AE2015 - Aquaculture, Nature and Society

aquaculture europe

VOL. 40 (1) MARCH 2015

Advances in Meagre

Year 1 of the EU DIVERSIFY project



Shellfish culture developments in Washington

Welcome to Rotterdam!

aquaculture europe 15

eas

THE MEMBERS' MAGAZINE OF THE EUROPEAN AQUACULTURE SOCIETY

1st Semester 2015
Afgiftekantoor: 8400 Oostende Mail

ADVANCING AQUACULTURE AROUND THE WORLD

Global experience, local expertise and healthcare solutions for improved performance and sustainability in fish farming

MSD Animal Health

aqua@merck.com
www.aqua.merck-animal-health.com

VOL. 40(1) March 2015

FEATURE ARTICLE

Aquaculture Europe 2015 – Welcome to Rotterdam

AQUACULTURE EUROPE

EAS is a non-profit society that aims at promoting contacts among all involved in aquaculture. EAS was founded in 1976. Aquaculture Europe is the members' magazine of EAS.

www.easonline.org

Secretariat
European Aquaculture Society (EAS)
Slijkensesteenweg 4, BE-8400 Oostende, Belgium
Tel. +32 59 32 38 59; Fax. +32 59 32 10 05
Email: eas@aquaculture.cc; http://www.easonline.org

Membership
Membership of the EAS includes the Aquaculture Europe magazine (2 issues/year; institutional and sponsorial members receive 2 copies), Aquaculture Europe e-mail publication (6 issues/year), Online access to our peer reviewed journal Aquaculture International (AQUI). Institutional Members of EAS also receive one free half page advert per year in the magazine. E-membership does NOT include the magazine.

	Standard	Reduced*
Individual member	€90	€60
Institutional member	€300	€200
Life member**	€720	
E-member***	€30	

(€ 7,50 for handling charges (mandatory) should be added to prices above)

*Reduced membership fees are available for:
- students (copy of current student card required)
- retired persons (certification of retired status required)
- residents of certain countries
(see http://www.easonline.org)
**Individual Life membership offers the general EAS benefits for full lifetime duration
***Only available to persons who have not been an EAS member during the last 5 years. It can be renewed for max. 2 extra years (i.e. 3 yrs in total).

See www.easonine.org for more information on membership categories and benefits.

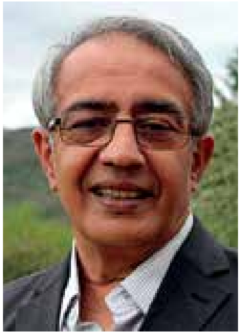
Subscription to the Aquaculture Europe Magazine: €85

For air mail add €16 to prices above

Design: James Lewis, Capamara Communications Inc.

Printed in Belgium ISSN 0773-6940

Advertisements



I am pleased to present my greetings to all members of the European Aquaculture Society on behalf of the newly-elected Board of Directors. I very much look forward to working with the new board, which is a mixture of those who have been contributing to the EAS for some time and also with newly elected members from different parts of Europe.

The AE 2014 event at San Sebastian last October focusing on "Adding Value" was a great success. We owe this success to the old board and the extremely active local organisers. This event has left the new board with good news and also challenges to keep up the spirit and enthusiasm for the years to come.

The forthcoming event in Rotterdam, The Netherlands between the 20th and 23rd October 2015 shall deal with "Aquaculture, Nature and Society" where we do hope to continue to maintain the spirits of EAS in maintaining the close interaction between science and society in the large area of aquaculture.

EAS has also a major role in contributing towards EU policies in the area of aquaculture in its various facets. We shall as the board continue to play this role in an active manner. As representatives of the various stakeholders of European aquaculture, we have this commitment to support and strengthen our links with other regional aquaculture associations. It is also our mission to strengthen and support the students' group of EAS and to further develop or reactivate our thematic groups.

I am honoured to represent all of you as President of the board of the EAS and shall strive to serve you well to keep up the spirit of EAS in all its activities.

Sachi

The 2014-2016 EAS Board. From left to right: Elena Mente (GR), Diego Mendiola (ES), Kjell Maroni (NO), Bjorn Myrseth (NO), Sachi Kaushik (FR), Herve Migaud (UK), Margriet Drouillon (BE) and Hilde Toften (NO). Inset – Stefan Meyer (DE).

MARK YOUR CALENDAR
ROTTERDAM, OCT 20-23, 2015

Taking an ovarian biopsy from meagre to determine stage of maturity.

ADVANCES IN MEAGRE *(Argyrosomus regius)* RESEARCH DURING THE FIRST YEAR OF THE PROJECT "DIVERSIFY"

CONSTANTINOS MYLONAS AND ROCIO ROBLES

During the first year of the DIVERSIFY project (Dec 2013-Nov 2014), a variety of research activities have been undertaken with meagre, and a summary of the most relevant results is provided below.

REPRODUCTION

An evaluation of the genetic variation of a large number of the available captive meagre broodstocks of 13 research institutes and SMEs from 7 European countries has been carried out by Fundacion Canaria Parque Cientifico Tecnologico de la Universidad de las Palmas de Gran Canaria (FCPCT, Spain, Dr. J.M. Afonso) using 2 multiplexes of 18 microsatellite markers. The examined broodstocks, as a whole, appeared to originate from three different populations and sufficient genetic variation exists to form a base population for a breeding program (Fig. 1). However, care will be needed in selecting families within each broodstock and an increase in the number of families is recommended, in order to avoid problems and ensure improvement of desirable traits.

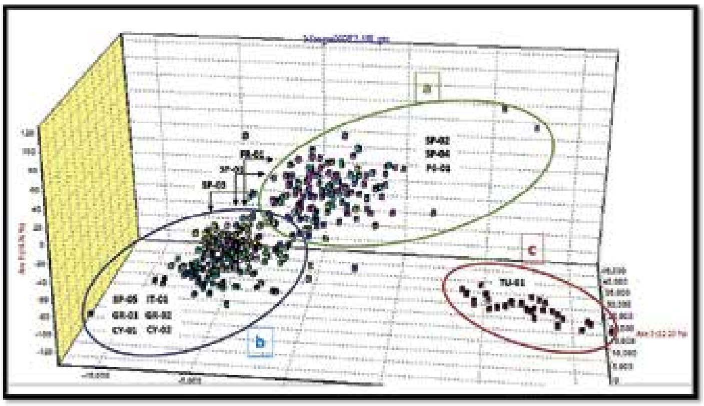


Fig 1.- Factorial Correspondence Analysis from 18 loci and 376 fish distributed in 13 Mediterranean meagre broodstocks maintained in captivity for research or aquaculture production, showed three different original populations.

