Following the TAPAS workshop on "*New and flexible approach to aquaculture licensing*" held at EAS2018, this presentation provided a comprehensive overview of the objectives and progresses achieved so far in TAPAS for improving planning, monitoring and management of aquaculture production systems in Europe. The main bottlenecks for establishing and operating an aquaculture site in Europe as well as the strategic requirements for decision making in different

countries and for different aquaculture production systems were identified. TAPAS delivered 11 summary recommendations to tackle issues and bottlenecks in licensing and regulation, to improve administrative efficiencies, to reduce the time for licensing and to simplify procedures and number of organisations involved.

The European Aquaculture Sustainability Toolbox is still under construction and currently undergoing a consultation process with stakeholders to develop methods, guidelines and integrated tools to support best practise for aquaculture impact assessments in Europe. New and refined methods, guidelines and tools will be available in the toolbox i) to support best practices for licensing and policy, ii) for monitoring and assessment environmental impacts and risks associated to aquaculture, iii) for improving information and communication and iv) to strengthen planning and management strategies, using models and tools for spatial analysis, near-field and far-field models, database for large data stream (Copernicus, in situ data) and to understand the contribution of aquaculture to ecosystem services. The Aquaculture Sustainability Toolbox will be presented next year at Aquaculture Europe 2019 in Berlin.

The last presentation of the session provided the «*European Guidelines for a Sustainable Aquaculture of Seaweed*» developed within the PEGASUS project. Seaweed aquaculture is an expanding sector with a 6,7% increase of the global production per year since 1984. In spite of increasing interest for many industrial applications, seaweed aquaculture is still in infancy stage in Europe and there is not a reference framework to support the sustainable development of seaweed sector. The guidelines propose recommendations to the EU Commission regarding i) the domestication process of seaweed species and the need to get a better knowledge on seaweed biology, ecology and distribution; ii) the sources of seaweed strains and the dependency on wild stocks which represent an important bottleneck for future development and the risk related to the use of alien species; ii) the productivity and quality of seaweed production, in relation to genetic strains and the environmental conditions; iii) the cultivation techniques available at sea and in land based facilities, in monoculture and in Integrated Multitrophic Aquaculture systems. The presentation concluded on the importance to define geographical limits of seaweed sources at local level, to develop technical Centres of References for help producers at regional level and to implement training courses for seaweed producers.

Non-food aquaculture

Chair: Hugues de Verdal (CIRAD, France)

The non-food aquaculture session was short with only four presentations, but relatively broad in terms of subjects with studies on three different animal species and one presentation on the skill development.

Regarding the three species, it appeared that two of them are used for food industry (seahorse for Traditional Chinese medicine and the spiny soft-shell turtle mainly in Asia) and the last one, the clown fish, is reared for aquarium hobby. An increasing market demand is visible for these three species with a special interest on the improvement of the rearing practices.

In clown fish aquaculture, the most important trait right now is regarding the coloration of the fish since it is reared for aquarium hobby. It was shown an impact of the source of carotenoids in the diets on the accumulation of pigments in the tissue and the skin. Furthermore, the background colour of the aquarium can impact on the coloration of the fish.

In seahorse, the main challenge is to develop good rearing practices. The demand is particularly high (150 million of seahorses per year) and is currently dependent of declining wild resources, only 10 million being produced by seahorse culture. To increase the production and reduce the seahorse overfishing, it is needed to improve the rearing practices and develop culture.

In spiny soft-shell turtles (*Apalone spinifera*), an improvement of the growth is wanted. To this purpose, the impact of the addition of a probiotic (*Bacillus subtilis*) in the diet or in the water was studied on growth performance, shell composition, gastrointestinal tract development and intestinal microbiota. It appeared that the oral way was better than the water way, with significant positive impacts on growth performances, straight carapace length gain and intestinal concentration of different bacteria.

Finally, the last presentation was relatively different, with a focus on skill development and accreditation for cage-based aquaculture. The presentation highlighted the existence of knowledge and skills gaps within the cage-based marine fish farming sector. The aim of the presentation was to understand these gaps in view to propose innovative vocational education and training solutions.

Nutrition: Feed additives

Chair: Torunn Forberg (BIOMAR, Norway)

Session sponsor: BIOMAR

The use of feed additives to promote general health, growth and survival against pathogens has become more and more frequent in aquaculture. In theory, fish reared under optimal conditions fed well-balanced diets do not need feed additives to thrive, however in reality there are several environmental factors that put extra demands on fish and thereby their diets.

From a sustainability perspective, the use of marine raw materials in fish diets need to be reduced, but the robustness of farmed fish should not be compromised, especially taking into account the urgent need to reduce the use of antibiotics worldwide.

During this AQUA18 session several types of feed additives were presented which can roughly be categorized in three categories; 1) alternative protein or lipid sources to counteract negative effects of reduced marine content in the diets, 2) additives with antagonistic effects against pathogens or

other harmful substances, and 3) additives improving fish health through improved antioxidant or immune function.

One of the main challenges related to unicellular marine lipid/protein replacement products is the fact that several of them are produced by the use of genetically modified organisms, limiting their use to countries with a more liberal GMO legislation. This may change in the future but it remains a major bottleneck as the nutritional profile of the native, non-GMO unicellular protein or lipid-producing organisms is most often not close enough to that of marine raw materials.

Additives with antagonistic effects towards pathogens such as phytogenic feed additives, organic acids and monoglycerides that can improve survival of the fish and reduce the need for medication show great promise, and work is ongoing to ensure that the additives are delivered intact to the site of action, and to define their mode of action. There is also an ongoing discussion on whether it is best to use naturally produced phytogenic compounds (with the major con being variation in purity and concentrations) or to use chemically produced pure products.

Some of the additives thought to have antagonistic effects also influence the fish performance and immune status, but whether this is a direct effect or is due to a response to changes in the host microbiota warrants further studies.

Documenting effects of feed additives and describing the mode of action is still a major challenge, at least if we look past the traditional fish performance and survival parameters. A promising method to assess the metabolic consequence of new feed ingredients or additives is analyzing the plasma metabolome of fish after feeding.

Overall the feed additives session at AQUA18 highlighted the diversity of available feed additives with the potential to improve the health of farmed fish or compensate for the reduction of marine ingredients. As health issues and raw material limitations are likely to be important issues also in the future there will be an increasing need for studies into the effects and mode of actions of functional feed additives.

Nutrition: Functional ingredients

Chair: Cláudia Figueiredo Silva (Zinpro Animal Nutrition, Inc. The Netherlands)

Session sponsor: BIOMAR

Functional Ingredients Session at AQUA 2018, included a total of 13 presentations split between Sunday (10) and Monday morning (3) sessions. The session covered recent studies evaluating functional ingredients and additives with potential health and growth benefits for fish (11) and shrimp (2).

The importance of functional feeds is well recognized as part of the solution in meeting the nutritional and health needs of highly performing animals, grown under increasingly challenging production and environmental conditions. The number and quality of the studies presented in this session is proof of the great effort being made by the aquaculture industry to meet economic, regulatory and sustainability constrains of a challenging market while caring for the welfare and health of farmed animals.

Most of the studies presented at the session result from the close cooperation between academia an industry partners, in screening for new ingredients and additives that by contributing for healthier animals could help in the reduction of antibiotics use.

Nutritional and health potential benefits of functional diets including i) ingredients such as krill meal, brown seaweed, grape marc extract and shrimp hydrolysate, ii) feed additives such a single- and multi-strain yeast, combination of prebiotics and phytogenics, nucleotides and iii) essential nutrients such as trace minerals and amino acids were discussed. Special emphasis was given to the modulation of immune response and resistance to different pathogens and bacteria but also mechanical stress such as handling, by feeding fish and shrimp with functional ingredients and feed additives.

