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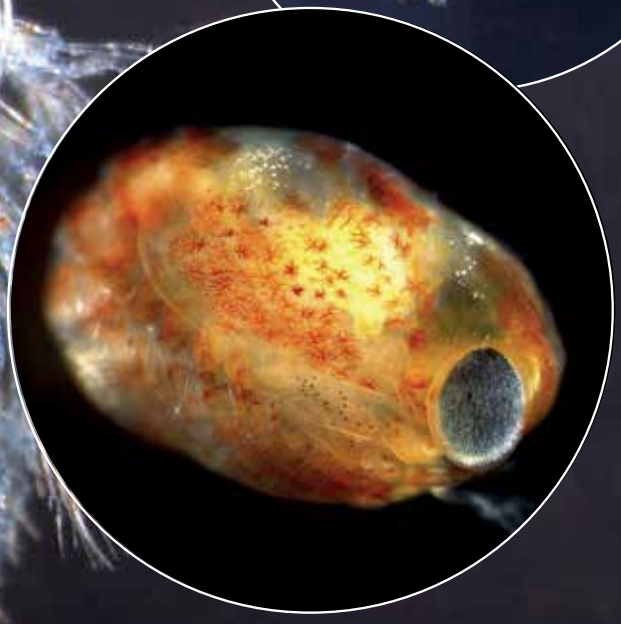
New Developments in European Lobster Aquaculture



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Dear EAS members,

On behalf of the members of the board of EAS, I am pleased to invite all of you to the forthcoming Aquaculture Europe 2016 in Edinburgh, where the main theme is "Food for thought". With more than 600 abstracts split into 27 sessions and 11 industry forums, the event is very promising indeed. I am sure that AE 2016 will continue, as is customary, to provide you with opportunities to have access to some of the latest research achievements from all across Europe and beyond. The plenary sessions planned will focus on the present status and future of Scotland' aquaculture, even involving pupil from schools.

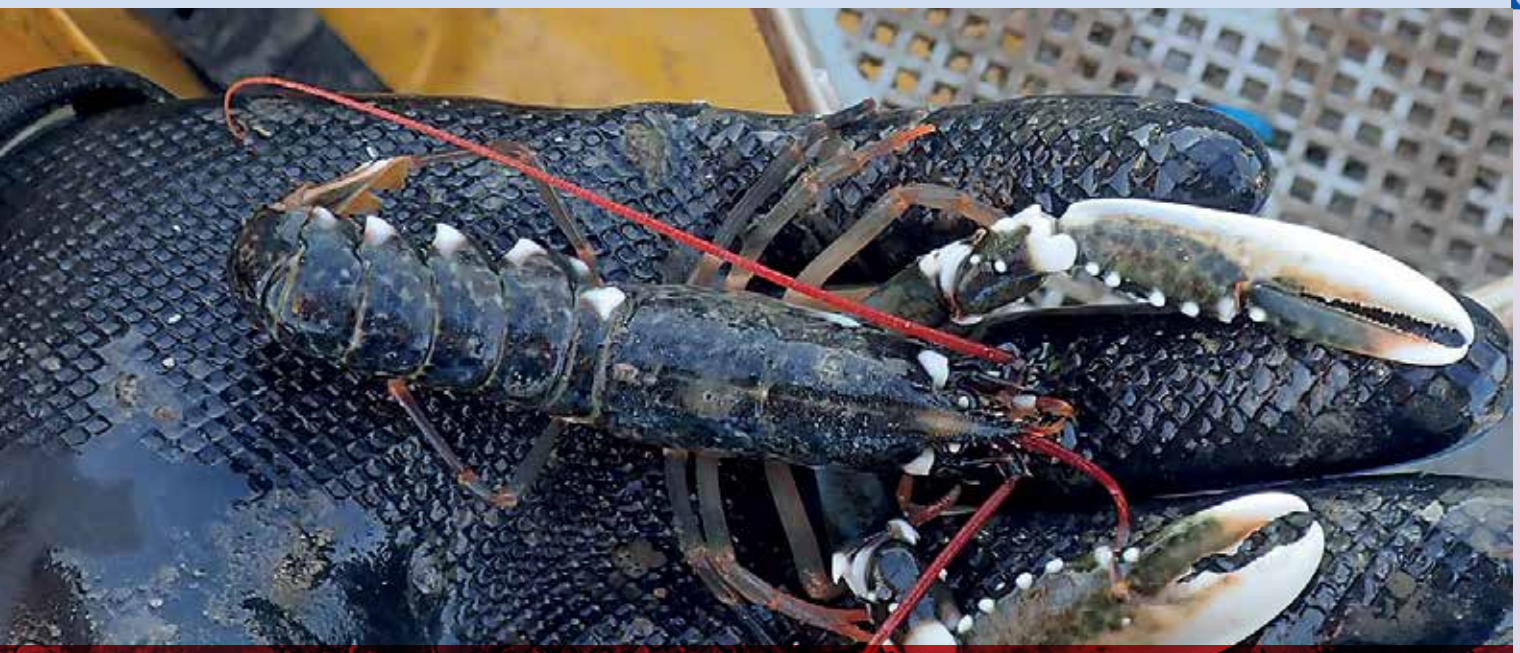
As you all know, EAS turns 40 this year. We have also made AE2016 to be a unique occasion where you can meet almost all past-presidents and see their continued interests and commitments to the causes of EAS. Special events are planned to mark this event.

We will also have the general assembly of EAS on September 21st. I welcome all of you to take part actively for your society. The full agenda and the procuration forms, for those who cannot be with us physically, will be sent out by our secretariat, well ahead of AE2016. This general assembly will also be the occasion for me to bid farewell as President, welcome the new board and the new President. The coming EAS board has some new members and will be presided by Bjorn Myrseth, a well-known figure who has already served EAS in the past as the President. This is my last column as president of the board and I wish to take this opportunity to express my sincere thanks to all the board members with whom I have had the occasion to work with and to Alistair and Linda for all the support I have received over the past years.

Please make sure also to retain the dates of October 17-20, 2017 already for our next Aquaculture Europe event in Dubrovnik, Croatia. AQUA 2018 will be an event jointly organized by EAS and the World Aquaculture Society (WAS) and will be held in Montpellier, France from August 26 to 29, 2018. AE2019 will be held in Berlin, Germany. I request all members to be as active as ever and continue to support EAS.

Awaiting to see you all in Edinburgh,

Sachi Kaushik
EAS President 2014-2016



New Developments in European Lobster Aquaculture

BY ADAM POWELL AND ELCE

Introduction

Crustacean farming is currently small in terms of production and value across EU member states. About 225 tonnes of crustaceans were produced from aquaculture (mainly freshwater crayfish, and the emerging specialist marine shrimp subsector). However, this is dwarfed by a European aquaculture production total of about 2.6 million tonnes, represented by finfish (*ca.* 75%) and molluscs (*ca.* 25%)[1,2].

The EU production of crustaceans arises mostly from wild caught decapods such as lobsters, crabs and prawns. Landings of European lobster (*Homarus gammarus*) rarely exceed 5,000 tonnes per year[3], compared to American lobster (*H. americanus*), which are nearly 60,000 tonnes per year in Maine alone[4]. With the price of European lobsters about £10,000 (EURO 13,000)/tonne[5] and a high global demand exceeding supply, fishing communities around Europe could be missing out. Future threats to crustaceans include emerging viral pathogens, climate change and anthropogenic inputs (plastics, pesticides and antifoulants). American lobsters introduced to European waters may cause a range of additional pressures, such as hybridisation, competition and disease transfer.

Historically, safeguarding lobster stocks has implemented fishing effort management, alongside efforts to protect or restore discrete habitats or fishing areas. Aquaculture is increasingly viewed as an additional approach, and this article aims to provide an overview of current and future innovation arising from the sector, which seeks to promote the sustainable supply of lobsters across Europe.

The lobster life cycle and hatchery "state of the art"

Female lobsters extrude fertilised eggs underneath their abdomen, where they remain attached and develop slowly over the winter. During development, the colour of the eggs changes from black to dark

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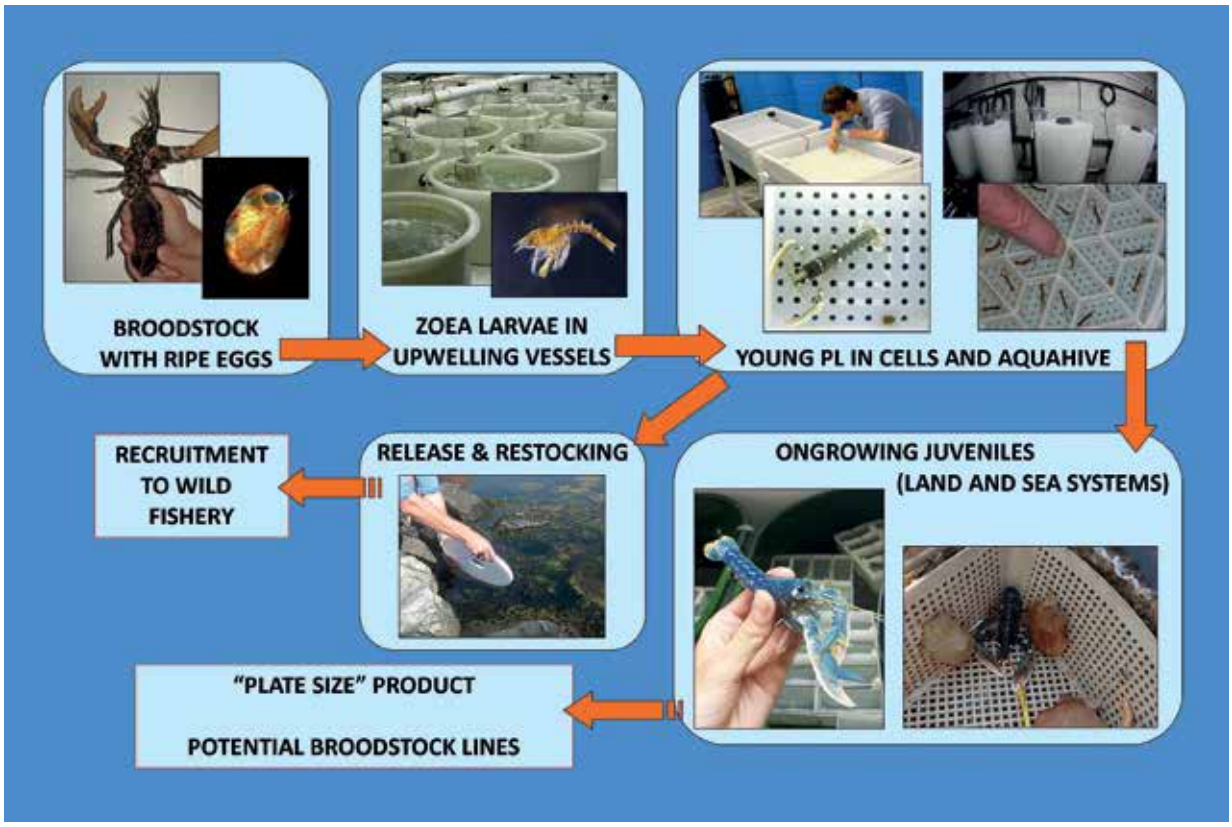

Figure 1. General rearing techniques and life cycle of the European lobster *(images courtesy of ELCE group)*

continued from page 5

red as yolk is exhausted. Embryos directly hatch into the water column at dusk over several successive evenings. Larvae are precocious, pelagic and motile, and develop in the water column over several weeks.

Three successive larval stages exist: Zoea (Z) 1, Z2 and Z3, which increase in size from about 8 to 14mm total length between moults. Development rate and success improves with increasing temperature, but also the quality and quantity of planktonic feed. Late Z3 larvae become increasingly benthic and eventually metamorphose into "post-larvae" (PL) which resemble very small adults. Juvenile *Homarus gammarus* remain cryptic for several years, and appear to be relatively site-specific, before being recruited into the fishery.

Homarus sp. reproductive biology and culture has been investigated on both sides of the Atlantic since the late 1800's, with hatchery manuals available[6]. A large adult female may release up to 20,000 larvae during hatching, however survival in the wild, from Z1 to adult, is likely to be very low indeed. The technical aims of lobster hatcheries have been to improve larval and PL survival and growth by reducing predation, promoting access to food, and by accelerating development via securing optimal, steady water temperature and quality. Wild "berried" females carrying eggs ("broodstock") are fished using static gear, with holding temperature sometimes varied to promote or retard development of embryos and prolong larval supply. Otherwise, larvae are allowed to hatch naturally, and are typically collected from all hatching females and reared communally in cylindroconical vessels *ca.* 70L volume. These are well aerated with a high water turnover to promote water quality, distribution of larvae and feed, and to reduce cannibalism. Alternatively, larger mesocosm ("green water") systems also work well, additionally adding microalgae to zooplanktonic feed[8]. Late Z3 larvae and PL are typically removed and ongrown individually in separate cell-like rearing containers (Figure 1).

The overall aim of hatcheries can be divided into two complimentary routes: The improvement or remediation (restocking and stock enhancement) of the lobster capture fishery by releasing young juveniles; and the emerging sub-sector of commercial lobster farming (in closed systems on land, and extensive container culture at sea). Whilst genetic and phenotypic screening of broodstock, the resulting larvae and PL may be the ultimate goal for lobster farming, this is in contrast to release of PL at sea for stock remediation. Securing genetic diversity, particularly with respect to local populations, demands the continual procurement of wild mated females.

Lobster culture constraints and considerations

In comparison with other aquaculture sectors, there is an overarching drive to improve economic sustainability which includes consideration of production and energy costs, the origin of feed components, and reducing feed use and waste.

More specifically, lobsters are aggressive and cannibalistic at larval and PL stages. Whilst current hatchery practices yield survival many orders of magnitude higher than in the wild, there is still room for improvement on the typical survival to PL (perhaps 25%). This may be achieved by moving away from live or "wet"

Figure 2. International ELCE workshop held at the Sven Loven Centre-Kristineberg, March 2016
(further information at http://www.nationallobsterhatchery.co.uk/whats-it-all-about/european-lobster-centre-of-excellence/)

feeds, and embracing a dry formulated feed designed for the species according to life stage.