continued on page 6

Updated findings of all of the species involved in the DIVERSIFY project will be presented in a session entitled "New and Emerging Finfish Species" at Aquaculture Europe 2015 in Rotterdam

continued from page 5

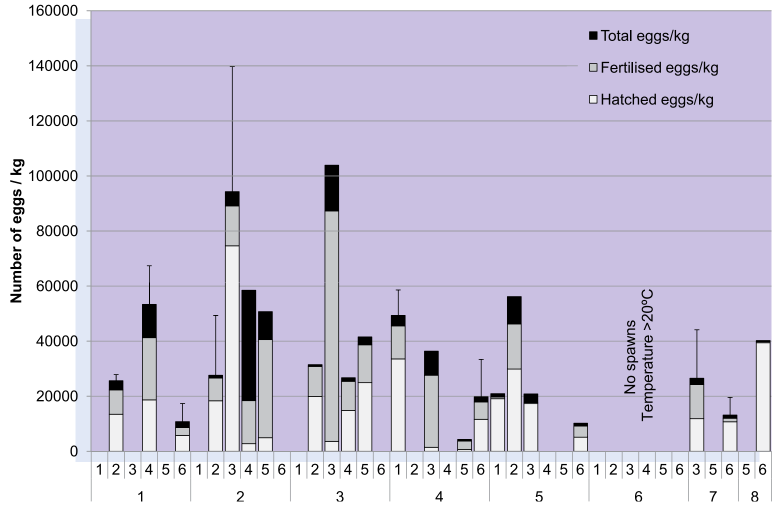


Fig 2.- Mean (± SD) daily fecundity of meagre in response to multiple (8) GnRHa injections. Total number of eggs was multiplied by percentage fertilization and hatch to determine the number of fertilized eggs and larvae produced.

Paired crossings with six pairs of females and males were carried out in the Institute de Recerca I Technologia Agroalimentáries (IRTA, Spain, Dr. N. Duncan). Spawning was induced with GnRHa injections (15 µg Kg^{-1} for females and 7.5 g kg^{-1} for males) every 7-10 days. Breeders that did not spawn after 2-3 induced spawning attempts were replaced. A total of 41 different pairs were induced to spawn, of which 10 pairs produced >500,000 eggs, 16 pairs produced >250,000 eggs and 19 pairs produced >100,000 eggs that hatched (Fig. 2). Poor spawning results were not caused by maturity status, repeated spawning or inductions, and different individuals had clear differences in egg production and quality.

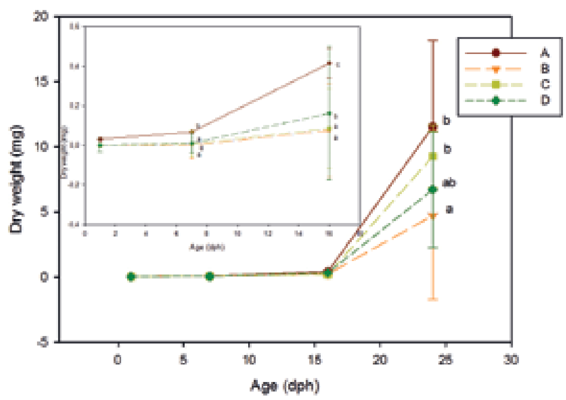
An additional experiment was also carried out at the Hellenic Center for Marine Research (HCMR, Greece, Dr. C.C. Mylonas) with four pairs of breeders to determine how many successful spawns can be produced in response to consecutive weekly injections of GnRHa. Up to 17 consecutive spawns were obtained with high quality eggs that had >80% hatching success and larval survival to 5 days post hatch. These two trials demonstrated that paired spawning of high quality eggs is possible, and the method could be used in breeding selection programs.

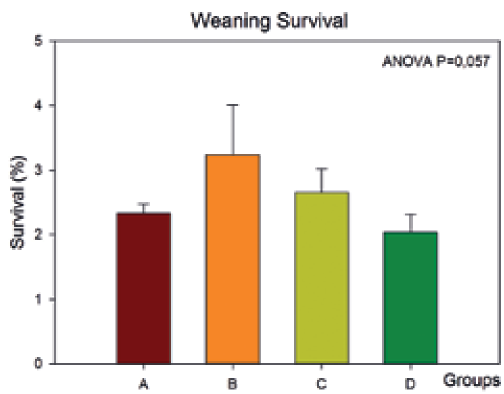
LARVAL CULTURE

A weaning assay was carried out in IRTA (Dr. A. Estevez) to advance the time for weaning in meagre. Larvae were weaned either at age 12, 15 and 20 (the usual age) days post hatch (dph) using half the amounts of enriched *Artemia* metanauplii and a commercial weaning diet (Gemma Micro, Skretting). Growth (Fig. 3), survival rate (Fig. 4), fatty acid composition as well as digestive system development (histology and enzymes) were analysed. A high incidence of cannibalism was detected from day 12 dph onwards, resulting in very low survival (2-3.3%). The experiments will be repeated in 2015 and several new approaches will be taken, including increasing the photoperiod to give more chances of the fish to eat the weaning diet or increase the initial stocking density.

NUTRITION

A trial was conducted by FCPCT (Dr. L. Robaina) to investigate the requirements of meagre larvae for n-3 HUFA in relation with vitamin E (vit E) and vitamin C (vit C). After feeding the larvae with combinations of different levels of n-3 HUFA (0.5 and 3.5%) and vit E and vit C (150 vit E + 180 vit C, 300 vit E + 180 vit C and 300 vit E + 360 vit C) from day 14 to 28 dph, results showed a clear improvement in growth when dietary n-3 HUFA levels were 3.5%, whereas the effects of vit E or vit C and the interaction between both nutrients and the n-3 HUFA levels were not significant. Regarding biochemical composition, larval contents of n-3 HUFA reflected clearly dietary levels (table 1), being significantly higher in larvae fed fish oil, and elevation of dietary n-3 HUFA and vit E + vit C tended to increase larval lipid contents. Study of larval foregut histological characteristics showed that larvae fed 0.5% HUFA presented very pigmented enterocytes with centered nucleoli and very little lipid vacuoles, while larvae fed higher levels of dietary HUFA, such as in the 3.5/150/180 combination, showed larger





Figs. 3 and 4: Growth (dry weight in mg) and survival (%) of larvae of the different groups after weaning.

Table 1.- Culture performance and morphometric parameters of meagre larvae (initial total length 4.07±0.26 mm and dry weight 0.058±0.01 mg) fed early weaning diets containing several n-3 HUFA, vitamin E and vitamin C levels from 14 dph to 28 dph.

	Diet					
	0.5/150/180	0.5/300/180	0.5/300/360	3.5/150/180	3.5/300/180	3.5/300/360
Total length (24 dah)	4.8±0.44b	5.0±0.39a	4.9±0.40ab	5.0±0.45a	5.0±0.48a	5.1±0.38a
Total length (28 dah)	5.2±0.46ab	5.2±0.43ab	5.1±0.51ab	5.3±0.44a	5.0±0.31b	5.3±0.59a
Dry weight (24 dah)	0.19±0.04c	0.21±0.02bc	0.20±0.03bc	0.21±0.02bc	0.22±0.02ab	0.24±0.03a
Dry wieght (28 dah)	0.23±0.02	0.21±0.04	0.21±0.03	0.27±0.05	0.23±0.05	0.24±0.04
Survival (%)	12.1±4.9	8.0±5.2	15.1±4.1	14.2±8.3	16.7±3.5	15.2±7.7

* Values (mean ± standard deviation) with the same leters are not significantly different; ANOVA. P_{Length} <0.01; P_{Weight} <0.05.