Health issues of high concern to the industry and the focus of many of the studies were infestation with parasites such as sea lice, specific bacteria such as *Edwarsellia tarda* and white spot disease in shrimp. Many of the studies presented focused on salmonids and on how to enhance their mucosal barriers and mucosal immunity- as first line of immune defense- through nutrition. Alone or in combination, functional ingredients and feed additives proved to be an important and effective approach for a good health of mucosal barriers, namely of gills, skin and gut epithelium.

Relevant knowledge is being generated on how to improve the health of aquatic animals through nutrition, especially in the context of fish meal replacement with alternative plant protein sources that may be limiting in several essential nutrients such as amino acids, fatty acids, minerals and vitamins. Contributing for these great achievements, is the research being done in the fields of immunology and general health of aquatic species. Development of new technologies and methodologies-from transcriptome to metabolomic analysis- that contribute for a more quick and efficient evaluation of health and health biomarkers in aquatic animals, was also an important topic of the Functional Ingredient session.

Despite all the advances made in the field of functional nutrition and health of aquatic species, it would be of interest from a scientific as well practical stand point to look further at the interaction and potential synergies of different functional ingredients and feed additive on performance, health and welfare of fish and shrimp. In addition, development of functional diets should be accompanied by the adjustment of feeding concepts and protocols, all adjusted to specific production conditions. It would also be important to evaluate and determine in a more precise way the economics and environmental benefits of functional diets in farming of aquatic species free of antibiotics.

Nutrition: Protein and Lipid Sources

Chair: Sandrine Skiba (INRA, France)

Session sponsor: Lallemand

The development of aquaculture has been initiated at the beginning of the eighties and corresponds to the implementation of measures limiting fisheries captures in order to avoid overfishing and to preserve ocean resources. Due to fisheries captures relatively static since the 80's, aquaculture has dramatically grown to support the increasing demand of fish for human consumption. Aquaculture is expected to further increase as the FAO rely upon aquaculture production to provide sufficient animal proteins to more than 9 billon people at the horizon 2050. To take up this challenge, bottleneck should be overcome in terms of nutrition and feeding to support the sustainable development of aquaculture.

The production of aquafeeds based on fishmeal and fish oils has been a key element in the recent development of aquaculture. However, the stability of the fishmeal and fish oil production and the dramatic increase of their costs are compromising the sustainable development of aquaculture. Improving growth while reducing production cost represents a real challenge for the sustainable development of the aquaculture production sector. Fish diets have evolved, with an increased proportion of plant protein sources and vegetables oils. Unfortunately, the total replacement of fishmeal and fish oil has not been reached, especially in carnivorous species, as it negatively affects growth performance and reduces fish quality by suppressing dietary n-3 long chain polyunsaturated fatty acid (EPA and DHA) supply provided by fish oil.

The presentations performed in the "Lipid and protein sources" of the AQUA2018 WAS congress in Montpellier highlighted the great interest of the scientific community for alternatives sources of protein and lipids to efficiently replace fish meal and fish oil. In a perspective of circular economy, a particular attention is now paid to by-products from either the industry of vegetable production (example: okara, by-product of soy milk and tofu production) or the animal production sector (blend of amino acids produced by hydrolysis of feather keratin).

In the area of fish nutrition, a lot of work is being done all over the world on the utilization of new ingredients such as insects and yeasts as alternative protein sources or microalgae as an alternative source of EPA or DHA. New vegetable sources also appear as interesting solution to replace fishmeal and fish oil, especially in the context of local economy development. However, utilization of such new materials still raise a lot of questions in terms of impact on growth performance and digestibility, inflammation of the intestine and general immune status of the animal that need to be further explored.

On the feed production side, utilization of new ingredients might have consequences at technological level on the production process that require to be investigated. Conversely, extrusion process could modify the quality and nutritional value of the ingredient which need to be checked. Finally, in a context of global changes, it now appears as essential to consider the environmental impact of the introduction of new ingredients in aquafeeds.

Nutrition: Requirements – finfish and crustaceans

Chair: Marisol Izquierdo (Grupo de Investigación en Acuicultura (IU-ECOAQUA), Canary Islands, Spain)

Despite the large number of fish and crustaceans species produced by aquaculture worldwide, the number of species for which qualitative and quantitative nutritional requirements are determined is very small. Empirical determination of the more than 40 nutrients required by all cultured species by testing 5-6 dietary graded levels of each one is very man-power, time and money consuming. Moreover, optimum dietary levels for nutrients frequently depend on the levels of other dietary nutrients, interactions with different nutrients, environmental conditions, fish age, etc. Therefore, studies on nutritional requirements continue increasing during the last years. But at the same time new indicators, including molecular ones, and methodologies, such as multifactorial designs or modeling, are been developed to simplify determination of nutritional requirements.

Despite the ideal protein concept (IPC) has been long used, this method, which largely simplifies determination of essential amino acid (EAA) requirements for the ten proteinogenic EAA, gives similar values to the empirical determinations in certain aminoacids but different ones for others. In this session, the application of the IPC in combination with the FBM to define the quantitative requirements for each of the ten EAA for shrimp was reviewed and widely discussed with the audience.

Essential fatty acids (EFA) such as eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids are important to maintain cell membranes permeability and functioning. They are particularly necessary to preserve epithelia function, robustness and health. Integrity of epithelia in skin, intestine and gills are determinant of fish health, since they are barrier tissues that form the first line of defense against pathogens infection. Despite Zn is also an essential trace mineral necessary for skin functioning, there are no studies regarding the interactions between dietary EFA and Zn on skin quality. In this session it was demonstrated that EPA+DHA and Zn strengthen the skin increasing robustness and barrier functions in Atlantic salmon.

The current tendency in aquafeeds to substitute fishmeal by other protein sources is leading to changes in the basal mineral contents of the diets and this in turn requires a better definition of mineral requirements for fish. Moreover, comparison of inorganic versus organic forms of trace minerals suggests differences in absorption, deposition and efficiency among the different sources. For instance, supplementation of rainbow trout broodstock feeds with OH-SeMet markedly increased glutathione peroxidase activity and gene expression in the fry produced, in comparison with the same dietary levels of NaSe.

Even fewer studies address the nutritional requirements of fish and crustaceans during the larval stages. Particularly, requirements for fat-soluble vitamins A, D and K during larval stages are very scarce, despite its supplementation in early weaning diets for European sea bass markedly affect the incidence of bone anomalies.

Finally, in order to cover the nutritional requirements, nutrients must be supplied as ingredients, but increasing demand of raw materials is imposing an elevation in their market prices. At the same time, a substantial portion of prepared food in restaurants or supermarkets is wasted, despite its potential nutritional value for fish and crustaceans. In this session a series of studies demonstrated that is possible to supplement feed formulations for Nile tilapia with food waste reducing aquafeed costs and contributing to recycling of natural resources.

Ocean Aquaculture

Chair: Hans Bjelland (SINTEF; Norway)

This session showcased technological advances to farming at sites exposed to demanding weather and sea conditions. The presentations also discussed important non-technical bottlenecks to this, like regulations and stakeholder interests. The session was well attended, with time for responses from the audience between presentations.

Exposed farming locations could be ideal for production and simultaneously reduce key environmental effects. Exposed areas provide more stable culture conditions and greater dispersal of wastes due to constant water flow, both of which improve the production environment.

Exposed farming requires novel technical solutions combined with operational concepts to maintain safety and ensure reliability. Farmers who have gradually started to utilise more exposed locations, report considerable difficulties in maintaining reliable production. Farming in exposed areas poses unique challenges to operations, structures and equipment due to severe and irregular wind, wave and current conditions, and sheer remoteness. There are sites that have been abandoned because of difficulties to perform key operations effectively and when required – a fundamental requirement for profitable and sustainable farming.