Further ongrowing of PL demands culture in separate "cells" to prevent aggression and mortality. Aquahive technology (see below) has recently reduced the husbandry requirements to rear PL for release and stock enhancement purposes. The ability to ongrow juvenile lobsters to "plate size" at commercial scales, which demands increasingly larger cells and long term management, is also underway.

European Lobster Centre of Excellence (ELCE)

To promote innovation in the sub-sector, *ELCE* was formed in April 2013 with a mission statement to share knowledge and experiences in order to fast-track lobster aquaculture and stocking programmes (Figure 2). Universities, charities and private companies are current participants, with membership from across European hatcheries, charities, farms and allied research institutes (currently Iceland, Norway, Sweden, Denmark, UK, Spain and Italy). The most recent ELCE activity was a practical workshop during March 2016, at Sweden's first pilot lobster hatchery at the Sven Lovén Centre (Kristineberg), University of Gothenburg (http://loven.gu.se/english/about_the_loven_centre/kristineberg). This investigated the effect of larval provenance (i.e. female origin) on size, survival and physiology by collecting and rearing larvae discretely with respect to female. The results showed brood-specific response on fitness-related endpoints such as immune response, growth and survival. This is important since most hatcheries culture larvae accrued from several different females. Future attempts at domestication may aim to close the life cycle using larvae and PL with known traits, and this is the first step to see if these exist and are worth investigating. Valuable traits, could include fast growth rate, high survivorship, attractive colour and shape, and potentially low aggression or ability to subsist on feeds containing alternative proteins and lipids.

Formulated feed development

With the precedent long set by the Penaeid shrimp industry, the testing, production and use of a dry formulated feed specifically designed for *Homarus sp.* could prove very beneficial. The March 2016 ELCE workshop also found that replacement of a typical lobster hatchery feed (wet, sterilised plankton) with a commercially available pellet feed did not impact negatively on larval survival and development. It was also found that there was no change in feeding behaviour when individual larvae were presented with a wet feed or a dry feed. An ongoing project (*Nomaculture*; http://vbcv.science.gu.se/english/nomaculture) has created test quantities of feeds (moist and dry) using raw ingredients (off-cuts from local industry), to investigate if this could yield further benefits in terms of sustainable sourcing and food miles (Figure 3). Test feed is created by processing raw products using pH extremes (either low, acidic or high, alkaline preparations). Experiments have shown that PL exposed for 24h to feed created under low pH conditions, followed by identical feed created under high pH, resulted in a reduced feed intake (Figure 4). Conversely, feed intake increased when

continued on page 8

Figure 3. Test feed production and composition analysis of feeds and larvae. *(Courtesy of James Hinchcliffe, University of Gothenburg and Chalmers University of Technology)*

Figure 5. Automated larval collection, and feeding of formulated diets at Norwegian Lobster Farm AS *(image courtesy of Asbjorn Drenstig, NLF)*

the order of feed was swapped, suggesting that processing conditions are important to promote feed palatability and acceptance. Further work will analyse the composition of *H. gammarus* larvae and PL to enable a formulated feed to be designed which closely matches the species profile.

The importance of formulated feed development is shared by Norwegian Lobster Farm AS (Norway; http://www.norwegian-lobster-farm.com/), who agree that manufactured dry diets can be tailored to meet the different nutritional requirements of the various life stages, have a consistent nutritional value, and are easy to store, transport and handle. In addition, dry feed promotes biosecurity and hygiene in hatcheries, certainly compared to "live" feeds. NLF have found that no commercially available feed can match the growth performance in juvenile lobsters reared on a range of fresh or frozen natural feeds, since they are not designed for *H. gammarus* and are likely to have sub-optimal protein and lipid composition (Table 1) and potentially minor and trace nutrients such as specific fatty acids, mineral ions and astaxanthine. The company have developed proprietary feeds which consider both the nutritional value and the physical aspects of a dry diet, so the pellet is resilient to leaching at desired culture environments (thermal optima of 20°C and 33‰). Dry feeds also enable utilisation in mechanical feeders, promoting the realisation of a fully automated farming concept (Figure 5). Automatic feeding also enables precise and bespoke rationing to individual lobsters, in order to avoid excessive feeding and waste.

Approximate % dry composition	*Larval Homarus sp.*	*Fresh brine shrimp*	*Preserved plankton preparations*	*Commercial Artemia replacement diets*
Protein	70	60	60	55
Lipid	5	5	>12	15
Carbohydrates	7	15	10	10
Ash	18	20	>6	>12

Table 1. Comparison of lobster larvae proximate composition with commercially available "wet" feeds and potential dry replacements. Source7 and company websites

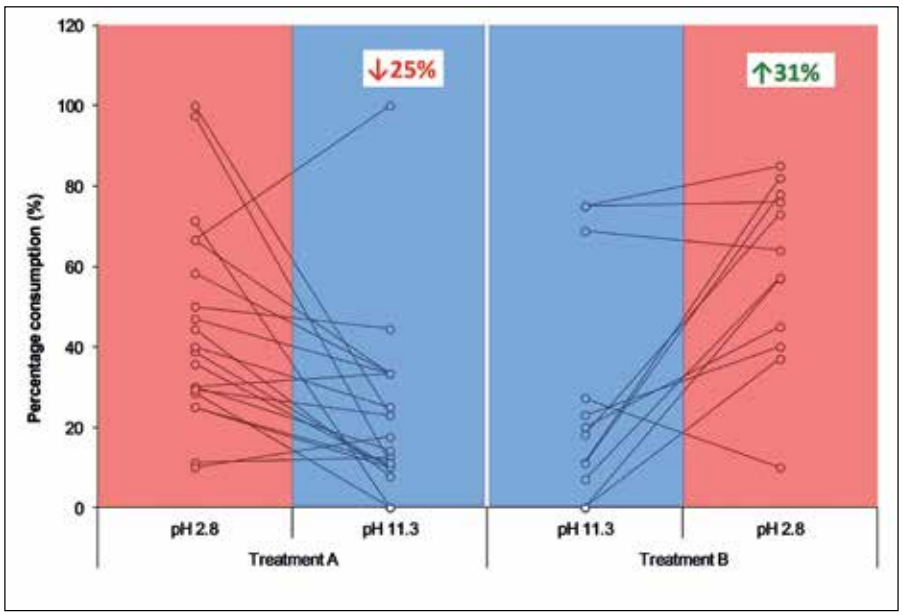

Figure 4. The effect of pH processing on feed intake.
(Courtesy of James Hinchcliffe, University of Gothenburg and Chalmers University of Technology)

Further to the overall proximate composition of feeds and total lipid content, phospholipids, long chain PUFAs and eicosanoid precursors are essential for a range of developmental and physiological processes, including neural development, membrane function. Of the total fatty acids present in wild lobsters, 7.7 and 18% consisted of EPA and DHA[9]. Lobsters have a limited ability to synthesise long chain PUFAs from shorter chain precursors and they need to be provided in formulated feed. Recent studies have investigated moulting success of larvae, which is crucial to maintain

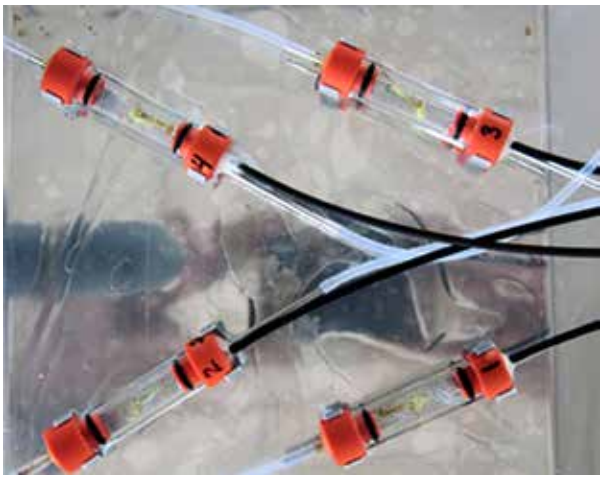

Figure 6. Intermittent flow respiration chambers for measuring oxygen consumption in zoea IV lobster juveniles. (*Image courtesy of Ivar Lund, DTU Aqua.*)

high recruitment of PL and reduce exuviae entrapment, which often results in death. In single chamber experiments at DTU Aqua (Denmark; http://www.aqua.dtu.dk/) there is a clear positive influence of supplementary dietary long chain PUFAs on larval survival and moulting ability of larvae from Z1 to PL. This work is crucial for the future development of formulated feeds. Further studies with juveniles raised on wet and dry diets have used respirometry chambers and oxygen partial pressure measurements to calculate metabolic rate (Figure 6). Understanding how feed type and temperature influences the metabolic scope of PL can inform optimal feed energy content, rations and culture conditions, so that more of the energy budget can be used in growth. Additional experiments using Y-mazes aim to ensure optimum welfare of juveniles under different feed treatments, by testing the ability of lobsters to explore new environments, search for feed and react to stressors.

Although Iceland has the potential to incorporate free geothermal energy for aquaculture (see below), there remain some key questions regarding suitable feed and rearing parameters. Growth rate, metabolism and survival were investigated according to different feed, temperature and photoperiod treatments. In initial feed trials, two experiments were conducted simultaneously at different locations (Sudurnes Science Learning Centre, SSLC and Saebyli Ltd). Commercial Arctic charr feed was offered at both locations, compared to an additional shrimp supplement at SSLC, and at Saeblyi Ltd a proprietary feed developed for the European lobster (Figure 7). Over a 7-8 week trial, very similar SGR was observed between locations and feeds, with the exception of feed supplemented with shrimp which showed a significantly higher SGR. This indicates that available dry feeds do not satisfy complete dietary requirements, and that improving the growth capacity by making an optimal PL feed is a priority. In other respects, lobsters were found to be quite robust with little change in metabolism according to photoperiod, temperature shock and between those cultured in flow-through or semi RAS systems. Anticipated growth and feed conversion efficiency was reduced in cold water treatments, although survival was higher. Future studies will investigate feed formulation, rearing conditions and metabolism, alongside the effect of photoperiod on moulting and survival. In depth results are to be made publically available in 2016-17.

Culture system developments

Advances in ongrowing technology and engineering also aim to reduce operating costs and improve the production of lobsters. For example, the practice of placing PL individually across cells reduces cannibalism, but demands cleaning and feed of potentially thousands of cells. To solve this problem, Shellfish Hatchery Systems Ltd (UK, http://www.aquahive.co.uk/) have developed the *Aquahive*, a system of circular, stackable trays containing a honeycomb of adjacent cells. Continuous upwelling water delivers intermittent food particles, allowing feeding and cleaning of PL within minutes. The overall footprint is also reduced by about 100-fold, compared to original raceway-based cell systems. This has led to further reductions in hatchery size, resulting in a portable and cost-effective *Hatchery in a box* (Figure 8, 9). Deployed inside a shipping container, this has made lobster culture more affordable and within reach of conservation charities, fisheries organisations and education institutes such as the Firth of Forth Lobster Hatchery (UK; http://firthofforthlobsterhatchery.org.uk/).

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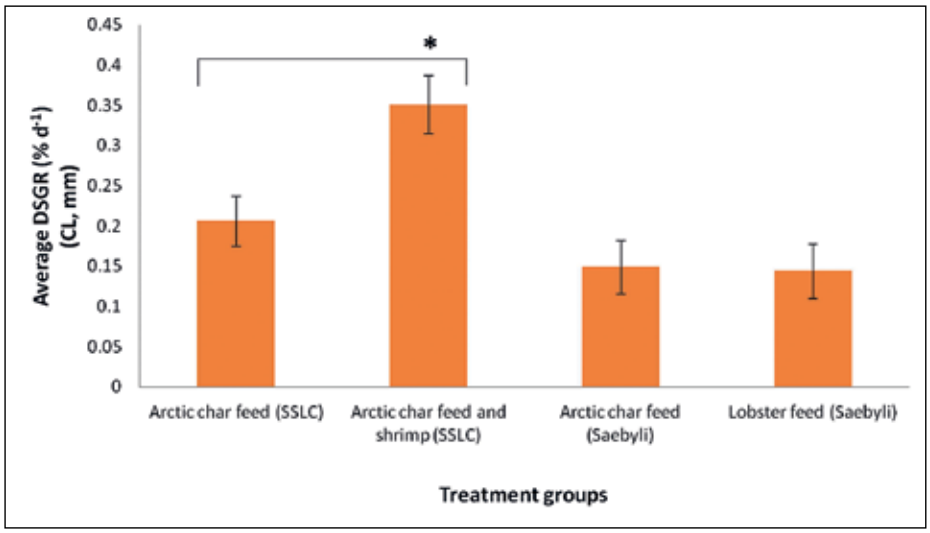


Figure 7. The effect of proprietary and commercial feeds on SGR in PL lobsters. EuroLobster is co-ordinated by Svinna Engineering Ltd and other ELCE project partners (NLF, DTU-Akva). Other participants include Institute for Marine Research (IMR) in Norway, the National Lobster Hatchery (NLH) in Padstow UK, the University of Iceland´s Research Centre in Sudurnes, Sudurnes Science and Learning Centre, the Southwest Iceland Nature Research Centre and abalone farm Saebyli Ltd. *(Courtesy of Ragnheidur Thorarinsdottir, Halldór P Halldórsson and Soffía K Magnúsdóttir)*