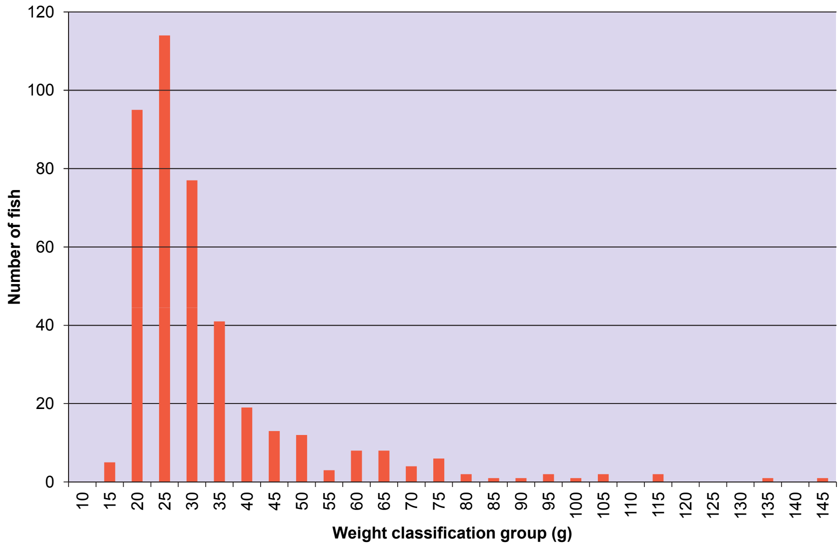


Fig 5.- Frequency distribution of meagre in each 5-g size classification. The weight shown is the upper value of the classification, for example classification 15 g contains fish from 10.1 to 15 g.

and more developed enterocytes containing lipid vacuoles around the nucleous, reflecting the higher lipid absorption activity. These results suggest that there is a high requirement of this species for n-3 HUFA to promote growth, and vit E and vit C to prevent fatty acid oxidation during larval stages. Thus, weaning diets for meagre larvae must be supplemented with increased n-3 HUFA, vit E and vit C in order to be improved. Selected diets were used to conduct studies on resistance to handling stress, stress bio-markers such as gene expression of HSPs (FCPCT), specific fish behaviour, evaluation of metabolic cost after sub-lethal stress, video analysis of activity, escape responses and sensory acuity (Danmarks Tekniske Universitet, Denmark, Dr. I. Lund) and digestive enzyme (protease, amylase and lipase) and gut ATPase activities (University of La Laguna, Spain, Dr. C. Rodriguez).

In the following years, the essential fatty acid requirements will be examined in grow out diets (Skretting Aquaculture Research Center, Norway, Dr. R. Fontanillas) for meagre by feeding six levels of docosahexaenoic, eicospentaenoic and arachidonic acids (FCPCT). During the last three months of 2014, information on the nutritional requirements of meagre have been collected and a basal diet formulation for grow out has been defined.

ONGROWING

Size variability in juvenile meagre during pre-grow out makes regular grading essential to avoid cannibalism, and grades of smaller fish may be related to poor performance when transferred to sea cages. Experiments were carried out by IRTA using meagre juveniles of a mixture of 5 known families, to simulate the commercial hatchery situation and in order to study differences in growth rate. Juveniles were separated into three size grades, and were stocked into tanks at the same initial density and fed the same commercial diet. After 4 months the distribution of all the size grades across the different tanks / grades was compared and 70% of the population was observed to be in the size range of 15-30 g (Fig 5).

The population was skewed to larger fish with 30% of the population in the range of 30-145 g and this wide dispersion of sizes made management difficult. The normally distributed 70% of the population was graded into three grades of 73 large fish (25-30 g), 89 medium fish (20-25 g) and 86 small fish (15-20 g) and growth was monitored.

A random sample of 50 fish from each group was weighed and measured (length) every 3 weeks. The large fish have grown from 27.2±1.5 g to 113±21.0 g, medium fish have grown from 22.7±12.2 g to 94.2±19.8 g and small fish have grown from 17.9±1.8 g to 71.6±31.31 g (Fig. 6). On all sample dates there have been significant differences (ANOVA, P<0.05) between the grades, and the fish in each group have grown significantly during the study (ANOVA, P<0.05). The different size grades appeared to have very similar growth potential. The trial finished on 11th December 2014 and the fish will be characterised genetically for parentage assignment (HCMR, Dr. C. Tsigenopoulos) to establish if differences in growth were a consequence of genetic origin.

The effect of cage depth on meagre grow out was studied by HCMR. The trial started in May 2014 using cages of 180- m^3 (6x6x5 m, Shallow) and 290-m3 (6x6x8 m, Deep) at the Souda Bay pilot cage farm (Dr. N. Papandroulakis) in duplicates, and juveniles

continued on page 8

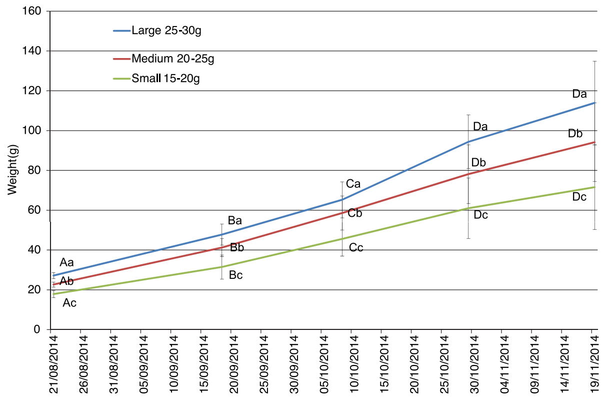


Fig 6.-Mean (± SD) wet weight of meagre classified to three grades as large (initially 25-30 g), medium (initially 20-25 g) and small (initially 15-20 g). Capital letters represent significant differences (P<0.05) between sample dates for the same size grade. Lower case letters represent significant differences (P<0.05) between size grades on the same sample date.

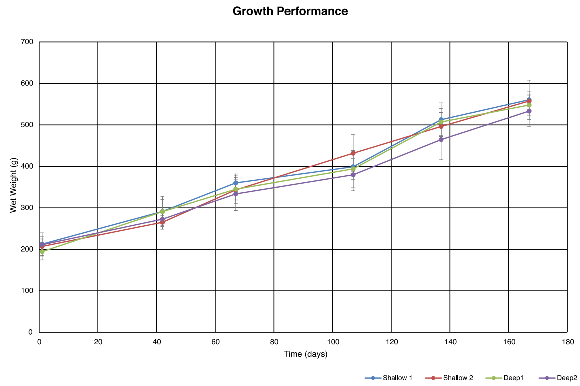


Fig 7.- Mean (±SD) growth performance of meagre at the Souda Bay pilot cage farm (HCMR).

obtained from the HCMR hatchery. Eggs were from a single spawning and larval rearing was performed at the Mesocosm hatchery. Juveniles of 2 g were transferred at the cage facility and they were reared under similar conditions until the beginning of the trial. Then, 4 groups were created, two of ~5,150 fish for the 180-m3 cages and two of ~8,240 fish for the 290-m3 ones. The wet weight at the beginning of the trial was 200±20 g. During the experiment, growth performance was estimated with monthly samples (Fig. 7).