Off the Shelf Solutions for Finfish and Shellfish selective breeding

Chair: Christopher Bridges (Tunatech, Germany)

In this one-day session, a broad review was achieved of the state of the industry and some of the innovative ideas coming through to supply the industry with its coming needs for a selective breeding programme.

An initial review of breeding and industrialization in Marine fish aquaculture from the Kindai University in Japan , the world leader in this field, was presented by Keitaro Kato who outlined the advances made in various marine species in Japan. He was able to show that over a selective breeding programme encompassing 30 years a steady increase in production numbers had been achieved.

His presentation was followed by one from Antonio Colli (Selonda) looking at the industrial requirements for selective breeding in sea bream and sea bass from the Mediterranean perspective. This very informative presentation looked at costs within the industry and the aims of breeding programs to elevate intrinsic growth rates and the adjustment to new feeds. The choice and identification of specific traits which would be remunerative for the aquaculture industry were also discussed. He also gave some valuable feedback from the industry in terms of where further funding or financing of such selective breeding programs could be achieved.

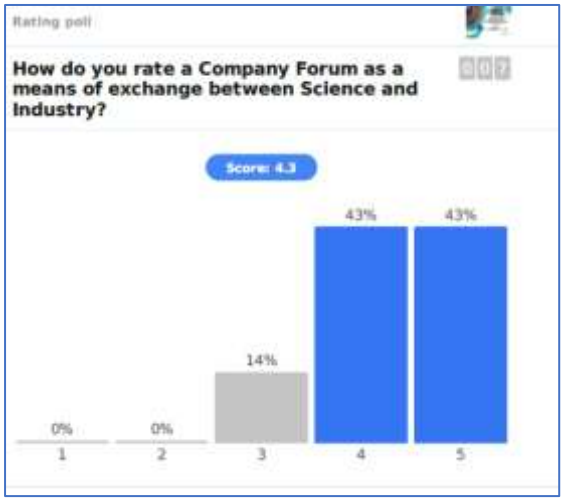
As the main theme of the workshop was “off-the-shelf solutions” the next presentation by Stylianos Kyriakidis (Xelect Ltd) illustrated the development of high throughput amplicon sequencing pipelines for haplotypes for parentage assessment in aquaculture breeding. This hands-on approach gave the audience a real insight into the need for accurate data acquisition and analysis to determine breeding programs. Ian Johnstone ((Xelect Ltd) then gave us is visions for the future of genetic selection programs and examples taken from his own company´s developments over the last few years, with phenotypic selection, family selection, MAS genomic selection and finally to precision breeding. His presentation also covered numerous tools such as Optimate and the curation of data from breeding programs and looking towards the future for cost effectiveness of genotyping and genomic selection solutions. Finally

the chairman Chris Bridges (TUNATECH, GmbH) summarized some of the question still to be asked and reviewed the results of previous workshops held in Edinburgh and Bergen.

During the session the SLIDO system was used for questions and polls which could be contributed both online and off-line. The poll presented during the session looked into the usefulness of Company Forums (CF) and other key questions:

- Which fields of the Aquaculture Industry are you interested in?
- How do you rate a Company Forum as a means of exchange between Science and Industry?
- How can the CF help your Company?
- Which of the following organisations have you heard of or have contacts with?
- Is a genetic breeding programme applicable to your company.
- Should gene-editing be used in aquaculture?
- Which factor is limiting growth for your company?
- Which off-the shelf solutions would your company be interested in?

With the following selected results (Results omitted where to few responses received (<5)



The CF was rated as being a good means of exchange between science and industry scoring between four and five on a rating of 1 to 5. When asked how the CF could help their companies the majority stated that it could provide a confidential forum for new ideas to be discussed, but other possibilities such as providing expert advice, estimation of costs, integration of EMBRC infrastructures and moreover as a forum to articulate the needs for EU research directions. When asked whether a genetic breeding

programme was applicable to their companies 88% scored 4 or 5 on the scale of 1-5 for applicability. Of those asked 43% said their company growth was limited by the lack of research funding and 43% through the lack of capital investment. The lack of qualified personnel and governmental administration and planning permission only accounted for 29%. Other unspecified factors accounted again for 29% of the answers. When considering the off-the-shelf solutions broodstock monitoring and reproductive performance with the first priorities followed by paternal assignment of eggs or larvae and sex determination offspring at an early stage. The use of Marine infrastructures and facilities only accounted for 13% of the answers received.

Parasites

Chair: Annemie Decostere (Ghent University, Belgium)

Parasitic infections may cause large economic losses to the aquaculture industry worldwide, compromising the animal's health, welfare, growth and eliciting increased mortality.

In addition, these may be disadvantageous to neighbouring wild fish. To be able to control parasitic diseases, in first instance, optimised diagnostic assays are crucial with proven adequate sensitivity and specificity. In addition, not only the mere presence of the parasite but especially the parasitic load needs to be assessed reliably, as this may determine whether or not a treatment will be installed, the density will be reduced etc.

Secondly, alternative methods to control parasitic infections are pivotal. These include selection for resistance and sustainable biocontrol agents. Additionally, it is important to understand how parasites interact with their host and how selection for resistance may be established, since this may lead to novel therapies.

Preventing and Mitigating Farmed Bivalve Diseases: VIVALDI

Chair: Isabelle Arzul (IFREMER, France)

For AQUA 2018, the EU Project VIVALDI consortium[1] organised an open workshop entitled "*Acting together to better prevent and mitigate farmed bivalve diseases*".

The workshop brought together more than 75 stakeholders, from 14 different countries, 4 continents. 2/3 of the participants were coming from the research sphere. Industry representatives represented almost 25 % of the audience. Other categories such as the competent authorities, decision-makers and media were represented. The aim was to share the mid-term results of the project and exchange with the different stakeholders involved in the shellfish industry at large, so as to assess their interest in the tools and approaches developed in the project. Recent findings, including many VIVALDI outcomes, were presented and discussed, as well as the expectations from the main stakeholders towards research.

The first keynote speaker, Melba Reantaso, from the Food and Agriculture Organisation (FAO) introduced a new concept to address aquatic disease problems: the Aquaculture Biosecurity Progressive Management Pathway. Some perspectives of collaboration emerged from this exchange. In addition to the panel presentations and round tables, a focus group discussion was organised at the beginning of the day. It aimed at exploring the attitudes and perceptions of stakeholders in the shellfish industry regarding disease control and prevention strategies, which are most suitable for their industries.

The discussions that took place during the workshop brought some perspectives in terms of future research activities, within and beyond the scope of the VIVALDI project. Also, from this experience, some ideas have arisen on how the consortium could better involve stakeholders in the definition of some future major VIVALDI outputs, such as the manual for disease management and biosecurity, the guidelines with recommendations to reduce mortalities or the definition of optimal husbandry practices.

Over these past years, the shellfish production has faced a series of disease outbreaks. This frequency and intensity increase could be related to the climatic evolution and to increasing animal movements. In this context of global change and world scale trade, VIVALDI aims at developing tools and proposing strategies to prevent and mitigate farmed mollusc diseases.

At the ecosystem level, the key challenges are:

- To maintain a balance between farmed and wild animals. Farmed mollusc species are maintained in open areas and share the same ecosystem as wild mollusc animals. Maintaining healthy ecosystem with healthy wild populations is compulsory for a sustainable aquaculture;
- To favour diversity, encourage the development of local endemic species rather than exotic ones and avoid immoderate movements of animals.

The EU regulations now encompass public and animal health within a unique "One health" framework. Optimising detection tools and surveillance approaches regarding both public and animal health is now expected and should be cost effective.