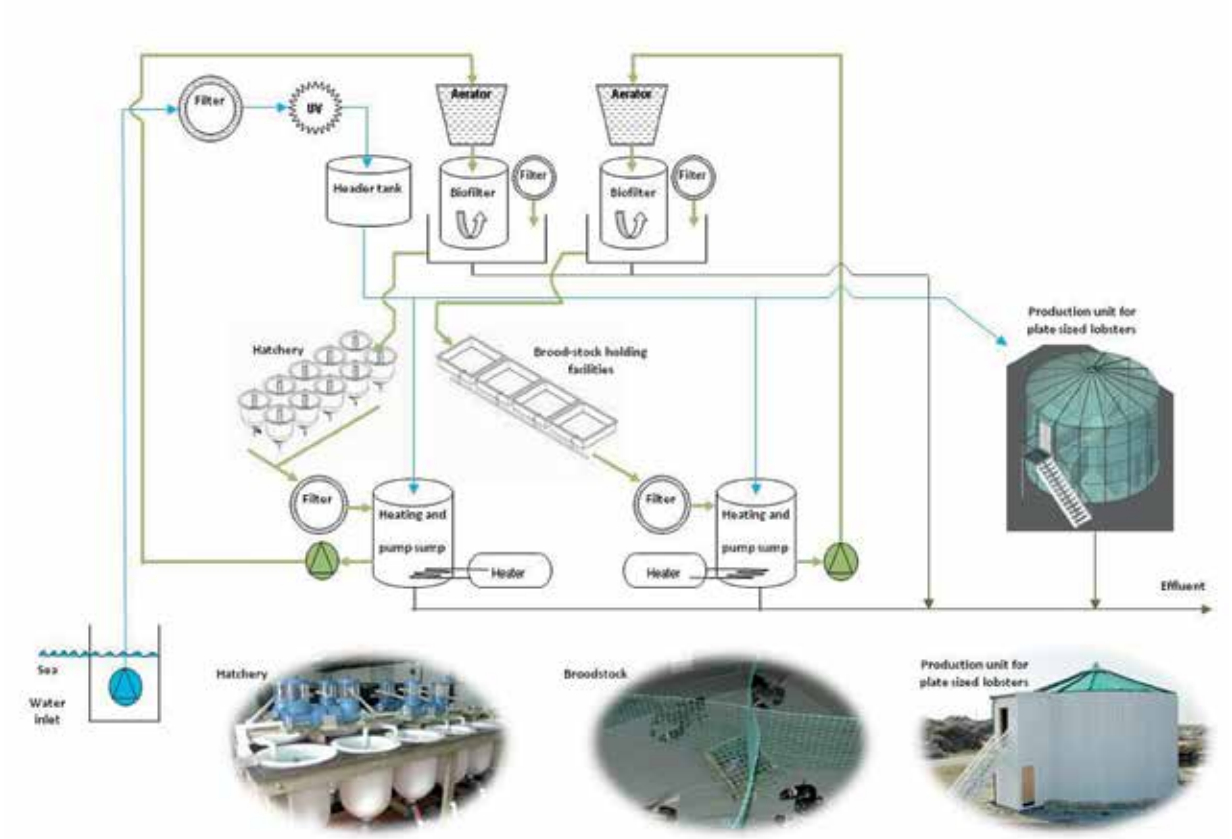
continued from page 9

Figure 8, 9. *Hatchery in a box*, containing larval rearing vessels, Aquahive and RAS technology, incorporated and deployed inside a shipping container. (*Images courtesy of Jane McMinn, Firth of Forth Lobster Hatchery)*

Land based ongrowing

Longer term farming of lobsters beyond small PL size demands further innovation to maintain feeding, cleaning and separation of juvenile lobsters as they grow. Norwegian Lobster Farm AS (NLF) have been at the forefront of automated ongrowth technology, with commercial production of plate sized lobsters proven using a robotic system in RAS[10]. Generation 2 of their advanced land based single cage *DEVAELA* system is currently under development via a recently awarded Eurostars project, with hatchery partners Norsk Hummer Drift AS (http://www.norskhummer.no/).

Integral to this system is a robotic cage handling technology, consisting of 5-80 individual lobster cages accrued in pairs of 10 module high columns. A typical 200 cage-module section will house up to 1,000 plate size lobsters (*ca.* 300g, or 20cm). The robot shifts one cage–module in sequence upwards through one of the columns until it reaches an overhead feeding unit. Feed is delivered, and the cages are subsequently moved downwards through a parallel column allowing the next cage-module to be fed. The time required is max. 15 min to complete one cycle per section (i.e. to feed 1,000 lobsters). The automated feeding unit is straightforward to manage, and enables feeding intervals (2/day) of 5 different pellet sizes with an accuracy of +/- 0.1g. Additional automated monitoring systems allow daily control of production parameters via image technology (growth, moulting frequency) and maintenance of water quality. An advanced size and quality grading system will assist "plate sized" lobster harvest. NLF are close to validation of a larger scale automated system with a desire to establish the first ever profit-



able land-based farm with production greater than 150 tonnes per year. The system does not require large water bodies and is modular, enabling it to be installed in existing buildings close to seawater. The product will be sustainable, biosecure, available around the year with reduced human error (improved reliability).

Ozone, UV and probiotics[11] have been tested in the National Lobster Hatchery (UK; http://www.national-lobsterhatchery.co.uk/) as a preventative, non-medicinal strategy to reduce opportunistic infections, improve survival of larvae and hence enhance PL recruitment. These could also play an important part of any upscaling and automation, to promote hygiene standards across such a facility.

Iceland is situated on the North Atlantic ridge and has abundant and well managed access to geothermal energy. Geothermal energy produces hot water for almost all domestic and municipal buildings. The low carbon source of stable, relatively high temperature water is of particular interest for valuable, cultured species which have the capacity to grow faster at specific thermal optima. With abundant, high quality fresh water and sea water, ELCE partners are focusing on diversifying the direct use of geothermal energy for food production and processing. Since 2014 Nordic Innovation has supported an innovation project coordinated by Svinna Engineering Ltd (Iceland; *EuroLobster*[12], http://eurolobster.svinna.is/) focusing on biological and technological challenges that need to be solved for land based farming of the European lobster (Figures 7, 10, 11).

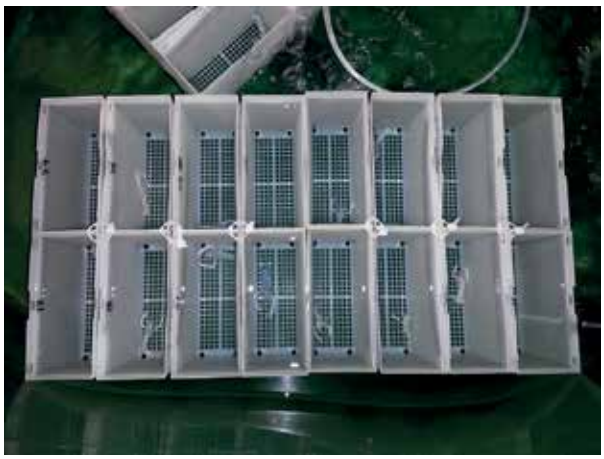


Figure 10,11. Geothermal energy providing a source of low carbon energy for land based production of lobster juveniles in Iceland. *(Images courtesy of Ragnheidur Thorarinsdottir, Halldór P Halldórsson and Soffía K Magnúsdóttir)*

Extensive sea culture

An alternative approach to land based farming is extensive sea-based culture. PL lobsters are placed in perforated containers (such as commercial oyster baskets), and are deployed on ropes at sea, without food supplementation. Relatively quickly, fouling organisms are attracted to the surfaces of the baskets, and alongside plankton form candidate feed for the growing lobsters. Initial deployment studies in Ireland and Spain showed promising results about a decade ago under the AquaReg initiative[8], including ELCE members Instituto Galego de Formación en Acuicultura (Spain; http://www.igafa.es/). More recently, a UK consortium led by the the National Lobster Hatchery, has continued with sea trials at small to medium scale (*Lobster Grower* projects, http://www.lobstergrower.co.uk/; Figure 12, 13). This established good short term survival and growth rates, with low energy and zero feed cost, at a fixed unit cost of production[13]. *Lobster Grower 2*, which kicked off early in 2016, aims to develop bespoke container design and deployment mechanism of sea-based container culture (SBCC) systems, across a pilot scale lobster extensive culture site rearing up to 45,000 juveniles. Growth, survival and health of the stock will be monitored, alongside environmental impact of the culture site. Using data from the pilot culture site as well and economic and social data, an aqua-economic model will be produced to help potential investment in the lobster aquaculture sector.

continued on page 12

Figure 12, 13: Extensive sea based culture of juvenile lobsters in containers under *Lobster Grower* and *Lobster Grower 2* (funded by from Innovate UK, BBSRC and The Fishmongers' Company; additional partners Westcountry Mussels of Fowey, CEFAS and Exeter and Falmouth Universities). *Images courtesy of Carly Daniels and Jake Scolding, The National Lobster Hatchery.*

Conclusions and future considerations

Colleagues across the wider ELCE group have established the key requirements required to expand lobster farming, principally in dry formulated feed technology and farming infrastructure. It has previously remained challenging to rear lobsters from metamorphosis to commercial size in 2-3 years solely, or even largely, on a compounded diet[14]. Norwegian Lobster Farm has successfully demonstrated production of several metric tons of plate sized lobster solely based on use of pelleted feed. It is now potentially the economies of scale, and clever innovations in RAS and use of geothermal or waste energy, that could foster an economically viable land based operation. As exciting is the fast development of extensive cage based farming led by the National Lobster Hatchery, which could develop alongside the current expansion of marine renewable energy emplacements; and the improved hatchery accessibility due to the miniaturisation spearheaded by Shellfish Hatchery Systems.

The benefits of knowledge transfer and co-operation have started to lower the threshold for commercialisation and the technical, financial and ethical challenges. European lobster aquaculture continues to prove a rewarding topic with proven collaborations between researchers and industry. Hopefully the overall European landings and value returns will see lobsters playing an increasing role in the years to come.

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Advances in Atlantic halibut (*Hippoglossus hippoglossus*) research: the DIVERSIFY project

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The Atlantic halibut (*Hippoglossus hippoglossus*) is the world's largest flatfish and can attain a weight of over 300 Kg (**Fig. 1**). It is highly prized at markets worldwide, having a characteristic flaky white meat with few bones and semi-fat flesh that is rich in omega-3 fatty acids. However, availability of wild Atlantic halibut has been decreasing steadily in the last decades, and the fish is classified as endangered on the IUCN red list. These characteristics led to the inclusion of Atlantic halibut in the project DIVERSIFY – (FP7-602131, www.diversifyfish.eu)- as a great candidate for fish species and product diversification in European aquaculture.

Research and cultivation efforts of Atlantic halibut started in the 1980's, but the total annual production of cultured Atlantic halibut is still only ~1600 t (Norwegian Directorate of Fisheries). In Europe, Atlantic halibut farms exist in Norway and Scotland. The desired market size is 5-10 kg and production time is currently 4-5 yrs. Despite a significant research effort between 1985 and 2000, the complicated life cycle of Atlantic halibut made aquaculture progress slow, and very little research funding has been allocated thereafter. However, during this time slow but steady progress has been made by the farmers in order to improve production stability, and interest in cage culture is growing. The remaining bottlenecks for increased and stable production are related to a steady supply of fry and a need to decrease the production time. The latter may be achieved with the recent establishment of "all female" juvenile production (Hendry et al., 2003; Babiak et al., 2012). The project DIVERSIFY addresses some other important bottlenecks in reproduction, larval nutrition and husbandry, and fish health, in order to improve the existing rearing methods and enhance the commercial production of Atlantic halibut.

Figure 1. Atlantic halibut broodstock at Institute of Marine Research, Austevoll Research Station.
Photo: Institute of Marine Research.

REPRODUCTION & GENETICS

Even though empirical data suggest a significant difference in spawning performance between wild-caught (wild) and hatchery-produced (farmed) Atlantic halibut females, systematic documentation is lacking. The Atlantic halibut is a group-synchronous, batch spawner and in captivity wild females will release 6-12 batches of eggs during a period of 2-4 weeks in the spawning season (February to late April in southwestern Norway). Females have to be manually stripped of their eggs according to their individual ovulatory rhythms, to prevent over-ripening and deterioration of

	Domesticated Females	Farmed (F1) Females
n	3 (4•)	5
length (cm)	150.7 ± 6.2	113.4 ± 3.9
weight (kg)	48 ± 5.7	19.2 ± 2.3
number of batches - female $^{-1}$	7.3 ± 0.6	9.4 ± 1.7
spawning interval (hours)	82.2 ± 8.4	72.4 ± 22.9
batch volume (mL)	2300 ± 900	700 ± 300
total fecundity (mL - female^{-1})	16700 ± 420	6800 ± 130
relative fecundity (mL - kg^{-1})	347 ± 70	349 ± 84
average fertilization (%)	89 ± 7	61 ± 29

Table 1. Spawning performance of wild and farmed Atlantic halibut breeders at IMR, Austevoll.

the eggs (Norberg et al., 1991). Although wild females generally adapt well in captivity, displaying high fecundity with egg batches spawned at regular intervals, farmed females (F1/F2 generation) appear to suffer from a reproductive dysfunction, releasing small batches of eggs at irregular intervals. There is, however, a lack of thoroughly documented evidence describing this reproductive dysfunction in farmed females. Consequently, reproductive performance of wild Atlantic halibut and farmed females was compared in the framework of DIVERSIFY.

One group of wild breeders held in captivity for at least 4 years, and one group of farmed females were closely monitored for ovulation during the spawning seasons of 2015 and 2016 and were strip-spawned and the eggs fertilized *in vitro*. Eggs were incubated at 6°C under standard hatchery procedures (Mangor-Jensen et al., 1998) for 72 day-degrees (11 days at 6°C). For calculation of hatching percentage, eggs were collected and divided into 500 ml beakers with sterile-filtered seawater and incubated in darkness at 6°C for 72 hours. Hatched larvae and dead eggs were counted in a binocular microscope and larvae were also photographed in a dissecting microscope, in order to document any possible aberrations from normal development.

Overall, the wild females appeared to spawn fewer, larger egg batches with higher and more stable fertilization success (**Table 1**). Relative fecundity did not differ between the two groups. Careful monitoring and timing of stripping, as close to ovulation of the whole batch as possible, was necessary in order to obtain high fertilization of eggs (by avoiding over-ripening). In cases where the whole egg batch could not be strip-spawned, domesticated females generally released the remaining eggs into the tank. Farmed females, in apparent contrast, tended to keep a small "residue" of eggs, typically 100-250 ml, which were held in the ovary. These eggs had to be stripped 6-12 hours after the main batch so that the overripe residue would not have a negative impact on the viability of the next, maturing cohort. Once this was established as an additional routine in strip-spawning eggs from farmed females, the fertilization success stabilized at levels above 75-80% in most individuals, with occasional batches having up to 90-94% fertilization.