Monitoring growth of meagre juveniles

Every second month, blood samples were taken for haematological (hematocrite, hemoglobin), biochemical (osmotic pressure, glucose, lactic acid, free fatty acids), immunological (lysozyme, myeloperoxidase serum) and hormonal (cortisol) evaluation. The samples are currently being analyzed.

The vertical distribution in cages was monitored using an echo integrator. Although a technical problem has not allowed the monitor during the first month of the trial, an upgraded system (CageEye 1.3, Lindem Data Acquisition AS, Norway) was installed in June 2014 and the trial was implemented as planned without further alterations. The analysis of the data is not completed yet, but an interesting observation has been made already. The vertical distribution of meagre shown for a period of 3 days (Fig. 8), demonstrates clearly that the fish are located mostly at the lower half of the cage for a period of ~12 hours, while the rest of the period are distributed almost homogeneously in the whole available volume of the cage. This observation is independent of the cage depth and it is correlated with the light and dark period of the day. To our knowledge this is the first time that such behavior has been observed.

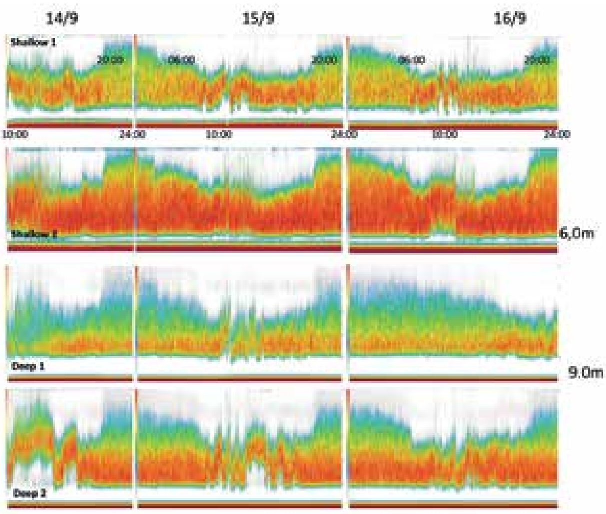


Fig 8.- Vertical distribution of meagre in the experimental cages for a period of 3 days.

HEALTH

Meagre were sampled for collecting data on specific growth rate and to collect chronological samples for the immune ontogeny study. Duplicate sets of samples were collected at each time point (Fig. 9); one set was fixed in formalin for histological analysis, and a second set was collected in RNAlater for extraction of RNA to be used in gene expression analysis. As fish became more developed and organ tissues were recognized easily, individual tissue samples were collected in formalin and RNAlater. Tissues collected included spleen, head kidney, gills and intestine. Samples for immune gene expression analysis are being stored at -80°C. The original plan was to collect animals that were of a medium size, as well as animals from the larger end of the growth spectrum to see how differential growth may lead to premature immune maturation. We eliminated this idea due to a reduction in the overall size of the population. The original population was diminished greatly due to cannibalism during the growout.

A search of the online database GenBank was performed to identify and collect existing sequences for genes of interest from extant marine teleost species for the study of the immune system. The sequences collected were used for the preparation alignments for designing degenerate/consensus primers for amplification from cDNA of meagre tissues. Samples for the preparation of RNA and subsequent synthesis of cDNA for preparation of these gene expression asssays (table 2) has already been done during the growout period of fish being used in the earlier experiment. All of this process for isolation of gene sequences and development of the specific gene expression assays were initiated in the first quarter of 2015. ■

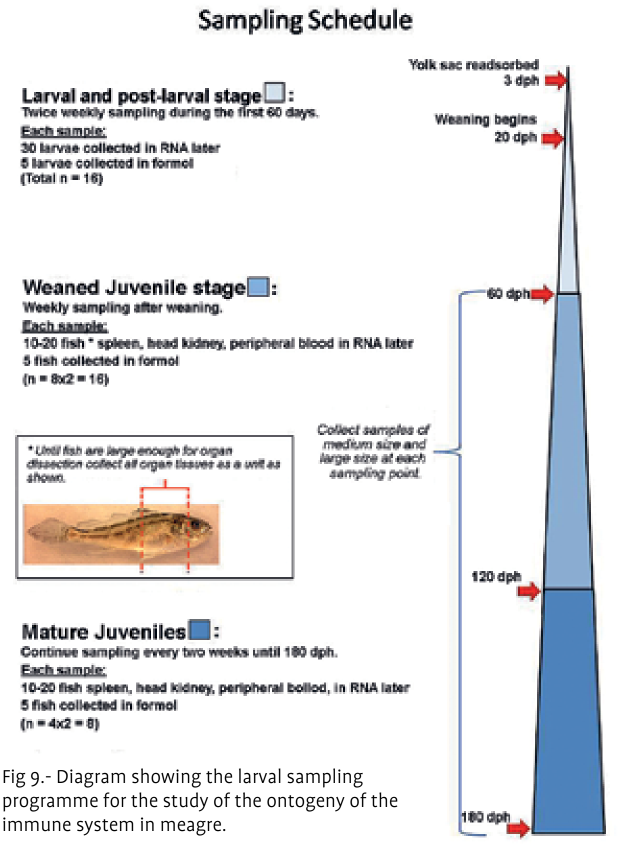


Fig 9.- Diagram showing the larval sampling programme for the study of the ontogeny of the immune system in meagre.

Co-funded by the Seventh Framework Programme of the European Union

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 38 partners from 12 European countries –including 9 SMEs, 3 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".

Table 2.- Genes targeted for characterization of the immune system of meagre. The unknown gene sequences should provide amplicon sizes approximating those shown, if there exists a high degree of conservation between species. These estimates are based upon data from existing sequences found in GenBank.

	Target Gene	Degenerate/ Consensus Primers	Amplicon size
Endogeneous Controls	EF1 (Elongation Factor)	X	230
	GAPDH (Glyceraldehyde Phosphate Dehydrogenase)	X	239
	18S	X	-
Innate Immunity	Piscidin1 ("Defensin")	X	110
	Piscidin2 ("Defensin")	-	-
	Piscidin3 ("Defensin")	-	-
	Lysozyme	X	220
	Metallothionein	X	80
	MX protein	X	570
	NOD2 (Toll Like Receptor - TLR)	X	1390
Adaptive Response	RAG1 (Recombination Activating Gene)		
	IgM		
	IgT		
	TcR (T-cell Receptor)		
	C3 (complement)	X	1202
	TNFa (Tumor Necrosis Factor)	X	250
	IFN alpha (interferon)		
	IFN gamma		
	IL-1beta (Interleukin)		
	IL-2		
	IL-4		
	IL-10		
	IL-17		
	IL-22		
Inflammatory Response	COX2 (cyclooxygenase 2)	X	1500
	MyD88 (myeloid differentiating factor)	X	130

Aquaculture, Nature and Society

aquaculture europe 15

ROTTERDAM • OCTOBER 20-23, 2015

We have the pleasure to welcome you to Aquaculture Europe 2015, to be held from October 20-23 in Rotterdam and with the theme "Aquaculture, Nature and Society.