The main threat is coming from what we do not yet know: one key challenge is to be able to early identify and control emerging diseases. In this context, Vivaldi develops tools including biosensors and

[1] This event was supported by the European Union, via the VIVALDI project (H2020 Programme – Grant N°678589), IFREMER, The University of Montpellier (F) and CeMEB, the Mediterranean Centre for the Environment and biodiversity.

passive sensors to early identify emerging pathogens. VIVALDI partners also work on the development of risk-based surveillance model that will help to focus surveillance effort on most risky farming areas.

VIVALDI has now reached its mid-term and it is time to work all together to identify recommendations regarding disease management measures, design a manual of best practices and more generally prepare the future. Developing tools and designing strategies must be done by taking into account stakeholders' perception and by bringing everyone in building a biosecurity plan. Shellfish diseases are not only a concern for European producers but also for producers worldwide. VIVALDI is building an international network on shellfish diseases which includes members of the advisory exert panel and which is regularly enriched with new members notably during event such as the open industry workshop.

Stakeholders and members of the international network on shellfish diseases will be invited to participate in designing a biosecurity plan and to join the final VIVALDI meeting, which should take place in Brest (France) at the end of 2019.

VIVALDI website: http://www.vivaldi-project.eu/

Recirculating Aquaculture Systems

Chairs: Jerome Bosmans (IDEEaquaculture, France) and Bertrand Barrut (COLDEP, France)

Sponsored by Faivre

Although RAS technology has been used for decades, it is still at an early stage of development with respect to large-scale commercial grow-out, particularly of marine species. Most of this technology has been developed for the freshwater Industry (Salmon, tilapia, eel and catfish) and the potential of RAS continues to attract investment as the technology is gradually improving, demonstrating more and more reliability and cost effectiveness.

The session considered advances made in the capacity of RAS to use less and less new or make up water and the best ways to recycle sludge and effluent. The technical and scientific focus was mainly made on:

- The Importance of ozone in the organic matter control and the way to control its dosage.
- The use of sludge as a carbon source for denitrification reactors.
- Aquaponics / hydroponics to treat, use or re-use RAS effluent.
- The intensification of Catfish farming in RAS.

The control of ozone is crucial to RAS, especially in sea water where toxic by-products are generated. It is well known that ozone is implemented in RAS as a continuous water treatment technology improving water quality by oxidizing organic matter and reducing bacterial abundance. As a surrogate parameter, the redox-potential is used for monitoring the oxidizing power of ozone but the absence of a linear relationship between residual ozone concentration and redox-potential is a disadvantage of this method, as well as the often variation in probes monitoring accuracy.

During the session we found out that the organic matter fluorescence of RAS water is highly sensitive to ozonation and fluorescence spectroscopy could therefore be used as an indirect method to determine ozone delivery and its impact on water quality. This could be a breakthrough in the control of ozone use to optimise dosage and to avoid toxicity.

The session also allowed to learn several technological paths for re-cycling RAS sludge and effluent waters. Sludge can be used as a source of carbon for the denitrification reactors instead of the more "typical" sources. Effluent water can be treated through a bio-floc system to obtain a near zero discharge intensive RAS. The effluent water quality can also be controlled in the aim of being used for aquaponics / hydroponics systems and plant growth, or to be re-used as make up water for intensive RAS.

Many of the treatment processes employed in RAS are adaptations of unit processes used in the wastewater treatment industry. Over the years, these have been modified to conform to the higher water quality standards in aquaculture. It is crucial that researchers keep working closely with the Aquaculture Industry so the technology developed is simple, safe, reliable and cost effective.

RAS technology has demonstrated the advantages of fish production under controlled environmental conditions in terms of fish quality, superior growth rates and feed conversion ratios, reduced disease outbreaks, lower use of therapeutants and site flexibility. But as pristine water source will become more and more scarce, Aquaculture technology must also demonstrate that it can tends towards intensive cost effective near zero discharge systems.

Restoration projects using aquaculture organisms

Chair Pauline Kamermans (Wageningen Marine Research, The Netherlands)

The main purpose of aquaculture is food production. However, a relatively new development is using aquaculture organisms for restoration purposes. The session on this topic comprised of six contributions from different parts of the world (Netherlands, South Africa, Italy, U.K. and U.S.). The presentations involved different species (mussel, abalone, oyster, sea urchin, snook). The main conclusions from the contributions were:

1. Selection of the right habitat for restoration efforts is important. Desk studies including larval dispersal modelling can help with that.
2. Selection of the source population is important. It needs to be disease free and able to adapt to the new location. Use of hatchery reared organisms or spat collection is more sustainable than collection from natural populations.
3. An acclimation period of the introduced organisms is in some cases necessary. An example of hatchery reared organisms that seem to be able to adapt quickly was presented.
4. Generally, when a species is not present anymore the habitat has changed as well. Providing extra features such as substrate, elevation structures or predator exclusion can improve the habitat.

New results may be shared at future conferences as some of the restoration pilots that were presented were in the early stages.

Selection and breeding programmes

Chair: Matias Medina (Aquagen, Norway)

The session considered advances made in the selection process of different aquatic species in the framework of stablished breeding programs. It was possible to see how important the support of the Government is for the development and maintenance of breeding programs for species that are of national interest. The latter allows selection processes to be maintained independently of the economic situations that might affect the production of species and/or countries. This has been the case of the national cod breeding program in Norway, which despite the total disappearance of commercial farms in 2014, continued its activities. The program has now reached its fourth generation and has reached a significant increase in growth rate, encouraging some companies to try cod farming again.

Governmental support has been also important for the research on economically important species in France. When it comes to egg production in trout, a gap of information was closed by documenting for the first time, the genetic parameters of successive spawning of the same individual. This type of more precise knowledge related to egg production in general, is allowing breeding programs to become more effective and thus, more efficient. This efficiency is being combined also with information about the heritability of fish resistance to relevant diseases as well as its genetic correlation with production traits. The latter allow to think on a significant improvement of trout production in this country.

The session also allowed to learn the significant effort that fish breeding programs are allocating into improvement of fish efficiency. The improvement of this trait is crucial to enhance fish farming sustainability; however, it has not been achieved because individual feed intake is difficult to measure in fish held in groups. New methodologies involving precise video recording and indirect selection by measuring the performance of correlated (with feed efficiency) traits is demonstrating to be a significant step forward towards overcoming this challenge. Here, the selection on tolerance to fasting, a trait shown to be both easy to measure and heritable in sea bass, arise as a novel methodology that could be applied to other species, thus contributing to management and breeding aquaculture practices around the globe.

During the meeting it was also possible to see how technologies that have been developed for economically important fish species are starting to become available for the breeding program of less profitable but important invertebrate species. For instance, cryopreservation of mussel sperm has been improved significantly and a low-density SNP chip for shrimp is now commercially available. Considering the worldwide production of these species, the boost that these advances will bring to their selection processes will also contribute to a more efficient and sustainable aquaculture.

Sex Determinism and Sex Control

Chair: Jean-François Baroiller (CIRAD, France).

On the basis of the 13 accepted communications, the session on sex determination (SD) and sex control (SC) was structured into 3 main parts. The first concerned SD and SD studies in gonochoristic fish species (Nile tilapia, carp, turbot, European sea bass and common dentex) but also in protogynous (common pandora and red porgy), protandrous (gilthead seabream) or rudimentary (sharpsnout seabream) hermaphrodite species. The second part focused on the effects of the environment (in particular temperature and density) on SD and sex differentiation in European sea bass, eel or African catfish; a review reported the epigenetic mechanisms that may be involved in these environmental effects and the issues and perspectives it can raise for SC. Finally, in the last part, two presentations reviewed SD

and SC in non-vertebrate species of major importance for aquaculture, belonging to crustacean decapods and Molluscs.