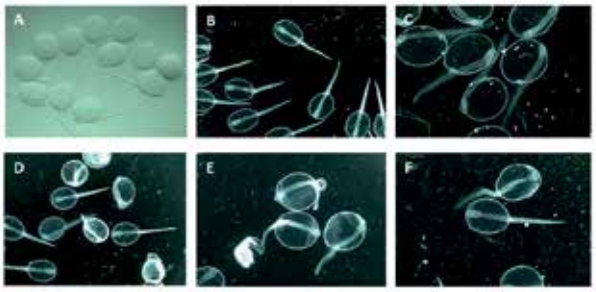

Figure 2. Newly hatched larvae from wild (A-C) and farmed (D-F) Atlantic halibut females. Note spinal deformities in embryos from farmed females. *Photo: Institute of Marine Research.*

Eggs from farmed females generally appeared heavier, and would sink to the bottom of the incubator/beaker, while eggs from domesticated females remained buoyant near the surface. Hatching success was lower in eggs from farmed females, and dead or deformed larvae were observed more frequently when eggs from farmed females hatched (**Fig. 2**). It is not clear what caused the deformities, but one possible cause may be mechanical damage of the heavy eggs, that sank and rested at the bottom of the beaker for two days. Further work is needed, however, in order to establish whether this is the cause or if there are genetic/epigenetic factors that contribute to a higher rate of deformities in larvae from those females.

Overall, wild females were predictable spawners that consistently gave eggs of very high quality (>85% fertilization). Farmed females also produced eggs of high quality when their ovulatory cycles were identified and stripping carried out close to ovulation. However, for commercial, as well as breeding purposes, it is not practical to rely on wild-caught females. As at both IMR and SWH, relatively few farmed females produced eggs with fertilization rates >80-85% consistently, it may be necessary to include wild-caught broodstock also in future in order to ensure a broad enough genetic material. Identifying potential high-quality breeders and concentrating the strip-spawning effort on those females may be useful in order to reduce the very considerable workload connected with spawning and egg collection of Atlantic halibut.

One way of alleviating the reproductive dysfunctions of farmed females, might be to use reproductive hormone therapies, such as controlled-release delivery

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Figure 3. Atlantic halibut broodstock treated with GnRHa implants to induce ovulation at IMR. *Photo: Constantinos C. Mylonas.*

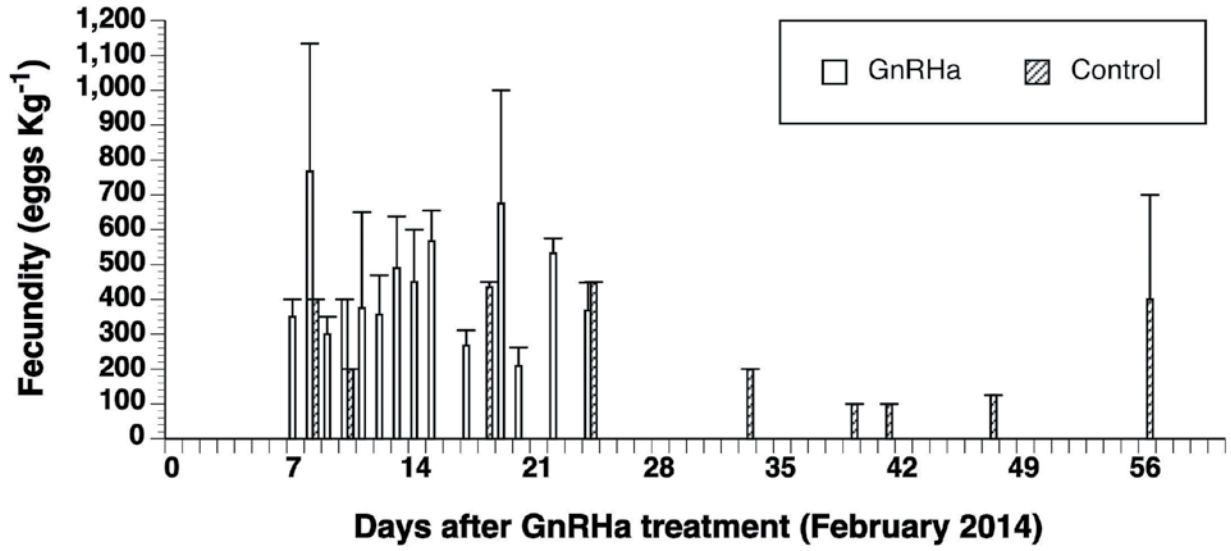

Figure 4. Mean (±SEM) daily egg production of Atlantic halibut treated with GnRHa implants (50 or 100 µg kg-1) or sham-injected as Controls at IMR, Austevoll.

systems (implants) loaded with gonadotropin releasing hormone (GnRHa) to induce oocyte maturation and ovulation. Such therapy has been highly effective in other teleosts (Mylonas et al., 2010) including flatfish, such as the coldwater batch-spawner yellowtail flounder (*Pleuronectes ferrugineus*; Larsson et al., 1997). To examine the application of GnRHa implants in improving reproductive performance of farmed Atlantic halibut (**Fig. 3**), females were selected based on ovarian biopsies and were treated either with GnRHa implants for an effective dose of 50 µg kg^{-1} or 100 µg kg-1, or were sham injected (Control group). Two commercial trials were then made based on these result, using females with outer signs of maturation: ovary visible on the exterior of fish but not enlarged near the ovipore, degree of swelling and color of ovipore, and based on documented spawning performance. All females chosen had given average to low amounts of eggs in previous seasons. Females were implanted with 75 µg GnRHa kg-1 or were sham-injected as Controls.

Although GnRHa implantation did not advance spawning time significantly in Atlantic halibut females, in two of the trials there was an apparent synchronization in spawning time between individuals, as all treated females had completed spawning 1 month before all Control fish were spent (**Fig. 4**). Spawning in Atlantic halibut normally occurs during a period of 2 to 3 months both in captive broodstock and in natural populations (Norberg et al, 1991; Haug1990). This is most likely an adaptation that will ensure production of viable offspring independent of year-to-year fluctuations in temperature and feed availability for larvae. In a commercial production, however, synchronization between individuals can be an advantage as staff efforts can be concentrated to a relatively short period. Atlantic halibut females ovulate and release their eggs (*i.e.* spawn) in captivity, but fertilization of eggs released in the broodstock tank happens only occasionally. Therefore, Atlantic halibut breeders need to be monitored closely for ovulation and stripped on a regular basis for *in vitro* fertilization to be successful, and the use of GnRHa implants offers a logistic advantage to the commercial broodstock management of the species, by shortening the spawning season.

Figure 5. First-feeding Atlantic halibut larvae.

Photo: Institute of Marine Research.

On the other hand, spawning performance in terms of fecundity per female and fertilization success was not significantly affected by GnRHa treatment in Atlantic halibut females. In the first experiment, which was carried out at IMR, females implanted with GnRHa had a marked trend towards a higher fecundity than Control females. In the 2 commercial trials, however, this trend was not observed. So, at this stage the use of GnRHa

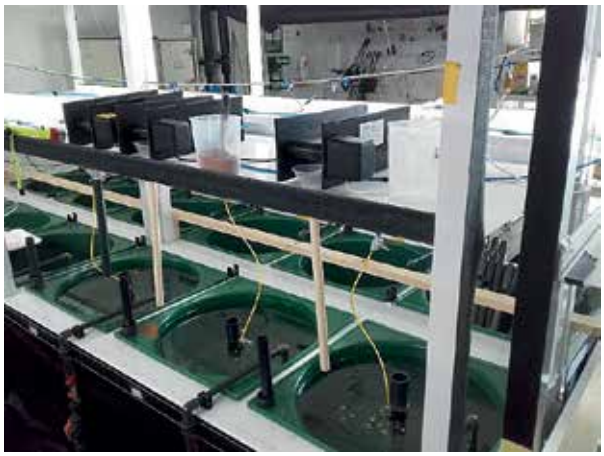

Figure 6. Tanks used for early weaning of Atlantic halibut larvae. *Photo: Institute of Marine Research.*

therapy to increase fecundity and/or fertilization success is not confirmed. Apparently, spontaneously maturing and ovulating females may produce as many eggs as GnRHa treated individuals. However, GnRHa was demonstrated to be highly effective in ensuring that all females matured and ovulated, as all treated females ovulated at least 3 to 4 egg batches, whereas in all trials some of the Control fish did not ovulate and appeared to resorb their ovaries. So, these results indicate that GnRHa implantation may be a useful tool to ensure that all females in a broodstock group reach maturation and ovulation, increasing parentage contribution to the next generation and increasing overall broodstock fecundity, without having deleterious effects on egg viability.

LARVAL REARING AND NUTRITION

Atlantic halibut larvae are approximately 12 mm in standard length (SL) at first-feeding and because of their relatively large larval size they are first-fed on *Artemia* (**Fig. 5**). The main constrains for Atlantic halibut hatcheries are (1) slow growth during the late larval stages and (2) high mortalities caused by opportunistic bacteria, and 3) slow growth after weaning. The slow growth in late larval stages may be overcome by early weaning. Most often, weaning of Atlantic halibut occurs only at 60 days post first-feeding (dpff), but attempts have been made to introduce formulated diets from 20 and 50 dpff, with varying results. The first problem arising is that the larvae refuse to eat formulated feed (Harboe, Hamre and Erstad, unpublished results). It has been observed frequently, however, that they ingest inert particles such as *Artemia* cysts and pollen from pinewood, the main similarity being that both particles have neutral buoyancy and a bright color. Previous experiments have also shown improved feed ingestion with floating compared to sinking feed particles. Furthermore, the structure of the visual system of Atlantic halibut larvae indicates that they hunt prey in the horizontal plane, favoring feed intake when particles stay in the same position in the water column for some time. Additionally, the type of feed could also affect digestive capacity of proteases, carbohydrases and lipases (Caruso et al., 2009) or even ATPase activity, which is essential to ensure the ion gradient necessary for nutrient uptake in the gut.

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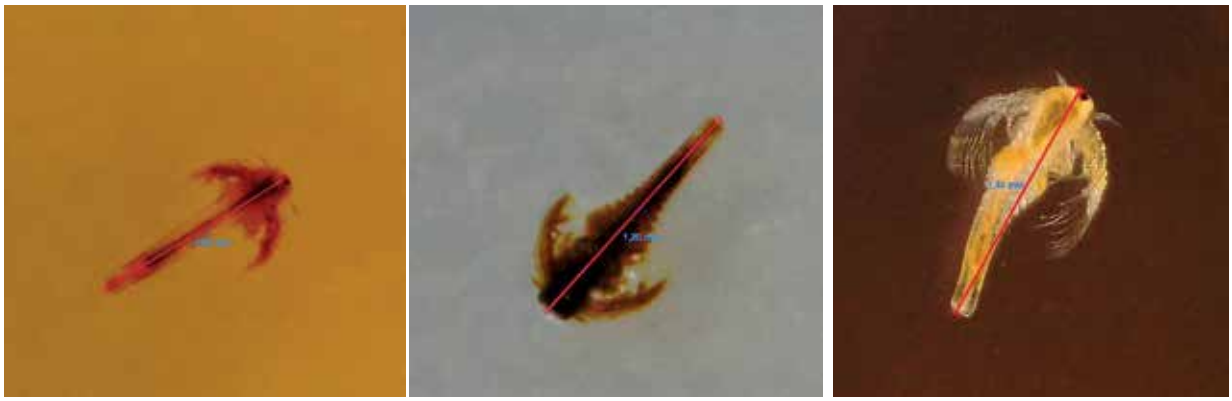

Figure 7. Artemia grown from nauplii for 2, 3 and 4 days. Length: 1.06, 1.2 and 1.4 mm, respectively. *Photo: Institute of Marine Research.*

Another strategy to alleviate the slow growth of later stage Atlantic halibut larvae is to feed them on-grown *Artemia*. On-grown *Artemia* are larger, contain more protein and phospholipids and have different micronutrient status from *Artemia* nauplii (Hamre and Harboe, unpublished results). Because of the larger size, they will probably also have a lower shell-to-soft tissue ratio. These differences may explain why Atlantic halibut fed on-grown *Artemia* have grown faster and develop into juveniles with better pigmentation and eye migration than larvae fed *Artemia* nauplii (Olsen *et al.*, 1999; Hamre and Harboe, unpublished).

In the course of DIVERSIFY, we have chosen three candidate feeds, anonymized as Feed A, Feed B and Feed C) based on their chemical content and earlier experience, and tested them on early weaning of larvae at 28 dpff and for 5 d (**Fig. 6**). In addition, experiments were performed in order to develop a production strategy for on-grown *Artemia* which was tested on the larval rearing of Atlantic halibut.

In the early weaning experiment, gut fullness was lower in the morning than in the evening, possibly because the larvae were measured before hand feeding and clay addition in the morning and after this procedure in the evening. According to the evening measurements, larvae fed *Artemia* were almost full on the first day and stayed full for the rest of the experiment. Larvae fed Feed B showed increasing fullness over the whole period and on day 5 almost 100% of the larvae were full in the evening. The fraction of larvae with food in their

gut increased more slowly on Feed A and Feed C. On the evening of day 5, 14.7±1.2 and 12.0±0.6 larvae, respectively, out of 28 had filled guts, while 0-0.3 larvae had partly filled guts on these diets.