Abstract submission is now open and we are proposing a very wide range of parallel sessions for you to submit to. Abstracts should be submitted before May 1.

The following articles give you some idea of recent developments in Dutch aquaculture that show the diversity and innovative approaches being made in this small country - one that has a long history in aquaculture research and farming systems for finfish and for shellfish.

The Netherlands also plays a significant role in seafood processing, traceability and international trade.

OYSTER REEFS FOR COASTAL DEFENSE

Fig 2: Natural *Crassostrea gigas* reef at the intertidal flat Viane in the Oosterschelde estuary

BRENDA WALLES, TOM YSEBAERT & AAD SMAAL

Oyster reefs are ecosystem engineers that can act as coastal protection structures in soft sediment environments. The use of ecosystem engineers is based on the natural capacity of the organisms to temper wave action and prevent shoreline erosion, combined with the potential to maintain their own habitat. This adaptive capacity secures the long-term sustainability of ecosystem-based coastal protection, especially in light of accelerating sea level rise. We studied the ecosystem engineering capacity of the oyster *Crassostrea gigas* in the Oosterschelde (SW Netherlands) (Fig 1).

The Oosterschelde is experiencing rapid erosion of tidal flats due to significant modifications to the basin by the so-called Delta works. These modifications resulted in a decrease in the tidal prism, the tidal range and the tidal currents resulting in a reduction of the deposition processes at the intertidal flats, while the eroding processes by locally generated waves were not changed. Sediment erodes from the tidal flats into the channels during storms, whereas tidal forces are too small to redistribute the sediment back to the tidal flats. On average a net erosion rate of 10 mm $year^{-1}$ on the tidal flats has been observed. The oyster *Crassostrea gigas* was introduced for oyster culture in 1964, after which the species rapidly spread throughout the estuary, forming dense reefs (Fig 2). It is occupying nowadays about 8% of the tidal flats (9 km^2). Until recently, C. gigas populations in the Oosterschelde were experiencing low pressure from predators and diseases. The oyster

continued on page 13

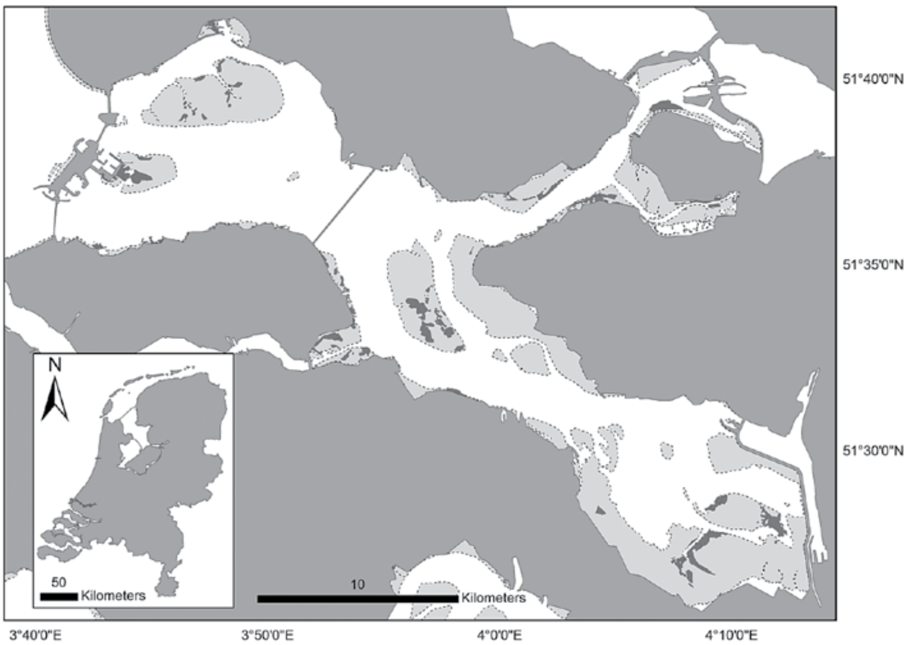


Fig 1: The Oosterschelde with intertidal wild oyster beds. Viane is the experimental reef site.

continued from page 11

Herpesvirus has been detected but dramatic impacts have not been registered on wild litoral oyster beds so far.

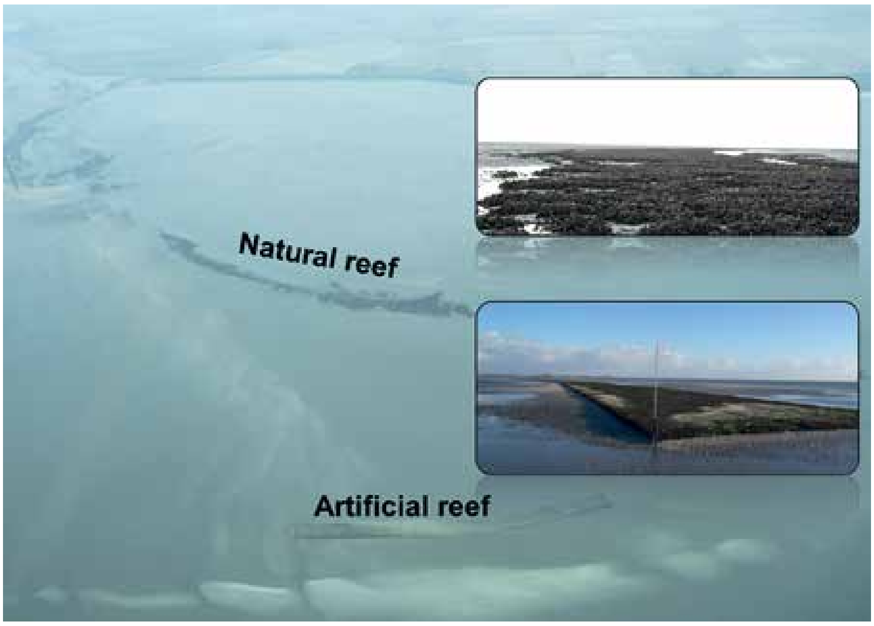


Fig. 3: Natural en artificial reefs at Viane site.

Within the framework of the innovation programme Building with Nature (BwN, www.ecoshape.nl), large scale experiments with constructed oyster reefs were executed to evaluate their contribution to mitigate the erosion of tidal flats in the Oosterschelde (Fig 3). Oyster performance, reef development, as well as the ecosystem engineering effects of the oyster on tidal flat morphology were studied in an integrated way. Ecosystem engineers that inhabit coastal and estuarine environments, such as reef building oysters, do not only stabilise the sediment within their reefs, but their influence might also extend far outside their reefs, affecting tidal flat morphology and protecting the surrounding soft-sediment environment against erosion. We measured the elevation around eleven natural *Crassostrea gigas* reefs in the Oosterschelde to quantify the spatially extended ecosystem engineering effect of Pacific oyster reefs on tidal flat morphology. Measurements were used to create 3-dimensional surface maps to obtain properties of the reefs and the surrounding soft-sediment environment. Various reef sizes were chosen to test the proportional effects of reefs on tidal flat morphology (Fig 4). The area of the oyster reefs ranged from 2 m2 to 1908 m2. Reef length varied between 1 and 61 m, reef width between 1 and 45 m, and reef height between 0.20 and 1.08 m. Elevated areas (>5 cm elevation from the background intertidal slope) were observed on the lee side of all reefs, caused by the interaction between the reef's structure and locally prevailing wave conditions. The elevated area (i.e. the spatially extended ecosystem engineering effect) affected by the reef was of the same order of magnitude as the reef area, extending to 75m behind a 61m long reef. The elevated area was related to reef properties such as reef length, width, and height. Reef length however, appeared to be the best predictor. Directional spreading and diffraction of waves were the mechanisms identified shaping the deposition area behind these reefs. Oyster reefs not only protect the tidal flat under their footprint, but as well an area beyond the boundary of the reef.