Due to various sexual dimorphisms (growth rates, feed efficiency, age of puberty...), but also to facilitate broodstock management, and/or to optimize egg production, SC is often a concern in aquaculture, whether it is fish, crustacean decapods or Molluscs. In the context of a sustainable aquaculture, and in order to protect aquatic ecosystems and water quality, the development of SC approaches that respect both the environment and the consumer remains a major challenge in aquaculture. In order to develop non-hormonal approaches, a better knowledge of SD is needed for all relevant aquaculture species.

Briefly, SD relies on genetic (GSD = Genetic SD) or/and environmental factors (ESD = Environmental SD or ESDI = Environmentally Induced Sex Differentiation). GSD can theoretically be based on major genetic factors with sex chromosomes (XY/XX male or ZW/ZZ female heterogametic systems) or on a multitude of minor factors (polyfactorial system). In the ESD or ESDI systems, environmental factors respectively control SD (especially Temperature = Temperature SD-TSD) or influence sex differentiation (Temperature Induced Sex Differentiation = TSDI). In various GSD fish species including tilapias, African catfish, European sea bass, Turbot but also in Molluscs, family sex-ratios depend upon both genetic and environmental factors. Temperature seems to be a prevalent environmental factor for ESDI in fish and Molluscs, but other factors could also be involved (i.e. food in Molluscs). In fact, temperature may be only one of the indicators used by offspring to predict the future quality of the environment they will enter. In the European eel, the estimation of the quality of the environment, could be the key factor influencing sex.

In most aquaculture species, sex chromosomes (where they exist) are not heteromorphic and, therefore, indirect approaches have long been used for SD analysis. While most farmed Decapod crustaceans (shrimp, shrimp and crayfish) have a heterogametic female sex-determination system (WZ/ZZ), fish and shellfish are characterized by a wide variety of sexual strategies (gonochorism/hermaphroditism) and SD systems (ZZ/ZW, XX/XY, polyfactorial/polygenic sytems, ESD/ESDI, or complex interactions between genetic and environmental factors). In an increasing number of species of aquaculture interest, genomic resources have been developed, and next-generation sequencing (RADseq, RNAseq[2]…) can now be used to identify sex-specific differences/markers, but also the relatively undifferentiated homomorphic chromosomes that carry the sex determinants. In the simplest systems, the major sex determinant has even been identified.

What emerges from the main studies on gonochoristic but also hermaphroditic fish species is the conservation of the genes involved in the male and female pathways (cascades leading to the differentiation of the ovary or testicles) and in the maintenance of sexual identity. On the other hand, there is a diversity of major sex determinants between species, including phylogenetically related species.

In an increasing number of fish species where sex chromosomes have been identified, genomic studies suggest that, besides the major determinant, sex and/or environmental influences can also be associated with other Linkage Groups (LG), at least in some families (turbot), or populations (tilapias). Moreover, in tilapias as well as in the European sea bass, population-specific variations of the genetic architecture of SD are reported. In the Nile tilapia, sex is associated to LG1 or LG23, depending on the strains or the populations. In the European seabass, different genetic architectures of SD between Atlantic and Mediterranean populations, suggest a population-specific evolution according to its environment. Interestingly, this evolution of SD depending upon the families or/and the populations are observed in species where SD depends upon a balance between genetic and environmental factors. A

[2] RADseq = Restriction site Associated DNA sequencing; RNAseq = RNA sequencing or whole transcriptome shotgun sequencing.

direct consequence of these frequent variations within the genetic architectures of sex determination is that sex chromosome markers can be population-specific. This means that before using them for sex control purpose (i.e. the production of YY males), they have to be validated for each population/stock.

As reported in the presented review, epigenetics (especially hypermethylation) has been proved to mediate the temperature effect on sex ratio in an increasing number of fish species (including European sea bass and tilapias): high temperatures effects are associated with hyper methylation of the promoter region and subsequent decrease expression of key genes for sex differentiation such as aromatase. As already validated in some plants of agronomical interest, integrating the presence/absence of specific epigenetic marks has probably to be integrated in future breeding programs for sex control in aquaculture.

Finally, in decapods, the Insulin-Like Androgenic Gland hormone (IAG) is considered to be the switch for sex differentiation. Using RNAi, it has been possible to direct this switch towards maleness or femaleness, and male or female monosex prawn populations can now be produced through a genetic approach using ZZ neofemales or WZ males obtained through parental AG cell transplantation.

All these data strongly emphasized that sex determination is a complex trait at least in fish and Molluscs, involving both major and minor factors, with frequent population-specific variations within the genetic architecture. This suggest that SD (in its genetic and environmental components) and SC in aquaculture have to be both considered at a population level.

Species: Percid fish

Chairs: Daniel Żarski (Polish Academy of Sciences, Poland) and Tomáš Policar (University of South Bohemia, Czech Republic).

Presentations covering all the aspects aquaculture of percid fishes were submitted. The session started with the presentation of a concept of implementation of studies on genetic variability of percids from the perspective of its suitability for commercial aquaculture production. Next, first results on implementation of this concept to the onset of domestication were introduced. Further, the authors were presenting the newest results on different aspects of controlled reproduction (including broodstock and gamete management), larviculture (including the effect of domestication and application of rotifers as the first feed on larviculture effectiveness) and juvenile production in semi-intensive (pond-based) and intensive (recirculating aquaculture systems) production systems. The session was closed with the presentation on flesh quality control in Eurasian perch fillet coming from different production systems.

The PERCID SESSION has shown very high interest in research and development (R&D) in aquaculture of percids, indicating that this group, from among freshwater finfishes, is still (since over a two decades) within high interest of industry and academia. It became apparent that in the last decade renowned research institutions are more and more involved in R&D activity tackling step-by-step commercially relevant problems of production technology, where still many issues are to be solved. However, the data presented during this session led us to the moment when we can surely state that grounds for commercial production of those species were defined successfully. This was also well reflected by the presence of numerous representatives of commercial farms of Eurasian perch and pikeperch, who very actively participated in the discussion. It should be also pointed out that vast majority of the research presented were focusing on commercial applicability of the results and some of the studies were literally driven by the private sector. This shows, that consistent growth of percid sector across Europe along with increasing production volume strengthened connections between academia and private

companies where scientific institutions are now more aware to tackle the problems pointed out by the farmers.

It was commonly observed within the last 20 years that typically Eastern and Central Europe was highly focusing on pond-based aquaculture of percid fishes and Western countries were investing in RAS-based production technology. However, in recent few years it became apparent that the two production technologies started to be combined, where either pond-based larviculture precede RAS-based ongrowing or intensively reared juveniles are stocked into the pond systems. This creates huge possibility of control over the production costs, which are still among the limiting factors toward expansion of the percid sector. However, this innovative approach in freshwater aquaculture require further studies on recognition of many different factors conditioning effectiveness of this type of combined production technology.

Despite the very positive picture of the percid fish culture sketched during the session it could also be observed that the slow growth of this sector is caused by very limited collaboration at the European level. We could experience that researchers being experts in particular fields (for example: reproduction, larviculture, nutrition, etc.) of percid's aquaculture are scattered all over the continent very occasionally having opportunity to work together. This stems from lack of well-defined funding and consequently difficulties in European-wide collaboration which would allow for timely knowledge exchange and transfer of the scientific results to the fish farms. Knowing, that production technology of percids is highly complicated, mostly due to the need of usage RAS technology and maintaining the entire lifecycle in fully controlled environment, the two aspects: international collaboration as well as knowledge transfer seems to be the key factors conditioning further development and expansion of percid's aquaculture. **That is why EPFC (European Percid Fish Culture) thematic group of EAS is currently trying to moderate European cooperation between research institutions and SME partners with the aim to increase development of percid fish sector.** This is well reflected in recent dissemination activities of EPFC (mainly through various workshops and on-line published materials), being a first step toward building bridges between different stakeholders, based on bilateral trust and professionalism.