For the production of on-grown Artemia, experiments were performed IMR and SWH. *Artemia* were hatched and either enriched directly with Larviva Multigain (Biomar, Denmark) or grown for 3-4 days on OriGreen (IMR) or Ori-One (SWH) and then enriched with Larviva Multigain (**Fig. 7**). Based on the evolution of protein and lipid content in the on-grown *Artemia* combined with labor costs, it was concluded that the optimum growth period is 3 days. There was no difference in larval performance. Survival measured as the number of fry at 70 dpff was between 42 and 48% of incubated larvae. Growth, except for the end point, has so far not been measured. However, at the end point there were no differences between the two groups. Both groups showed 100% normal pigmentation and good eye migration (score: more than 2.5/3). In the industry, the routine method is to feed *Artemia* nauplii and it is quite common to produce large fractions of Atlantic halibut larvae with abnormal pigmentation and lack of eye migration, although the Atlantic halibut juvenile quality has improved in recent years. In this study, larvae fed the *Artemia* nauplii had perfect pigmentation and eye migration, so the juvenile quality could not be improved further by feeding on-grown *Artemia*. It was very labor-intensive to produce the on-grown *Artemia* needed for the experiment, so on some occasions the on-grown group had to be fed nauplii to get enough food. As the fish grew, more feed

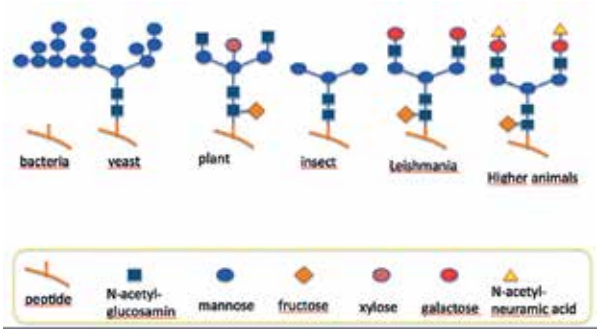

Figure 8. Glycosylation of proteins in different organisms, showing the extent of glycosylation.

was needed and due to capacity problems, the feeding period had to be shortened to last until 28 dpff instead of 45 dpff as planned. These are all possible reasons that no differences between the groups were detected.

HEALTH

One of the diseases that can affect Atlantic halibut culture is caused by the Viral Neural Necrosis (VNN) virus, which is also known as betanodavirus. The work included in DIVERSIFY was targeted at the development of a vaccine, using recombinant nodavirus protein. Recombinant capsid protein from nodavirus expressed in *E. coli* has been shown to induce protection when formulated in a vaccine and administrated by injection. However, bacterial cells do not glycosylate the expressed protein, as do

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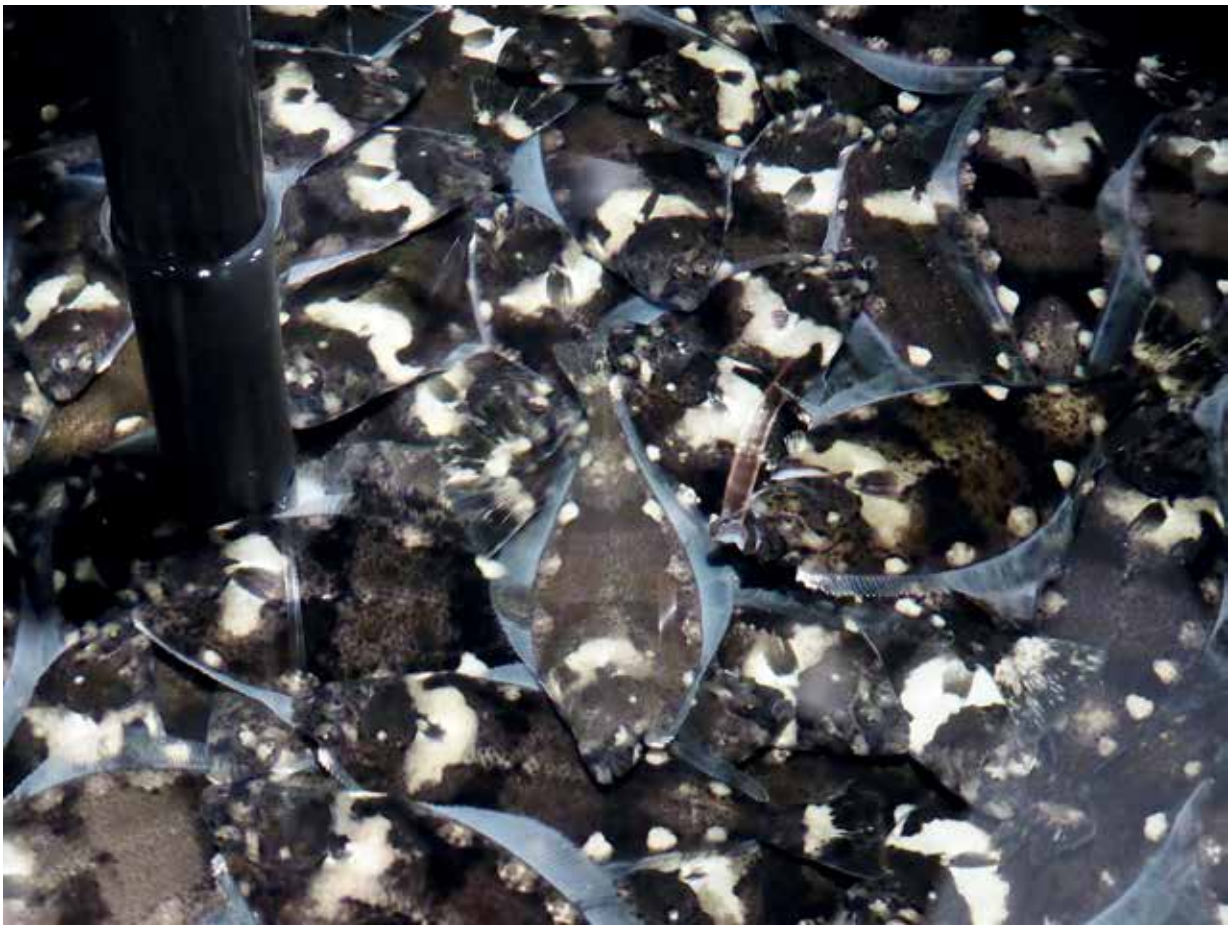

Fig 10. Farmed Atlantic halibut juveniles. *Photo: Sterling White Halibut.*

Figure 9. Atlantic halibut larvae produced at the IMR, Austevoll facilities. Ontogeny of lymphoid organs during larval stages has been characterized in detail to get an understanding of when the larvae are immune-competent and can be stimulated with immune-stimulants or vaccines. *Photo: Sonal Patel, Institute of Marine Research.*

higher eukaryotes. It might be that other expression systems (**Fig. 8**) may provide antigens more similar to the native viral proteins produced after viral infection. By expressing the capsid protein of nodavirus recombinantly in different Systems, it should be possible to find out if post-translational modifications influence antigenicity, thereby affecting its ability to induce protection when used as an antigen in a vaccine.

Assessment of the use of several expression systems for production of nodavirus capsid protein such as two eukaryotic expression systems; microalgae and a protozoan (*Leishmania tarentolae*), in addition to *E. coli* and tobacco plant was carried out. In addition, expression in microalgae is being assessed. Expression of the nodavirus capsid protein could be achieved in all three tested systems. However, it was only in the *E. coli* system that we achieved sufficient and high expression for further use of the protein as antigen for vaccination purposes. This protein has previously been shown to give partial protection in halibut (Øvergård et al 2013), but further optimization for sufficient expression in plant and protozoan systems and a method for purification of the recombinant protein is necessary.

In general, nodavirus infections and disease outbreaks in halibut are seen in larval and early juvenile stages (**Fig 9**). Thus it is important to have knowledge about when the larvae are immune-competent to plan the time-point for vaccination and avoid immune-tolerance (Patel et al 2009, Øvergård et al 2011). Moreover, size of the fish to be stimulated is a hindrance for traditional injection vaccination, especially during early larval stages. An alternative is to bath vaccinate or deliver the vaccine orally. To achieve oral vaccination the antigen has to be presented in a way that the target fish will accept and ingest. If we succeed to get uptake of the antigen by the *Artemia* offered as food item, we anticipate that it can act as a vector for oral uptake to the larvae. Vaccination of halibut during the late larval stages would provide protection during the transition period from live- to commercial- feed, and thus protection from VNN outbreak during some of the phases when halibut are prone to get the disease outbreak can be achieved. Ongoing work is focusing on two subsequent objectives. The first is to test the delivery of vaccine candidates to *Artemia* and then to Atlantic halibut larvae. The second objective includes the monitoring and assessment of the immune response and protection in the Atlantic halibut juveniles.

This 5-year-long project (2013-2018) has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration (KBBE-2013-07 single stage, GA 603121, DIVERSIFY). The consortium includes 37 partners from 12 European countries –including 9 SMEs, 2 Large Enterprises, 5 professional associations and 1 Consumer NGO- and is coordinated by the Hellenic Center for Marine Research, Greece. Further information may be obtained from the project site at www.diversifyfish.eu, the Atlantic halibut leader Dr Birgitta Norberg (birgitta.norberg@imr.no) and the Project Coordinator Dr. Constantinos C. Mylonas (mylonas@hcmr.gr).

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Application for Direct Fish Purchase and Traceability


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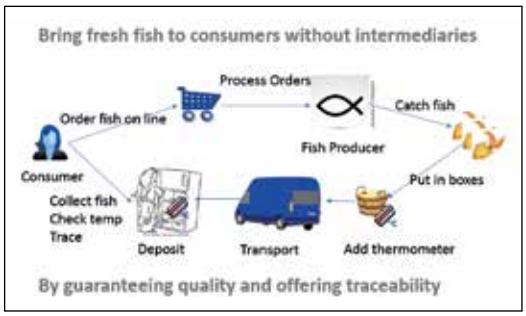

The vast majority of seafood in Europe, is traded through the traditional channel producer => wholesaler / retailer => consumer. Accordingly, we have narrow profit margin for the producer and not always a guaranteed quality of the fish product. 'FerTility' (**F**ish Dir**e**ct Pu**r**chase & **T**raceabil**ity**) solution combines mobile and web technological frameworks to allow **direct** fish purchase. Time temperature **sensors** are also utilized in the solution to assure that temperatures of the fish being traded are in between valid ranges. With our 'FerTility' solution we are opening a new era of consuming behavior for aquatic products assuring quality and also promoting locality through trust relations between producers and consumers.

FInish Challenge

'FerTility' was funded by the FInish project, which is a FIWARE Accelerator, marking the last phase of the Future Internet Programme. The FInish accelerator is currently funding 31 projects realizing intelligent systems - especially software applications - for supply chains of perishable food and flowers. They represent new ways of facilitating seamless business to business collaboration in complex supply chains and networks [1].

More specifically, FInish Accelerator stands for 'Food Intelligence and Information Sharing for Business Collaboration enabled by the Future Internet business domain' and is related to the Supply Chain of Perishable Food and Flowers; addressing solutions that will help to improve and provide a business value for e.g. growers, traders, processors, manufacturers, retailers, transport, logistics, service providers in the food and/or flower chain.

One year ago, FInish Accelerator opened a call to sub-grant small and medium sized IT enterprises that would propose the development of new software applications towards supply chains of perishable products and are intended to use in their proposed solution the FIWARE technologies and/or FIspace platform [2]. The latter technologies – tools form the results of the Future Internet programme and are intended to be promoted and reused for reducing effort and cost.

Prior to this open call, a discussion between a well-placed aquaculture producer – Plagton SA and Upcom Ltd (the SME that developed the solution and granted the fund) was made. The former had reached Upcom company for creating an e-commerce application for their unit. When the FInish call was launched, it was more than natural that Upcom would exploit the opportunity. FInish call had as a prerequisite for the IT company that would grant a fund, to cooperate with a business partner, as the aim of the funded project is to have solutions that can run and be sustainable and hence the inclusion of a business partner would drive the project towards this aim. Upcom immediately contacted Plagton to cooperate in the proposal writing. Moreover and in order to acquaint in depth the fisheries and aquaculture domain, Upcom contacted NAYS, another SME with extensive experience in consulting seafood producers and traders. Forming this group, a proposal for the 'FerTility' solution was authored and submitted.

The proposed solution was introducing a combined web and mobile solution that would allow the direct fish purchase from the producer as well the assurance of fish freshness and quality by usage of time temperature sensors and data loggers in each delivery fish package. **Temperature** is the basic condition that should be maintained within a certain range from harvesting and packing until the time the fish is being consumed, in order for the fish product not only to provide its maximum nutritional value but also to be safe for consumption. The solution proposed would exploit various tools and technologies from the FIWARE consortium as well as custom developments.

The proposal was submitted on the 12th of May 2015 and Upcom received a message of successfully being funded on the 27th of July, thus giving a green light to begin the project on the 1st of August of 2015.

Developing A Solution

The current situation in Greece but largely all over Europe, is that aquaculture and fisheries enterprises sell their fish almost exclusively to wholesalers and there is always a very narrow profit margin as sometimes the production must be sold in order to stock in the cages new fry, in the case of aquaculture enterprises. Moreover and as concerns the quality of the product, from the time the fish is packaged until it is delivered to its final destination, either a warehouse, store or a consumer, it may suffer condi-

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FerTility
fresh seafood

Fisherman.

Aquaculture unit.

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tions where it is being exposed to higher temperatures than the 0-4°C plateau. Thus said, the solution being developed addresses these two cases by providing an e-commerce platform and by placing time temperature sensors to log the temperatures during the transportation and trade of fish package.

Near Field Communication (NFC) logger

More specifically, a combined solution has been developed the last year being formed by the following modules:

- **E-commerce platform** for the following stakeholders; producers, transporters, consumers. Producers can place their products, view the orders they have to prepare, view the temperature information that has been logged during the order transportation and receive notification emails for the status of their order. Transporters can define delivery locations related to producers, view orders and receive notification emails. Consumers can view seafood products, select producer, select transporter, perform the order and view temperature information of the seafood delivered to them.
- **Near Field Communication (NFC) loggers** for logging the temperature of the fish or shellfish during its transportation. The loggers can be configured with various settings related to the logging procedure and can flash red or green in case of having measured invalid or valid temperature values.
- **Mobile application** for configuring the logger and sending the related data to the backend.
- **FIspace platform** for engaging the stakeholders [2]. This platform is a B2B collaboration platform that works as a social network to put in contact producers and transport companies.

Exploiting the technologies that FIWARE catalogue [3] offers, developers can put into effect their rich functionalities. Accordingly, UPCOM developers have successfully utilized those enablers alongside with FIspace [2], promoting a **European ecosystem** of **open source** technologies towards sustainable solutions for supplying fresh seafood products to healthily feed Europe.