The gregarious settlement behaviour of oysters and production of shell substrate (positive engineering feedback) are keys to the long-term persistence of oyster reefs (Fig 5). We studied the population demography of *Crassostrea gigas*, based upon three long-living *C. gigas* reefs (>30 years old), which have not been exploited or disturbed since their first occurrence in the Oosterschelde estuary. Oysters in the Oosterschelde estuary reach at least an age of 6 years, in which they grow to an average shell length of 170 mm. The demography study was used to estimate vertical reef accretion rates and carbonate production in these oyster reefs. The estimated accretion rates were validated in the field by excavating the entire vertical profile of the three oyster reefs. The observed accretion rates (7.0-16.9 mm year-1 shell material) indicate that these reefs are able to both grow and persist over time periods of decades, making them suitable for ecosystem-based coastal protection structures, that catch up with sea level rise. Oysters in the Chesapeake Bay for comparison, rarely exceeding 4 years of age due to diseases affecting reef dynamics,

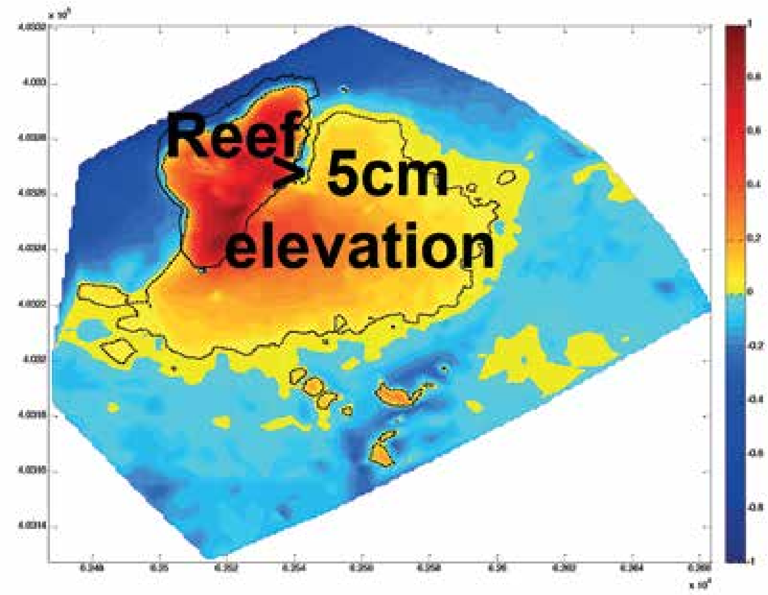


Fig 4. Sedimentation near a natural oyster reef.

continued on page 14

which affects the growth and persistence of reefs in these areas.

We also investigated if reef development is limited by establishment, growth and survival thresholds. The response of different life-history stages was investigated along an exposure gradient during a manipulative field study. The number of juvenile oysters showed an optimum around 36% exposure time. Shell growth of both juvenile and adult oysters was negatively related with exposure time. Overall condition of adult oysters was highest around 20% exposure time. Above 40 – 50 % exposure time condition index decreased compared to the start of the study. Oysters still show shell growth above 50 % exposure time, but shell growth and meat content were both lower at long exposure times indicating that oysters had reallocated energy away from growth under these environmental conditions. This did not result in an increase in mortality during the course of the experiment as mortality increased towards the less exposed sites. Winter mortality among juvenile oysters exponentially increased towards the longer exposed locations. Overall, adult and juvenile oysters differ in their response to the same response variable. According to recruitment, growth rates and oyster performance reefs could develop in the lower intertidal. Providing a suitable substrate for oysters to settle on offers a kick-start for establishment at places where they were lost or are desirable for coastal protection.

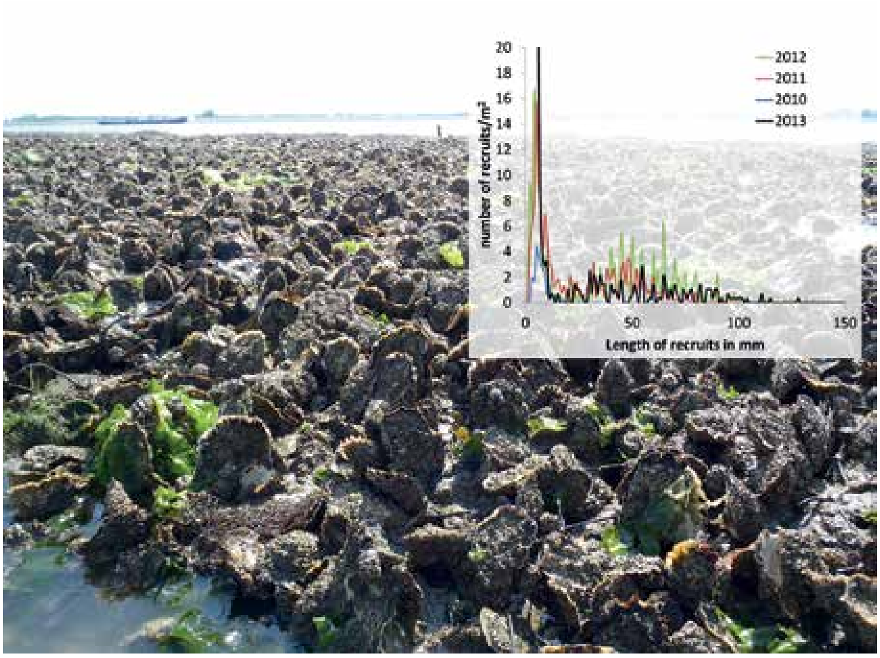


Fig 5. Recruitment and juvenile growth of oysters on an artificial oyster reef.