Species: Sea cucumber, sea urchins, polychaetes

Chair: Luisa Valente (Interdisciplinary Centre of Marine and Environmental Research of the University of Porto, Portugal).

This session took place in Tiberiade room that was very well adjusted to the number of attendees with only a few empty seats left. There were no presentations concerning sea cucumber and only one was about polychaetes. Sea urchin species were the main focus of this session with presentations from five different countries from two continents.

One of the main bottlenecks of sea urchin production is related to its long life cycle, with costly and extensive early post-larval mortality. A range of inductive substrates and chemicals on larval settlement and metamorphosis of *Tripneustes gratilla*, as well as post-settlement survival and growth of juvenile, were presented by Cyrus et al. from South Africa. The macroalgal crust, *Ulvella lens*, were shown to induce the best juvenile growth, compared with benthic diatoms used as industry standards. These findings contribute towards more consistent and successful production of *T. gratilla* juveniles and the development of echinoculture globally and within South Africa.

Mantilla-Aldana et al. from Spain provided a new approach to estimate the gametogenic condition of edible sea urchin *Paracentrotus lividus* using image analysis. This instrument gives information present

in pictures using mathematical algorithms that can avoid misinterpretation or sub classifications of the gonadal condition stages using visual analysis of histological slides.

The gonad quality and safety of two wild population of *P. lividus* harvested in North Atlantic coast of Portugal was further described by Rocha et al.. Most examined chemical and organic contaminants (HNS, BTs, phenols, and PAHs) were found below or near the limit of detention so gonads can be safely consumed all year round, but their nutritional value is higher during fall when market-related traits, such as color and texture are enhanced.

Loi et al. from Italy evaluated the influence of diet on gonad quality of *P. lividus* concluding that manufactured diets represent a promising cost-effective feed for aquaculture purposes, enabling a rapid and considerable gonad growth with a minimum amount of feed consumed. But more effective feeding protocols are required to enhance gonad colour as often artificial diets result in pale gonads compared to wild specimens. In fact, the protein requirements of *P. lividus* has not been evaluated yet and is of major importance to formulate balanced feeds. Lourenço et al. from Portugal evaluated the growth performance of *P. lividus* fed with extruded diets of different protein levels, suggesting that 30% dietary protein is the most adequate to promote gonad growth. Another study from Portugal by Rocha et al. showed that the dietary inclusion of synthetic β-carotene (10 mg/kg) resulted in similar gonads' redness and yellowness to those observed in wild animals. Moreover, colour was shown to vary between genders, suggesting that males and females have different metabolic uses of dietary carotenoids. But further studies are required to fully understand the mechanisms involved in the modulation of gonad colour, texture and taste through diets in order to potentiate the production of desirable gonads for consumers.

The session ended with a presentation by Wand et al from Norway that evaluated the nutritional composition of the polychaete *Hediste Diversicolor* cultivated with land-based aquaculture waste. Polyunsaturated fatty acids accounted for nearly 50% of the total fatty acids and a high content of DHA was found in all feeding groups. All essential amino acids required by aquatic animals were also present. It was concluded that worm biomass produced on smolt waste can be a potential protein and lipid source for formulated feeds in aquaculture.

In conclusion, several studies are being carried out worldwide in order to optimise rearing conditions for invertebrate species. In all cases, the optimisation of diets to each species nutritional needs seems crucial to boost echinoculture and polychaete production.

Species: Sturgeon

Chair: Harald Rosenthal (WSCS, Germany)

Session organised by the World Sturgeon Conservation Society (WSCS)

Sturgeon conservation and culture: the need for coordinated action

About 60 participants listened to a total of 11 presentations. Two of these were read by title because one was also allocated to a nutrition session and was presented there, while the other one had to be cancelled because our good colleague and sturgeon expert Dr. Patrick Williot was unable to attend due to health problems. The session chair conveyed best wishes to Dr. Williot to cope with the present problem as best as possible.

Several overviews were given, including several aquaculture issues from a sturgeon conservation perspective. The main focus was on three topics: (a) global trade and culture of sturgeon products,

including caviar and meat production, (b) on appropriate brood stock management for both aquaculture and species rehabilitation programmes and (c) on culture methodologies to achieve fitness of specimens destined for best performance after release to the harsh and highly competitive natural environment.

The session started with an overall presentation of the „**Vienna Declaration on global sturgeon Conservation**" which was recently published and co-signed by contributors from 17 sturgeon range states. Many aspects relevant to aquaculture and trade control of sturgeon products affecting aquaculture were addressed: (a) provision of sufficient resources that all relevant law enforcement agencies can effectively prevent sturgeon species from over-exploitation, (b) develop approaches of tackling illegal wildlife trade, across boarder, (c) apply state-of-the-art techniques (e.g.DNA/isotope analysis) to identify species/caviar and their origin, (d) implement close cross-border coordination of enforcement actions concerning illegal trade of sturgeon products, and (e) improve the CITES labelling to prevent misuse or loss of labels.

The Declaration recommends routinely monitoring of aquaculture operations in line with national regulations with special emphasis to prevent illegal import or laundering of illegally caught fish through aquaculture. The aquaculture industry should be encouraged to collaborate identifying tracking approaches to support enforcement authorities in trade control actions. Finally, farmers may become – in exceptional cases –partners in conservation programmes, however, specific conditions and obligations must be met to allow such a scenario.

Dr. Bronzi presented updated and new information on the global state of sturgeon meat and caviar production (up to 2016). At present, ca 50 countries with more than 2150 facilities are globally involved in sturgeon farming. The estimated global production of sturgeon reached over 130,000 tonnes with a caviar output of ca 310 tonnes in 2016. This trend met almost unprepared markets. Increasing product availability reduced market prices. A period of serious consolidation of this sector is anticipated soon.

Another presentation focussed on the differences in culture methods required when culturing species for release to the natural environment. (Rosenthal). While aquaculture production systems select for best survival, high food conversion efficiency, fast growth, culture for release needs the fish with the ability to respond to environmental cues in nature, recognize predators to be able to escape, and display robustness to abrupt changes in water conditions. Examples were provided for several species, including recent studies on sturgeons showing the effects of respective training programmes.

Furthermore, Dr. Bronzi demonstrated the need for long-term commitments when trying to save or re-establish a species. He described efforts for more than 30 years by different public and private entities to restore the population of the Adriatic sturgeon. Impressive interim results were obtained, indicating that long-term commitment is required to achieve the intended success, including proper brood stock management, and the follow-up by good monitoring

A brief overview (Jahrl, WWF Vienna) was given on a caviar market survey project (2011- 2012) to identify the dimension of the illegal caviar trade in Bulgaria and Romania. Violations of rules were detected and mislabelled products identified. These examples show that CITES requirements are not sufficiently implemented. Illegal caviar trade is reduced compared to previous years. However, the existing cases are alarming because the number of fish left in nature has drastically declined. Every caught illegally fish is today of serious concern as the impact on the remaining population is very high.

The principles and modes of action to perform sturgeon aquaculture for conservation was presented by Dr. Congiu, who emphasized the urgent need for proper establishment of captive broodstock, giving the objective to preserve the genetic diversity the highest priority. The choice of pairing individuals in controlled reproduction is crucial because when their offsprings are released, these will directly affect

the genetic make-up of the next generations. Possible negative effects can be a decrease of the adaptive potential of released fish to a number of environmental conditions encountered in the future.

Dr. Tillner (ALLER-Aqua) presented an overview on the advances achieved to improve feed composition specifically for various life cycle stages of sturgeons. Feeds are now available for juveniles, sub-adults and adults, reaching good growth. Also, nutritional aspects for improving the health status of the sturgeon species in culture have been developed and species-specific feeds are presently under research and development.