Piloting

The funded programme is coming to its end. Currently, the solution is under piloting procedure. More specifically and in order to discover potential pitfalls, in the month of June, we have performed various pilots with ordering, receiving and tracking the fish product. In all pilots the fish delivered in excellent condition from the time that it was packed in the producer's unit. Orientation of the packages and some logistics decision concerning the transporter have arose as issues and have been addressed in order for the solution to be finalized.

Conclusion

In recent years several European Union (EU) farm prices (including aquaculture and fisheries products) have experienced a significant decline, resulting in considerable financial stress to producers [4]. With the 'FerTility' solution we are targeting in redefining the supply chains through Internet. Having said that, the 'FerTility' solution allows the **direct** fish order and purchase as well as achieves **transparency** in the supply chains of perishable seafood by placing time temperature sensors in each pack. The latter will indicate in which **stage** during the transportation, the fish was exposed to environmental conditions that put the product's quality into uncertainty. Thus said, the producers and/or transporters could act accordingly in order to avoid such pitfalls in the future. The true winner is the consumer that now has the ability to select seafood directly from a producer of his/her choice and get the product with guaranteed quality of the temperature range that it was maintained during its transportation.

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Fig. 1: Larval rearing room at IPMA-EPPO (Olhão, Portugal) were meagre and seabream larvae microdiet weaning trials where performed.

Microdiets Designed For Fast-Growing Fish Larvae Improve Performance In Gilthead Seabream And Meagre

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Weaning of marine fish larvae: the good results can be improved

One of the priorities in European marine fish larval research over the past 20 years has been the development of inert microdiets that can effectively replace live feeds as early in development as possible. Major progress has been reached in this endeavor, with several established commercial microdiets providing good weaning results, in particular for major cultivated species such as European seabass and Gilthead seabream. Significant progress on weaning has also been achieved for some candidate species for the expansion of the Aquaculture industry in Southern Europe, such as Senegalese sole (Pinto et al. 2016) and greater amberjack (Conceição et al. 2016). Still, weaning diets for marine fish larvae can certainly be improved, as several questions regarding larval nutrition remain unanswered, as most of the knowledge in nutrition focusses on juvenile or adult fish.

Larvae nutrition: gaps in knowledge and fast growing species

Nutrition is an essential part of the larval rearing as it conditions the quality of the fish during ongrowing. It is important not only in terms of survival and growth performance but also in other developmental aspects, such as a healthy immune system or a normal skeleton formation. Though we know that fish larvae require

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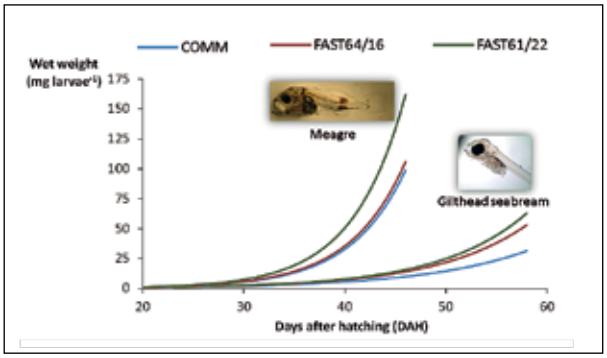

Fig. 3: Growth trajectories (wet weight, mg) of meagre and seabream larvae feed 3 microdiets.

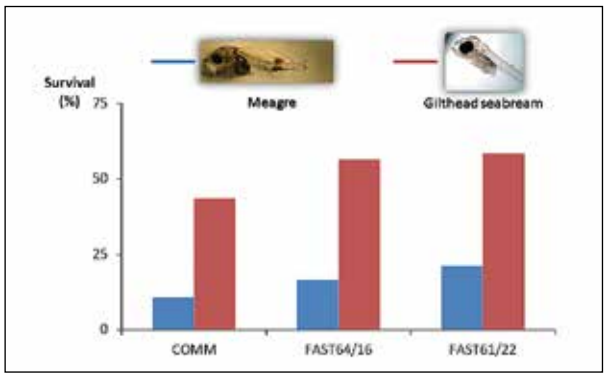

Fig. 4: Survival rate (%) of meagre and seabream larvae feed 3 microdiets.

Fig. 1: Bluefin tuna being weaned into inert microdiets at FUTUNA Blue España (Cádiz, Spain).

continued from page 25

high levels of protein and essential fatty acids in their diet, the exact nutritional requirements are very poorly studied (Hamre et al. 2013), even for the most cultured species such as seabream and seabass. Several commercial inert microdiets provide good results in terms of growth and survival, although quality problems such as skeletal deformities remain. Improvements in microdiet formulation and technology may still improve growth performance, survival and quality issues. The dietary lipid level is one of the formulation items that remains to be optimized. A high lipid level may be beneficial as an additional source of dietary energy and essential fatty acids, but some studies have shown that excessive lipid levels, in particular triglycerides, may negatively affect intestine function (e.g., Morais et al. 2007). Additionally, the optimal lipid level in larval microdiets may change with species and even with larval age. Moreover, fast growing species are likely to have particularly high requirements in amino acids, fatty acids and other nutrients, considering their tremendous growth rates. Therefore, special diets may be required, both in terms of nutrition and feed production technologies. Most available commercial microdiets were developed in Europe and Japan targeting slower growing marine species. Cannibalism problems often observed in larvae of meagre (Vallés and Estévez 2015; Saavedra et al. 2016) and greater amberjack (Conceição et al. 2016) Bluefin tuna and other fast-growing fish species, may be at least partially explained by the use of diets providing sub-optimal nutrition. Conceição et al. (2016) have shown that greater amberjack (*Seriola dumerili*) larvae fed on a novel microdiet developed for very fast growing larvae led to a 68% higher growth, reduced size dispersion and cannibalism compared to a control commercial microdiet.

Meagre larvae require microdiets rich in both protein and lipids

A novel microdiet (FAST) developed after a thorough evaluation of the optimal inclusion levels of all essential nutrients, a careful selection and testing of premium ingredients, and using microencapsulation technologies to protect some nutrients, was evaluated in meagre larvae in a trial at lab-scale that took place at IPMA – EPPO (Olhão, Portugal) in Spring 2016. This microdiet with two different lipid levels was compared with a current premium microdiet (COMM) for marine fish larvae, in a growth performance trial with meagre (*Argyrosomus regius*) larvae.

Weaning started at 20 days after hatching (DAH), using 9 cylindroconical tanks of 300L, an initial density of 15 larvae/L, while temperature and salinity were respectively of 21±1°C and 37±1ppt. From 20 to 30 DAH meagre larvae were co-fed with enriched Artemia and experimental, or a control commercial, dry microdiets (using automatic feeders). After 30 DAH larvae were feed dry microdiets exclusively. Initial feeding time was set at 8.00, and lasted until 02.00h. Three microdiets were used: a commercial microdiet

(COMM), widely used in seabream/seabass hatcheries, with 62% crude protein and 17% crude lipid, and where the main ingredients are fish, krill, fish roe, soybean lecithin, brewer's yeast, microalgae, fish gelatine, squid meal, vegetable fat; a prototype for fast growing larvae with high protein/high lipid (FAST61/22), with 61% crude protein and 22% crude lipid; and a prototype for fast growing larvae with high protein/low lipid (FAST64/16), with 64% crude protein and 16% crude lipid. The main ingredients used in both prototypes were fishmeal, squid meal, shrimp meal, wheat gluten, fish solubles, fish oil and soy lecithin. The daily ration provided ad libitum, but was always equal for all 3 treatments. Treatments were run in 3 replicate tanks until 46DAH.

Meagre larvae grew from a mean dry weight of 0.22 mg and 5.6 mm total length at 20 DAH, to 26.0 to 32.8 mg, and 24.9 to 27.4 mm, depending on treatment, over a period of 26 days (Figure 3). Microdiet used had a major impact on survival, with FAST61/22 and FAST64/16 leading to a survival rate 92% and 51% higher than the COMM diet, respectively (Figure 4). There was also a strong tendency for a better growth in dry weight (23% higher) in FAST61/22 compared to the other two diets. Moreover, a strong positive correlation between larval growth and survival rate was observed.
These results suggest that meagre have higher nutritional requirements compared to slower growing species, and require microdiets rich in both protein and lipids. The higher requirements for lipids of meagre larvae may be associated with a higher requirement for DHA (Vallés and Estévez 2015) and/or energy. The high protein requirement of meagre larvae was previously described by Saavedra et al. (2016).

Gilthead seabream larvae perform better with a microdiet rich in lipids

The same microdiets used with meagre larvae were also tested with gilthead seabream (*Sparus aurata*) larvae, in a trial at lab-scale that took also place at IPMA – EPPO (Olhão, Portugal) in Spring 2016.
Weaning started at 22 DAH, with larvae being reared in nine cylindroconical fibreglass tanks of 200 L at a density of 5 larvae.L^{1}. Water temperature and salinity were respectively 21.6 ± 0.7 ºC and 37±1ppt. From 22 to 34 DAH seabream larvae were co-fed with enriched Artemia and dry microdiets (using automatic feeders). From 34 DAH larvae were feed dry microdiets alone.. The daily ration was provided ad libitum, but was always equal for all 3 treatments. Treatments were ran in 3 replicate tanks until 58 DAH.

Gilthead seabream larvae at 22 DAH had a mean dry weight of 0.25 mg and 6.3 mm total length. They grew over a period of 36 days to 4.6 and 12.1 mg, achieving 14.2 to 18.1 mm, depending on the treatment. Results indicate that microdiet had a major impact on survival, with values of 56.4% and 58.7% in FAST61/22 and FAST64/16, respectively. Both values were higher than in the COMM diet (43.6%). There was also a strong tendency for a better growth in dry weight in FAST64/16 (9.4 mg) and FAST61/22 (12.1 mg) diets compared to COMM (4.6 mg).

These results suggest that gilthead seabream require microdiets with higher lipid content, and possibly also higher protein content, when compared to what is currently available in the market. The higher requirements for lipids may be associated with a higher requirement for DHA and/or energy.

Fast growing marine fish larvae need microdiets that meet their high requirements

These results obtained with seabream and meagre are in line with results for greater amberjack larvae (Conceição et al. 2016) that proposed that larvae of fast growing marine fish species require specific diets. While meagre seem to require higher dietary protein and lipid, due to their much faster growth (see Fig. 3), for seabream a higher dietary lipid may be sufficient to guarantee maximum performance. In any case, these results strongly support the urgent need for detailed studies on nutritional requirements in fish larvae proposed by Hamre et al. (2013).

Acknowledgments
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Figure 1. A sample of microplastics (particles, fibers, filaments, films) collected in the Bay of Brest, France. *Copyright UBO / Sébastien Hervé.*

POLYSTYRENE MICROPLASTICS ARE REPROTOXIC FOR OYSTER

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Worldwide annual production of plastics has been steadily increasing since 1950 and was estimated at 311 million tons in 2014[1]. Once in the environment, macro debris undergoes mechanical (erosion, abrasion), chemical (photo-oxidation, temperature, corrosion) and biological (microorganisms) degradations[2,3]. Plastic fragmentation is considered to be an endless process and may continue to lead to the continuous release of microplastics commonly been defined as plastic particles smaller than 5 mm[4] (Figure 1), and even nanoparticles (< 1 µm) of plastics recently established as possibly existing[5]. Plastic debris also enters the marine environment directly as micro-fragments from a variety of sources including industrial processes, cosmetics and clothing[6]. After less than a century of existence, plastic debris already represent from 60 to 80 % of the marine litter depending on locations[7]. They have been accumulating in oceans worldwide over the last decades constituting an ubiquitous pollution found in all compartments of marine ecosystems (water column, sediment, biota) and in all oceans, from coastal urban areas to poles[8] and mainly concentrated in gyres[9].

Approximately 70-80 % of plastic debris found on the coast come from the continental environment (wind-driven transport, rivers, leaching, urbanized areas)[4]. The rest of the plastic debris, 20-30 %, comes from marine activities (tourism, boating, fishing, aquaculture)[10]. Recently, Jambeck et al[11] estimated at 4.8 to 12.7 million metric tons of plastic wastes entering the worldwide oceans in 2010, with a steady increase expected in the coming years. If nothing changes, by 2025 the amount of microplastics is expected to increase by a factor of 10[11].