We tested under which conditions artificially constructed oyster reefs have the potential to become long-persisting, self-sustaining structures. Three-dimensional artificial oyster reefs were constructed for mitigating the erosion and for the conservation of ecological services of eroding tidal flats. Recruitment, survival and growth rates of oysters on the artificial reefs were compared to natural Pacific oyster reefs. The results of this study showed that sustainability was strongly dependent on the local environmental conditions where the reefs were constructed, with tidal exposure and sediment dynamics governing oyster recruitment, survival and growth dynamics. More recruitment was observed on the natural reefs, compared to the artificial reefs. Shell length of oysters on the artificial reefs are comparable to shell lengths observed on natural reefs. Therefore a vertical accretion rate in the order of 7.0 to 16.9 mm year-1 is expected, indicating that reefs are able to grow and maintain themselves. An interesting, but largely overlooked ecosystem service provided by oyster reefs is their potential buffering capacity in perspective of ocean acidification. By creating reef structures oysters produce significant amount of biogenic carbonate. These biogenic carbonate masses can act as a buffer against acidification. In the light of ocean acidification trends, these carbonate masses can be critical as a buffer for colonization of sessile benthic species in shallow water estuaries. Sedimentation, diseases and predation are however a potential treat which could reduce vertical accretion rates. At the right conditions, artificial oyster reefs can develop into self-sustaining, natural reefs and add to coastal defence schemes. Although oyster reefs can stabilize intertidal areas against erosion, as was demonstrated for the Oosterschelde case, they will not have a direct effect on protecting the dikes due to their location in the low intertidal as well as the size of the area protected by oyster reefs. They can however be used to limit coastal erosion by protecting intertidal flats and salt marshes, which in turn act as buffering habitats for the hinterland. When used for coastal protection, the exact placement of reefs in the intertidal area is important. Oyster reefs can potentially influence and protect a much larger area at their lee side due to their spatially extended ecosystem engineering effect. By doing so, they can facilitate the growth of other structuring ecosystem engineers (seagrasses, salt marsh plants) higher up in the intertidal zone. ■

Ref.

Walles, B 2015. The role of ecosystem engineers in the ecomorphological development of intertidal habitats. PhD Thesis, in prep.

Walles, B., Salvador de Paiva, J., van Prooijen, B., Ysebaert, T., Smaal, A. (2014). The Ecosystem Engineer Crassostrea gigas Affects Tidal Flat Morphology Beyond the Boundary of Their Reef Structures. Estuaries and Coasts, 37, 5 pp. 1-10

Walles, B., Mann, R., Ysebaert, T., Troost, K., Herman, P.M.J., Smaal, A. (2015). Demography of the ecosystem engineer *Crassostrea gigas*, related to vertical reef accretion and reef persistence. Estuarine, Coastal and Shelf Science 154: 224-233

RAGWORM FARMING IN THE NETHERLANDS: TOPSY BAITS

AAD SMAAL

As an example of landbased aquaculture, the pond culture of polychaete worms for bait, shrimp feed and medical applications, has shown a successful development over the past 30 years. The pioneer enterpreneur Bert Meijering started with the cultivation of the ragworm *Nereis virens* in 1983. At present his company Topsy Baits is the largest supplier of farmed live bait in Europe. Live worms are exported to some 14 countries and another 40 countries are supplied with frozen worms as maturation feed for the aquaculture industry. The farm is located in the Zeeland province, in the south-western part of the Netherlands. Saeawater is directly supplied form the adjacent Oosterschelde, for farming worms in ponds under extensive natural conditions. The annual production exceeds 100 tonnes (Fig 1).

Topsy baits ponds Wilhelmina dorp.

HISTORY

In 1983 the company Aquafarms was created and research into the farming of *Nereis virens* (Fig 2) was started. Two years later, 1985, a commercial, one hectare, farm was built. Severe winters in 1985 and 1986 resulted in high mortalities. After five years of experiments and failures, methods and comprehension have developed on how to work with the worm. After a joint-venture with in 1990 Normandie Appats the farm Topsy Baits was developed at the present location. After an initial start with with 14 ponds it reached 94 ponds (17 hectares) after three expansions, thereby following market demand. Initially Topsy produced worms only for the sea anglers as bait. In 1999 Topsy was approached by Seahatch, a shrimp hatchery on Aruba for polychaetes as a maturation diet to replace the American bloodworm, Glycera dibranchiata. Due to overexploitation of the wild population, prices of this polychaete soared, making it too expensive to use in hatcheries. It turned out that the ragworm is well suited as a maturation diet for shrimp. It is now distributed in more than 40 countries. Another interesting link was made with the cooperation with teh company Hemarina (France). This marine biotechnology firm develops oxygen carries for human health. They apply the polychaete worm *Arenicola marina* blood for organ transport. Hemoglobine concentrations and oxygen capacity of worm blood is very high in comparison to vertebrate hemoglobine, as this is packed in blood cells. Therefore there is a high levbel market for lugworm products, that are now produced by Topsy baits as well.

Since 2013 another 6 hactares of ponds is being developed at a nearby site, in connection to the landbased pond culture facilities of the Zealand sole project.

INNOVATION

The concept of the farming system is based on the physical and behavioural needs of the worm. The farming protocols are built around the worm, rather than forcing the worm in an existing system. The farming system evolves continuously, aiming at a stable and robust farm. The equipment including harvesting machines, packing machines, oxygenators and water movers have been developed at the farm. Existing machinery are improved continuously to increase the efficiency of the farm. Harvesting machines plough themselves through the ponds independently nowadays. The packing machine is half automatic needing only one operator. All pumps, watermovers and oxygenators are frequency controlled to save energy. Research is done into the farming of lugworms (Arenicola marina) in order to diversify the product range. But there are more commercially interesting worms around, such as the bloodworm (*Glycera* sp.) and the tubeworm (*Dioptera* sp.).

continued on page 16

CULTIVATION, PROCESSING AND QUALITY CONTROL

The culture cycle of ragworms expands over two years. There is annual spawning in April, larvae remain in the hatchery for 2 weeks without feed and grow out subsequently in open ponds with natural seawater supply, and with the addition of formulated carp feed. The ragworm is a scavanger that will eat dead and live animal or plant matter. The ragworm reproduces once in it's life and dies after reproduction. An average female can contain over one million eggs, but a record (wild) female was found to contain 7 millions eggs. In the hatchery the fertilised eggs are kept for two weeks untill they reach Nectochaetehood. At this stage the larvae are sown in the outside ponds. After five months the first worms can be harvested.

After harvest the live worms are cleaned and kept in running seawater for at least 24 hours to purge themselves. On order the worms are packed in plastic tubes with cold seawater, activated carbon and pure oxygen. On top of the tubes, in a polystyreen box, ice packs are added to keep the temperature low during transport. This allows for at least 24 hours of transport time during summer and more than 48 hours in winter.

Part of the production after harvesting, cleaning and purging worms are flash frozen in one kg flat packs. After packing the flat packs in polystyreen boxes they are stored in a freeze warehouse.

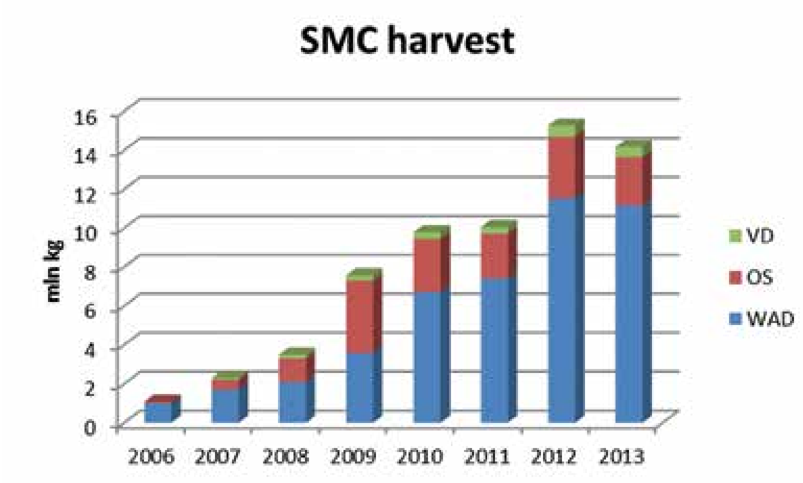
Each batch is tested for shrimp pathogens by the University of Arizona. All tests have been negative ever since Topsy started supplying shrimp hatcheries.