The contribution by Dr. Williot was read by title. As outlined in the abstract, another example is given for a dual approach to learn from aquaculture and improve methods for culture for release: culturing the Siberian sturgeon in France while at the same time being deeply involved in conservation culture for *Acipenser sturio* in the Gironde area.

The paper by Dr. Agh and co-workers provided a good example on how dietary soybean lecithin can positively affect the growth of juvenile stellate sturgeons while at the same time enhancing the overall strength of the immune system of this species under culture.

Dr. Ponomareva (Russia) presented results of physiological studies on the reproductive cycle of hybrids between sterlet (A.ruthenus) and great sturgeon (Huso huso), observing similar trends found also in related species cultured in RAS systems..

Finally, Dr. John Giovannini, representing "Storione Ticino" described the history of conservation of the Adriatic Sturgeon from the perspective of a long-term, family-driven programme. His father as fish farmer was already involved in culturing this species to restock natural waters, keeping wild broodstock in ponds (initially over 100 specimens) and after the controlled reproduction was obtained, producing fingerlings, thousands of them released in several years' intervals. The dual approach of commercial farming for markets and conservation farming was successful for more than 30 years, but the remaining large adults are now greatly reduced over time having only a small fraction of the original number left. Dr. Giovannini impressively demonstrated what can be done with private sector involvement and urged for more public involvement in the future to rescue the species as signs are there that some of the initial releases have survived and are now caught as large adults.

Species: Tilapia

Chair: Hugues de Verdal (CIRAD, France)

Nile tilapia, *Oreochromis niloticus*, the second most consumed fish species in the world is continuing to develop in several countries. With this development, a lot of questions are raising, regarding rearing practices, feed use and seeds. Nile tilapia is relatively easy to rear, with a large adaptation of the species to variable environmental conditions and feed composition. However, even if the species is well known, a large amount of improvements is still possible.

The studies presented in the AQUA2018 conference during this Tilapia session were mainly focused on strategies for the management and the economic viability of tilapia farming (in Ivory coast and Brazil), strategies to improve feed formulation and the impact of the feed formulation on the rearing environment. Globally, a large attention was given to develop a sustainable tilapia aquaculture, with questions raised regarding the fish strain, the environmental impact of the aquaculture production, the economic impact and the dissemination process.

More specifically, in Ivory Coast, the main tilapia strain is just coming back from Brazil, and the process of dissemination of this "new" strain need to be done carefully to keep the strain as good as possible.

In Brazil, the main question raised by aquaculture producers was the economic viability of their tilapia farms. The actual results were positive and optimistic, while tilapia feed price is still particularly high.

Feed is 50 to 70% of the production costs in tilapia. It is why studies focused on pellet feed reduction. In Bangladesh, it was shown that the optimal dietary composition is dependent on the culture condition, since extensive, semi-intensive and intensive ponds will not react in the same way regarding the dietary protein:energy ratio and the amount of feed given to the fish. Furthermore, it is interesting to note that pond zooplankton abundance is not impacted by the diet composition given to the fish. This is particularly important since in ponds, planktons are an essential component of the diet of Nile tilapia.

In view to reduce tilapia pathogens, it is important to understand the ecology of monogeneans of tilapia in several rearing systems. These monogeneans are not the same according to the rearing system and the tilapia species.

Finally, from the five presentations given during the Tilapia session, the real objective was always to develop a sustainable tilapia aquaculture, which is dependent upon many aspects, from the feed to the pathogens through the rearing practices and the economic viability.

Student Workshop

Chairs: Nuno Leite (SAEentia, Portugal) and Nicole Rhody (Mote Marine Laboratory, USA)

The theme of the AQUA 2018 student workshop was '**Preparing for a Career in Aquaculture: Tips for Success**'. The workshop was developed through a joint effort between the WAS Student Activities Committee and the EAS Student Group. The workshop began by a quick welcome by Nuno Leite (EAS-SG President) and an introduction to "A new era within the EAS-SG" by Dr. Kathrin Steinberg (EAS Board Member), explaining the recently created student representative position on the EAS Board and the reformulation of the EAS Student Group model. The session included three speakers and ended with a question and answer session where students were able to engage with panellists selected from academia, industry, and research. Jean-Michel Mortillaro (CIRAD) spoke on current opportunities in sustainable aquaculture development for students and recent graduates. Tips on how to prepare for a job interview were given by Nicole Rhody (Mote Marine Laboratory). Tomé Silva (SPAROS) discussed the use of bringing modelling tools from research into practical application.

Student Reception

The student reception took place at O'Sullivan's Irish Pub (62, Rue de Rhodes, 34000 Montpellier), and was well attended by students, young professionals, as well as EAS and WAS board members.

AWARDS

WAS Student Spotlight Competition

The plenary session of AQUA 2018 in Montpellier concluded by highlighting WAS student scholars and researchers via a spotlight competition. Abstracts were scored prior to the conference by members of the World Aquaculture Society and judged based on set criteria. Winning students were recipients of this year's travel award ($400 each). In addition, these individuals were invited to compete during the Plenary Session for the Student Spotlight Award. Winners were determined by the Plenary Audience either via the WAS Meeting Assistant App or paper ballot. The three presenters were awarded cash

prizes ($500 for 1st place and $200 each for 2nd and 3rd places) at the student reception, held at O'Sullivans Irish Pub.

The winner of the Student Spotlight Competition was ***Samuel Pountney*** (Advisor, Prof. Andrew Davie) from University of Stirling. Samuel's talk was titled "Temperature effects of captive Lumpfish *Cyclopterus lumpus* broodstock spawning season and gamete quality." (See photo below on left) The other two presenters were Inácio Mateus Assane (Advisor, Prof. Fabiana Pilarski) from São Paulo State University (photo centre) and Wouter Visch (Advisor, Prof. Henrik Pavia) from University of Gothenburg (photo left). Inácio's presentation was titled "Combination of antimicrobials as an approach to reduce their use in aquaculture: example of using thiamphenicol with florfenicol against *Aeromonas hydrophila*". Wouter's presentation was titled "Spatial growth patterns and nutrient mitigation capacity of the blue mussel (*Mytilus edulis*) and kelp (*Saccharina latissima*) on the Swedish west coast."



WAS Oral Presentation and Poster Awards

Cecilia Biancacci is the first place winner ($600) of the competition for her oral presentation titled "The application of a lab scale photobioreactor for laboratory cultivation of *Osmundea pinnatifida*". The second place oral presentation honor ($400) went to ***Amit Savaya-Alkalay***. Amit's oral presentation was titled "Reproductive barriers between *macrobrachium* species permit sustainable aquaculture and biocontrol of schistosomiasis in Africa." ***Matthew Hargrave's*** poster titled "Co-cultivation of bivalves and macroalgae: multi-trophic aquaculture without a fed species in Sweden" received the first place award ($600). ***Christopher Duke*** was awarded second place ($400) for his poster titled "Temperature-mediated plasticity in growth, sprint swimming performance, and body shape in rainbow trout *Oncorhynchus mykiss*".

EAS-SG Travel Grants & Poster Award

This year's awards were generously provided by SPAROS with each student winner receiving 300€. The travel grants were awarded to Francisco Guardiola Abellan, Aiman Imentai and Mohamed Mahmoud and the poster award was given to Gabriella do Vale Pereira for her work entitled "Probiotic bacteria modulation in intestine of in South American catfish *Rhamdia quelem*".

Photos: Top: Travel grant winners Francisco and Aiman. Bottom: Travel grant winner Mohamed and Poster award winner Gabriella.

Vaccines and therapeutants

Chair: Laurent Dupuis (Ictyopharma, France)

For the content of the presentations, it is sad to see that people continue to push antibiotics and associations of different antibiotics when resistances are observed everywhere. It is also very frustrating to see that in the different tools to improve farm managements, vaccination is not considered as an efficient tool. This can be due to the difficulty to register vaccines when the epidemiologic situation is changing faster than the registration process (when the vaccine is available, the strains in the field are no more the same and the vaccines do not induce protection).