This exponential increase in the production of plastics and the waste hence released may have an alarming effect on marine life. Given their ubiquitous nature and small dimensions, their ingestion and direct impacts on marine life are a cause for concern[12], notably for filter feeders, representing reliable ecological models for the scientific community. These animals filter large water volumes and may ingest significant quantities of microplastics[13]. In our recently published study in the Proceedings of the National Academy of Sciences of the

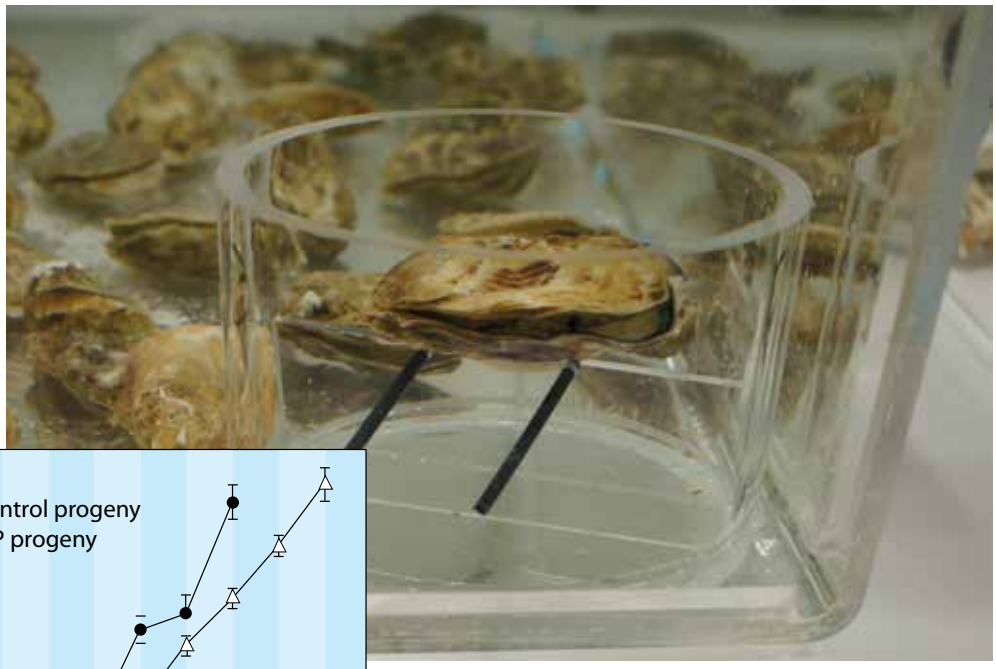

Figure 2. Exposed cupped oysters *Crassostrea gigas*. *Copyright Ifremer / Rossana Sussarellu.*

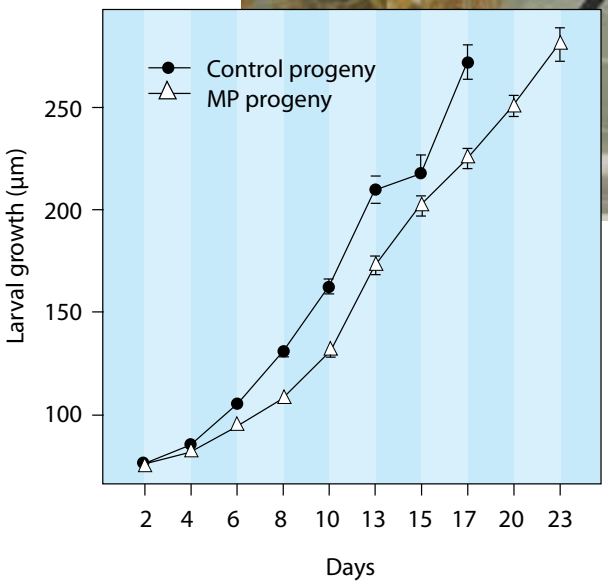

Figure 3. Larval size up to metamorphosis. Larval groups were obtained by crossing gametes collected from control genitors (control progeny) and from oysters exposed to micropolystyrene beads (MP progeny). A settlement delay of 6 d was observed in MP progeny compared with controls. For each group, mean and confidence intervals were obtained from triplicate larval rearing (n > 30).

United States of America[14], we aimed to increase the understanding of ecological impacts of microplastics on filter feeders by exposing the Pacific oyster *Crassostrea gigas* to bare polystyrene microparticles over a two month period covering the full reproductive cycle (Figure 2). Polystyrene beads, 2 and 6 µm in diameter, were in the range of the size of phytoplankton cells preferentially ingested by oysters. Once ingested, polystyrene microbeads were observed to be largely excreted by oysters with a large amount of beads detected in faeces and without any accumulation in the gut visible on histological slides, suggesting a high potential of egestion of polystyrene microbeads by oysters. However, this result warrants caution since the smooth and spherical characteristics of exposed polystyrene beads are different from plastic debris such as fibers or fragments of varying form and roughness present in marine environment. Even if largely and rapidly excreted, polystyrene microbeads were shown to considerably interfere with energy uptake and allocation, reproduction and offspring performance. Indeed, oyster presented significant decreases in total oocyte number (-38%), oocyte diameter (-5%) and sperm velocity (-23%), this latter being considered as a proxy of the sperm quality. The D-larval yield and larval growth of offspring derived from exposed parents decreased by 41% and 18% (Figure 3), respectively, as compared to control offspring emphasizing transgenerational effects. As a possible explanation, Dynamic Energetic Budget (DEB) modeling (Figure 4) and transcriptomic and proteomic profiles demonstrated a shift of energy allocation from reproduction towards high maintenance costs, and suggested

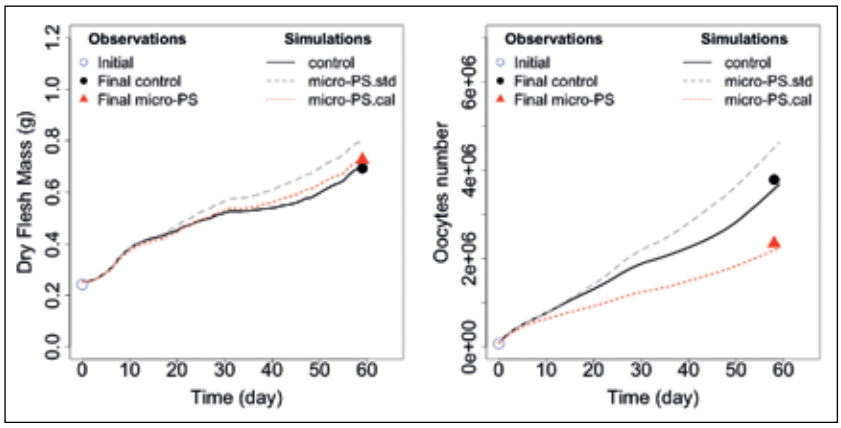

Figure 4. Control oysters were simulated with standard DEB-model parameters (action of energy used for growth plus somatic maintenance, Kappa = 0.45, and volume-specific cost of maintenance [ṗM] = 44 J cm-3 day-1) and with the absorption efficiency (AE) measured in the control ("control"). Exposed oysters were simulated with standard DEB model parameters and the absorption efficiency measured for this condition ("micro-PS.std"). Simulated relative differences in final dry flesh mass (DFM) and oocyte production were overestimated compared with values observed at the end of the two months experiment. In order to make the model parameters fit with observed DFM and oocyte production, numerous simulations were performed with a set of parameter values (Kappa from 0 to 1 and [ṗM] from 0 to 200 J cm-3 day-1). The best fit between observations and simulations ("micro-PS.cal") was reached with a single set of the two parameters corresponding to increases of 71% and 90% beyond standard values of Kappa and [ṗM] respectively, which show that energy flows have shifted toward organism maintenance and structural growth at the expense of reproduction. Initial and final dry flesh mass and oocyte production observed are plotted.

There Are Solutions!

Scientific monitoring and research are necessary for public awareness and policy makers and decision support. They include frames, such as the Strategy Framework Directive for the Marine Environment (MSFD) whose objective is to protect more effectively the marine environment across Europe[19].

Due to the diversity of uses and sources, no single solution will solve the problem of plastic waste. A sum of solutions, from source reduction to cleanup action, is needed to limit and contain the problem[20].

- Change our consumer uses: Plastic packaging is the first waste collected at sea (40%) due to its very short lifespan. So the first step to reduce plastic pollution is to reduce or refuse the use of packaging in our everyday lives and avoiding disposable products.
- Develop and promote the reuse and recycling of plastics.
- Promote technological developments by manufacturers and encourage industry to play the game: i) Biodegradable biopolymers made from renewable resources as an alternative to petrochemical polymers; ii) Large scale pilot already exists to remove microplastics in treated water treatment plants effluents[21], such as synthetic fibers from clothing or microbeads from cosmetic uses[22]; iii) The removal of polyethylene particles in cosmetics and their replacement with natural products is planned in an agreement signed by the world's largest producers of cosmetics[23].
- Legislate: The act published in 2016 in France, and more broadly the UE directive 2015/720, banning plastic bags goes in the right direction. Try to reduce marine debris will reduce further source of microplastics. Of course, for more efficiency this law should be worldwide.

endocrine disruption that may originated from the polystyrene microbeads. A drop in energy allocation via interference in digestive processes may have played a major role in the quantitative reproductive impairment (*i.e.* the reduced number of produced gametes) while endocrine disruptors would have a role especially on the reduced gamete quality. Nevertheless, the absence of endocrine disruptors in biological samples by Stir Bar Sorptive Extraction (SBSE) analysis[15] prevents us from drawing stronger conclusions about this second hypothesis.

This study provides ground-breaking data on the impact of microplastics in a marine invertebrate model and highlights the need for further in-depth studies in a wider range of species with a long-term view to providing stakeholders with the necessary data to limit the impact of the microplastic legacy. The monitoring of the on-going and increasing ecological impact of microplastics on the marine environment is necessary requiring environmentally realistic scenario[16]. The use of environmental relevant microplastic types and doses is still challenging[17] due to lack of consistent field evaluations of the presence of microplastics as small as those used in the present study[18] defining one incoming challenge.

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The science of augmenting marine finfish larval abundance is poorly studied in Indian seas

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Ecoclimate related zoogeography, fishery dynamics and management is a luminary subject. Mundane stock assessment are implausible. Sardine, Kingfish and anchovy landings have declined (Mohamed and Veena, 2016). Brachyuran zoeal density along river mouths determine serranid / lutjanid larval survival and abundance. Early larval fish survival data of Ocean assessed against modeling of impacts is essential to know species risk. A Masters course development on Oceanic Fishery development is pressing.

India has feebly studied research strategies for fish larval stock natural enhancement, though ichthyoplanktonic surveys have been reported (Selvam et al., 2013; Brinda et al., 2010). Information on fish egg and larvae are useful in fisheries biology marking reproductive period (Deepananda and Arsecularatne, 2013). Abundance of ichthyoplankton provides fair indication on fishery (Veerappan et al., 2009). Early contributions are foundations on early development of fish eggs and larvae (John, 1951; Nair, 1952; Bapat, 1955). Reports on spatial and temporal spawning patterns and fish larval assemblages in correlation to ocean stress physiological regimes are faint. Favourable habitats of larvae demand benign physical and biological physical attributes – copious live food, eco-shielding predators and favourable ocean circulations sheltering larvae within nursing zone (Health, 1992).

Even with healthier fishery management practices, prevailing eco-biological uncertainties and climate change effects are threats outside policy regulator control. We have overlooked social priorities and patronised economic prerogatives. Asian seabass hatcheries and larval escapees is a deterrent lesson. Australian Seabass grows faster and is favoured in India in 2016 (The Hindu, 2016). Commercially exigent *L.vannamei* and its hatchery escapees competing in *Penaeus indicus* feeding grounds is a risk. Indian white shrimp stocks

are declining (Mohamed and Veena, 2016). Large-scale destructive driftnet fishing impacts on wild ocean finfish egg and larval survival and abundance is poorly documented. Cuttle fishes are now preying on pelagic fish juvenile stocks as their predators are netted as by-catches. Our knowledge on dynamics of complex marine food webs of high seas is sparse. Reduction of upper marine trophic levels by varying orders of magnitude has never been addressed with remediation.

The Atlantic invasive Black stripped-mussel, *Mytilopsis sallei* reported in Mumbai and Vishakapatnam (Karande and Menon, 1975), its filtration efficiency, bioturbation potential and how metabolitic interactions changed marine food web are obscure. Bivalve activities lead them to a status of "ecoengineer", physically modifying environment (Jones et al., 1994, 1997). Multiplication of predatory fish density have been observed with bivalve invasions (Magoulick and Lewis, 2002; Sylvester et al., 2007). Non-indigenous species forming newer habitat and enhancing species richness is unknown (Sousa et al., 2009). Dearth of knowledge is on physical-arithmetic data within spatial-temporal limits for larval predator-prey from wild, pertaining production factors (Laurence and Lough, 1985). Research schools have attempted multidisciplinary field programs to elucidate problems (Lasker, 1975, 1981; Lough and Laurence, 1981). A prognosis of research paradigms required for fishery resource management is imperative to devise methodologies for enhancing ichthyological densities. Risk assessment initiatives for bioinvasive, alien species and their implications for genotypically endemic fish larval survival is needed. Wild larval fish growth and survival models with emphasis on larval trophodynamics, physiology and behaviour in ocean is wanting. In-depth studies into difficult-to-rear, economically significant, Ocean fish early larval gut for screening microbial assemblages associated with Exopolysaccharides (EPS) aggregates and deriving a capability for defining a gut microbio profile biofeedback to deliver precise control of early larviculture conditions is wanting. Any physiological linkages would prove ben-

eficial to culture of wild fish eggs and for augmenting finfish larval resources as future gene banks.

Has Indian marine sciences attempted listing complete trophic food web resources in full from mangrove and seagrass ecosystems and tallied with wild larval fish gut proper? Have δ 13C signatures been defined to confirm and determine their contributions? The ontogenic stages of fish from an egg involve habitat shifts related eco-specified feed resources and site-specific ecological processes (Beck et al., 2001). Most existent works abroad also point towards juvenile density alone as proxy indicator for augmentation of adults (Beck et al., 2001). Does linkages exist for transitional changes in mangroves quantity and quality on fish generation? Are there remedial measures to strengthen existing fisheries habitats? What proof exists to prove that habitat intensification and enhancement will lead to increased fisheries production? A host of information needs have been identified like studies on species-specific life histories, ecological connectivity between adjoining biotopes, when answered would really throw better insights and understanding into nature of any relationship between mangrove and seagrass habitats and fish populations (Saenger et al., 2012). Mangroves does serve as an important contra predator refuge and latent feeding grounds for fish and invertebrates (Huxham et al., 2004).

Mass mortality of marine fish larvae in ocean or in culture also correlate with final yolk absorption when larvae convert to exogenous feeding. Low planktonic sufficiency of live prey organisms is mostly responsible for mortality (Fyhn, 1989). A Worldwatch report read, "Red sea marine reserves established in 1995 increased catch per unit effort for environs by more than 60 percent within five years". Discrimination of French grunts (*Haemulon flavolineatum* Desmarest, 1823) from mangrove and coral reef habitats using otolith microchemistry is proven (Chittaro et al., 2004). Degradation of mangrove ecosystems have resulted in reduced recruitment of fish worldwide (Rogers and Beets, 2001). There is need to estimate economic implications of optimal stock recovery strategies which are now top priority for depleted resources (Caddy and Cochrane, 2001). Gary Sharp, highlighted that sub ocean surface observations and *in situ* process research demands high attention for future. John F Caddy strongly reiterated that ecosystem effects on recruitment occur principally in early life history and 'untrawlable refugia' are vital for bio conservation.

Adopting restorative protective practices from 20th century led to successful re-establishment of North Atlantic wild population, a typical success model for sustainability in human interaction with high seas (Lotze and Milewski, 2004). Indian coastal states show typical absence of an objective fisheries governance and control regime but exhibiting broad regulation of a 47-day annual ban on mechanized fishing ((Mohamed and Veena, 2016). There is nil ability/capacity to engineer a fast marine resource recovery under fisheries management regulations in practice (Worm and Vanderzwaag, 2007). Most evident drivers of recovery are anthropogenic impact reduction that caused exhaustion of stocks

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and degradation (Lotze et al., 2011). Most warming effects occurred in hemi-centennial past are anthropogenic (Singh and Agnihotri, 2016).