Some countries have a special status for autogenous vaccines that afford the possibility to reach faster the farms with the relevant antigen obtained by sampling. This evolution of regulation could help to have more affordable and efficient vaccines for an industry where only 1% of the fish are vaccinated.

What happened with salmon must be an example to repeat with warm water fish. This prophylaxis, combined with genetic, feed quality and management will probably be the revolution in warm water fish farming in the coming years.

Welfare

Chair: Sonia Rey-Planellas (University of Stirling, IoA, UK)

The AQUA 2018 welfare session had a great participation with 12 oral presentations and 11 poster presentations. It was a concurred session with questions and debate on the different presentations. Presenters came from different research groups, all over the world, and focused on a wide range of finfish species from Atlantic salmon or Sea Bass and Bream to new species with great potential for aquaculture like cleaner fish (Ballan wrasse and Lumpfish) or Maraena Whitefish.

Research themes addressed new recent issues such as light regimes for cleaner fish, the use of environmental enrichment to reduce fin damage in Atlantic salmon, thermal preferences for Maraena Whitefish and swim tunnel studies to evaluate the swimming performance both for Atlantic salmon and cleaner fish in exposed aquaculture conditions. A novel topic is the effect of Mycotoxins into the fish health and welfare and the potential toxicity for fish but also for human consumption.

Further research on stress related to the immune response combining physiological and molecular data was presented highlighting the impact stress has onto different fish species and how handling and confinement events should be reduced to the minimum to avoid compromise the fish health and welfare.

Personality is still a hot topic with a large scope for research, especially for their implications in health and welfare as well as their potential for strain selection. Several talks showed how Sea bass are consistent in risk taking tests through life and different situations and the genetic basis of this behaviours. Molecular and behavioural traits continue proving to be an excellent tool contributing to domestication and welfare. For established aquaculture species, recent work has been addressing issues such the use of behavioural prophylaxis to improve the production process and the health and welfare of fish. Also, nutritional additives as well as environmental conditions such as temperature and enrichment play a specific and important role still under constant research, on the final behaviour and welfare of the fish.

Research onto the 3R's concept of reduction, refinement and replacement was also tackled by a presentation on how to reduce the number of fish in experiments with shoaling species that will be

published soon and will be of great help for those working on fish health and welfare projects. Poster presentations also focused on this topic by showing some research on subjects such as refinement of anaesthesia protocols as well as the use of new anaesthetics and sedatives based on natural plant extracts.

The research on new species has been focusing heavily on the establishment of new protocols concerning light and temperature optimal conditions as well as swimming thresholds for cleaner fish.

Finally, both in the area of conservation and aquaculture, fish behaviour and physiological and molecular biomarkers are still being used as Biological Warning Systems in order to detect changes related to different levels of toxicity due to water pollution.

During the presentations some knowledge gaps became highlighted. The importance of enrichment to improve fish welfare and the validation of some operational welfare indicators and whether these will be species-specific. The final presentation on consumer perceptions and attitudes to fish welfare in European society highlighted the highest impact welfare has onto the consumers choice and an interesting debate was raised during the time for questions.

Trends in research seem to aim at deepening our knowledge onto the concept of robustness in fish together with personality traits to be used in selection. A practical use of the behavioural fever concept was presented in the form of behavioural prophylaxis and pond modification to allow for the expression of natural behaviours in fish. In the end, direct knowledge to be transferred to the industry will include the implementation of standardized operational welfare indicators (OWI) and behavioural phenotyping together with protocols for new species which will reassure the consumer about the quality and welfare of the fish consumed.

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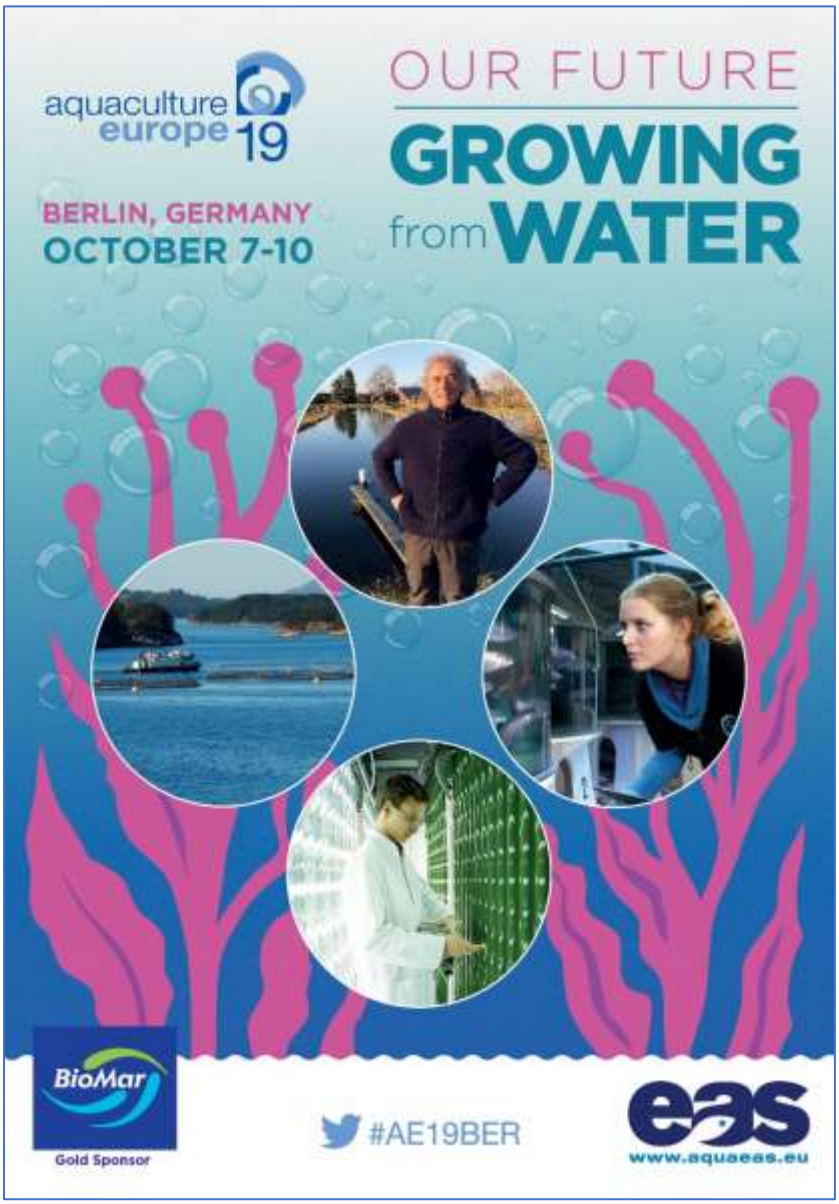
All life on earth emerges from water. Aquaculture nourishes and stimulates life in water in all its ways.

Our sector holds the potential to overcome many of the challenges our society faces. The future of healthy and sustainably produced food and commodities lies in the diversity of aquaculture, from single-cell microalgae in bioreactors to fish teeming in sea pens or freshwater ponds.

When we truly want to unlock this potential, we need innovative ways to support the economy of aquaculture, generating new business models and supporting start-ups. We need to proactively work towards the demands of existing and new markets for all our products, seeking new alliances in international trade and consumer support. We have to apply ourselves to the challenges of climate change and scarcity of natural resources in respect and appreciation of the ecosystems we are allowed to work with.



AE2019 will cover the full scope and diversity of European aquaculture. The thematic plenary and technical parallel sessions will comprise submitted oral and poster presentations. AE2019 will also feature an international trade exhibition, industry forums, student sessions and activities, satellite workshops and updates on EU research.

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