As part of its Intended Nationally Determined Contribution (INDC), India promised to reduce GHG emission intensity of its economy by one-third (Chaturvedi, 2015). Tides can significantly influence biology as well as geometry of lagoons (Ashley and Grizzle, 1988). A measure of fish larval dispersion or detention is largely unknown with their unpredictable dispersal trajectories and hardships in measuring dispersion over open seas. The wind speed over Southern Ocean belt of Indian Ocean has surged high in recent past and increased wave activity impacts nearshore physical oceanographic processes (coastal erosion, sediment disturbances) to a greater measure (Gupta et al., 2015). If thermal tolerance level does not rise within coral reefs, catastrophic bleaching would become annual or biannual for almost all reefs in Indian coastal region in next 30–50 years (NOAA, 2014) and marine biology community will get affected by near shore fluctuations which would indirectly influence catastrophic changes (Adhavan, 2014). Fish distribution and community structure will have pronounced changes due to warming of seas (Rutterford et al., 2015). Climate change has greatly influenced global oceanic weather patterns and can have long-term repercussions (Gupta et al., 2015). Tectonic signatures of Indian continental shelves and their silent effect on mangroves needs documentation. Ballast water control and management need newer policy regulations for India. Marine ecological aftermath of climate variations needs mainstay research focus.

Harmful algal blooms (HABS) with *Cochlodinium polykrikoides* really threaten planktivorous fish and larval bivalves in the Arabian sea coast mostly after rains. Exposure of fish and another algal species to *Cochlodinium* increased survival time of fish, suggesting very clearly that any additional cellular biomass mitigated ichthyotoxicity (Gobler, C.J. and Tang, 2009). Identification of trophic strategies for *Cochlodinium* blooms in relation to nutrient concentrations is needed (Kudela et al., 2008). Wilful blooming of *Skeletonema* can deplete surface nutrients forcing HABS to take nutrients from depths. Vertical migration coupled with nutrient uptake in *Cochlodinium* exists (Kudela et al., 2008b). A "phytoplankton functional group" approach, allows phytoplankton "types" to compete in an ocean model (Follows et al., 2007) which edifies stakeholders targeting HAB mitigation. The alteration of ecological niches, spatial and temporal opening and closing of "ecological windows" through allelochemical release is a void. Tailoring phytoplankton functional group dynamics (harmful :benign bloom ratios) need to be perfected.

"Length of food chain is function of primary productivity found in lower trophic level and efficiency of inter-trophic energy transfer. Species at end of food chain risk survival if less stable. Ocean Science is an engine of growth and is most crucial to revitalise Indian economy. A brain-storming theme says: "Ability to understand wild larval fish trophodynamics and resultant survival and relating this to fishery production would be major advancement in resource management capabilities" (Laurence and Lough, 1985).

Predation, productivity changes, fishing effort and environmental changes are found to affect early finfish larval abundance pattern. Climate-ocean research in relation to marine fisheries beckons greater funding as Climatology, ocean stress physiology and fisheries applications are priority focal points.

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Institute of Aquaculture unveils new management team

The University of Stirling's renowned Institute of Aquaculture has unveiled a new management team to take the leading research and teaching centre forward. The team is led by newly appointed Interim Director, Professor Malcolm MacLeod, Deputy Principal (Operational Strategy and External Affairs). He is backed up by Deputy Director, Professor Herve Migaud.

The Executive Committee also comprises Professor Brett Glencross, Director of Research, Dr. Darren Green, Director of Learning and Teaching, and James Dick, Director of Facilities.

Institute of Aquaculture Director, Professor Malcolm MacLeod, said: "This new team brings together an impressive mix of cutting-edge skills and valued experience in the sector which will help us advance our ambitious vision for the Institute. "Tasked with developing a new strategy which continues to champion pioneering research and teaching in aquaculture, and takes an outward-looking, international approach to operations, we look forward to an exciting period of growth."

The dynamic team will now oversee development of new state-of-the-art fish and laboratory facilities to support the world-leading research carried out on campus. A world leader in academic aquaculture research with a global impact on food security and sustainable fish farming since its formation in 1971, the Institute continues to support the development of the sector.

Professor MacLeod, added: "We will continue to forge and maintain strong relationships with industry and develop strategic partnerships with research institutes across the globe in order to build on our existing success."

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Salmon feed innovations set to boost Scotland's biggest food export market

(Left to right) Ben Hadfield, Marine Harvest; Susan Alexander, the University of Stirling; Fergus Ewing MSP; Dr Karolina Kwasek, BioMar; and Heather Jones, SAIC. Image credit: Ewen Weatherspoon.

The Scottish Aquaculture Innovation Centre (SAIC) last night announced over £140,000 support for two projects aimed at improving salmon feed formulations, amplified by over a quarter of a million pounds of funding from industry and academic partners.

The two new projects – which mark SAIC's first feeds-related projects and mean that the Centre is now active across all four areas identified as being priorities for innovation – were announced at an 80-strong consortium member event attended by industry, academia and Cabinet Secretary for Rural Economy and Connectivity, Fergus Ewing MSP.

Mr Ewing stated: "I am thrilled to see such innovative thinking as we look for ways to increase sustainable production across the sector. Scottish salmon is Scotland's single biggest food export and adds considerable value to our economy as a whole. Projects like these not only help the industry to grow economically but bring value through jobs, sustainability and environmental benefits. I want to see finfish and shellfish aquaculture continue to thrive, growing sustainably and led by world-leading science, innovation and research. I welcome the contribution of SAIC, in partnership with both industries.

The first project, led by BioMar in partnership with supermarket giant Morrisons, the Institute of Aquaculture at the University of Stirling and SARIA, will address a core challenge for the salmon farming industry: identifying alternative protein sources that are locally sourced and have low environmental impact, for use in feeds. It aims to highlight key issues and develop a roadmap to explore the use of avian-derived protein (from poultry).

Currently, global salmon feed production relies on three major protein sources: soy meal, fish meal and land animal protein. However, in the UK industry there is a higher proportion of ingredients from marine resources and imported vegetable protein sources like soy protein concentrates. Adopting avian protein could significantly reduce feed costs and, in doing so, overall production costs.

Although Chilean and Australian salmon farming sectors have been using avian proteins for over a decade without issue, there are still some challenges around consumer acceptance of introducing these products into the UK's food chain. Morrisons' Fisheries & Aquaculture Manager Huw Thomas says: "As one of the UK's largest supermarket retailers, we are committed to ensuring our seafood sourcing programme uses methods which are the least detrimental to the marine environment. This project will explore decreasing our reliance on marine resources for fish feed. If this concept proves acceptable to our customers, we could change our feed ingredient policy."

The project will also be innovative in its cross-sector approach, spanning the supply chain from raw material producer (SARIA), to feed producer (BioMar), through to UK retailer of farmed salmon (Morrisons). States Dr Karolina Kwasek, Product Developer at BioMar: "With data and insights incorporated from a multi-disciplinary research team of social scientists, biochemists, nutritionists and pathologists, the consortium covers the full salmon value chain and the power to influence change will be greater than ever before in the UK. Working with supply chain partners like SARIA, we can ensure that the adoption of avian protein into the UK aquaculture feed industry also guarantees better use of food chain by-products, resulting in significant environmental savings through more efficient use of local resources and the reduction of imported ingredients."

The initial six-month phase will focus on collecting data from retailers and consumers to identify the issues related to adopting avian proteins, and will cost £68,144 – of which SAIC is contributing £40,907. If consumer perception around avian proteins is found to be positive, later phases of the project could comprise nutritional and fish quality analysis.

The second SAIC-supported feeds project will see natural health and nutrition specialist Alltech partner with the University of Glasgow, Marine Harvest and NOFIMA to explore a key cause of poor growth in salmon: inefficient digestion, linked to the fish's metabolic rate.

Intestinal microbes are known to play a central role in how fish metabolise and harvest energy from feed, and greater understanding of these processes could reveal routes to improve growth efficiency of salmon. To this end, the team will develop a new experimental tool – SalmoSim – to explore the link between gut microbial communities and feed digestion.

The University of Glasgow's Dr Martin Llewellyn says: "Once established, the SalmoSim system will be a significant resource and research tool for the salmonid aquaculture industry in Scotland and Europe, as well as for basic science in the region. As such, we expect it will create added value by which other scientists and aquaculture companies across the world can access the technology to test scientific theories and novel compounds.

Alltech already operates a successful equivalent ex vivo gut model for dairy cows and a number of nutrigenomic platforms in its applied research capacity. However, there is currently no system available for fish. Alltech's international project manager for aquaculture, John Sweetman says: "The combined forces of customer demands for sustainable and ethically-reared fish, profitability and regulatory pressure for therapeutic-free aquaculture drives this research initiative. The potential for improving feed efficiency and maintaining optimal health status will benefit the industry and consumer alike.

The total project cost is £360,055, of which £101,644 is contributed by SAIC

Heather Jones, CEO at SAIC adds: "These two projects not only meet our priority innovation area focusing on feed quality and nutrition but come about as a direct result of industry-identified needs after our workshop on sustainable feeds. Salmon farming is an expanding sector that requires continual innovation in feed technology to sustain its growth, whether through innovating feed compounds or technologies to optimise nutrition. SAIC is proud to support projects which achieve this through sustainable practices and, in turn, boost the productivity of the aquaculture industry in Scotland."

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To add information on aquaculture meetings that are of relevance to European aquaculture, please send the details to eas@aquaculture.cc and we will then add them to this column.

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Aquaculture Europe 2016
Edinburgh, UK, September 20-23, 2016
AE2016 will feature a scientific conference, an international trade event, special sessions for aquaculture producers and satellite workshops and events.
General information: eas@aquaculture.cc

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Westport, Ireland. September 26-28, 2016
The 11th International Sea Lice conference will be focusing on the following key areas: Sea lice biology; Sea lice epidemiology; Sea lice genomics; Integrated pest management and sustainable production. Research covering Caligid copepods, mainly Lepeophtheirus salmonis and Caligus species, are invited.
Contact: Email: sealice.2016@marine.ie.
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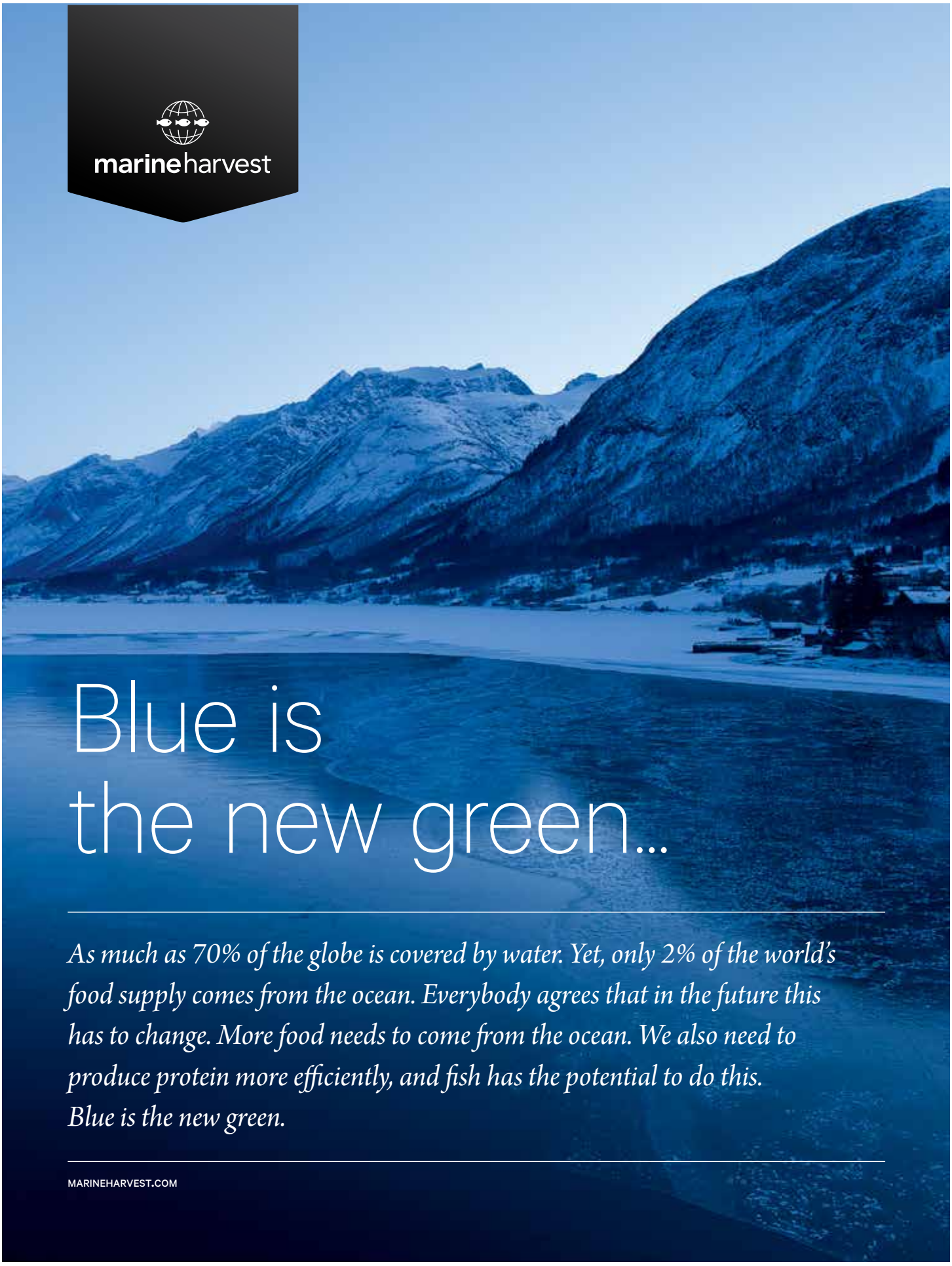
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