References

www.topsybaits.nl
www.hemarina.com ■

Seed Mussel Collectors In Dutch Coastal Waters

FEBRUARY 2015, PAULINE KAMERMANS, IMARES, THE NETHERLANDS (PAULINE.KAMERMANS@WUR.NL)



In the Netherlands, mussels (*Mytilus edulis*) are farmed on bottom plots in two coastal areas: the Wadden Sea and the Oosterschelde. For this, small mussels (seed) are fished from natural beds. In response to pressure from society to reduce bottom dredging and the desire to safeguard a steady supply of seed mussels the farmers signed a covenant together with the government and NGO's in 2008. This involves a transition process from fishing seed to harvesting seed with suspended collectors (PvU, 2010). A stepwise approach is taken: every two years a decision on reduction of seed fishing and expansion of the area reserved for seed collection is made based on the annual yield of the collectors. A seed collector consists of nets or ropes that are placed in the water column in spring when larvae are present (Fig. 1). Larvae attach to the substrate and grow to seed. At the end of the summer the seed is harvested and transported to the bottom plots for grow-out. The first tests with seed mussel collectors started in 2000 and the method showed a rapid development. In 2013 the total yield was 14 million kg collected in an area of 240 ha (van Stralen, 2014). The seed fishing yield in that same year was 21 million kg (PO Mosselcultuur). The collectors are used in Natura 2000 areas. The Dutch government is responsible for maintaining nature values in these areas and commissioned a project (2009-2013) to study if the use of Seed Mussel Collectors (SMC) affect nature values. IMARES Wageningen UR carried out the project in cooperation with NIOZ, Deltares and Marinx.

The new method and its associated activities can have a number of environmental effects. (1) The shift from fishing to using collectors results in a higher mussel biomass, because natural beds are no longer fished and spat survival is enhanced on the collectors. Competition for food (phytoplankton) between the extra mussel biomass and natural shellfish populations may result in overgrazing and possibly affect the production capacity. This can have consequences for the yields of cultured bivalve shellfish and for organisms that depend on cultured and natural bivalve shellfish stocks for their food such as birds. (2) Deposition of faeces originating from seed collectors may cause local organic enrichment of the sediment and ultimately changes in local benthic fauna diversity. (3) Activities associated with the use of seed collectors may disturb seals and birds. (4) Wear and tear of the used material can cause the production of microplastics.

Effects on **production capacity** were studied with time-series data analysis and model calculations. Models were adjusted to predict effects of increased seed mussel biomass on shellfish biomass. Targeted field measurements were carried out to estimate model parameters. In addition, different indicators for assessment of changes in production capacity for bivalve shellfish were investigated for the Wadden Sea and the Oosterschelde. Meat content and growth rates of shellfish can show if the shellfish are food limited. Cranford et al (2006) showed that the percentage of picoplankton (microalgae smaller than 3 µm) increases as grazing pressure increases. Picoplankton cannot be filtered by bivalves and thus the relative abundance can be an indication of overgrazing.

Results of the model calculations show that overgrazing takes place in the Oosterschelde. Algal biomass is limiting shellfish production. The effect is proportional to the increase in SMC-biomass. This is confirmed by results from the time-series data analysis, which shows that in years with high bivalve stocks low condition of mussels and less growth of cockles is observed. Measurements of picoplankton abundance show

continued on page 18

Floats for nets.

Seed on ropes.

Net with seed mussels during harvest with brushing machine.

seasonal fluctuations in both the Oosterschelde and Wadden Sea. Generally, the percentage is higher in the Oosterschelde than the Wadden Sea. Moreover, the percentage is higher in the Eastern part of the Oosterschelde, that has less water exchange with the North Sea. Local effects of grazing, indicated by reduced food concentrations (measured as chlorophyll a), were detected within SMCs in the Oosterschelde, but not directly behind the systems. Only at one sheltered location reduced food concentrations were measured behind seed collector. Whether this reduced food concentration also results in reduced growth is unclear.

Results of the model calculations for the Wadden Sea indicate that an increase in SMC-biomass also leads to a decrease in in natural shellfish stocks, but this decrease is less than the increase in SMC-biomass. The time-series data analysis for the Wadden Sea showed a negative effect of stock size on condition of mussels and growth of cockles in one area, but not in the other. Furthermore, the time-series data analysis indicates a rapid increase in razor clam biomass in the Western Wadden Sea. This suggests that at the present size of SMC-mussel stock no loss of natural stocks is occurring in this area.

Effects of **deposition of organic material** resulting from seed mussel collectors was studied using the BACI-method. Sediment samples were collected Before (directly after installation of the SMC-systems) and After (directly after harvest of SMC-mussels) and at Control locations (1000 m and 500 m away from the SMC-system) and to Impact locations (within the SMC-system). Organic carbon content, C/N ratio and stable isotope signatures (δ 13C en δ 15N) of sediment and mussel faeces were determined. Results showed no indication of enrichment of the sediment at the scale of the transect. More localised effects could not be detected with the method used. Unlike longlines for growing market size mussels, SMC-systems are placed in areas with relatively high current velocities. This may explain the lack of accumulation of organic material.

Disturbance of birds (Red-throated Loon and Eider ducks and moulting Shelducks) **and Harbour seals** by activities connected to the use of Seed Mussel Collectors has been studied in the Voordelta (off the coast of the province of Zeeland) and the Zuidmeep (Dutch Wadden Sea). These activities include placement of the systems in spring (e.g. drilling of anchoring poles), monitoring seed attachment and growth, harvesting and removal of the systems in fall. Ground observations from land and ships were carried out on days with and without SMC-activities. In addition, aerial surveys were carried out. At the present scale of SMCs detrimental effects on birds were not detected. The Harbour seal population is growing in the Wadden Sea. The increase is less in areas with many SMC-systems. However, information on other anthropogenic developments in these areas is lacking. Therefore, effects can not specifically be attributed to SMCs.

Microplastics can be taken up by shellfish and organisms that live in the sediment. Measurements were carried out to quantify production of microplastic through wear and tear of ropes, nets and floats used for Seed Mussel Collectors and the brushing machine used for harvesting. Quantification of the amount of microplastics produced proved to be difficult, but a first estimation suggests that nets show more weight loss than brushes. ■

References

Cranford PJ, R Anderson, P Archambault, T Balch, SS Bates, G Bugden, MD Callier, C Carver, LA Comeau, B Hargrave, WG Harrison, E Horne, PE Kepkay, WKW Li, A Mallet, M Ouellette and P Strain (2006). Indicators and thresholds for use in assessing shellfish aquaculture impacts on fish habitat. Canadian Science Advisory Secretariat Research Document 2006/034, 116p

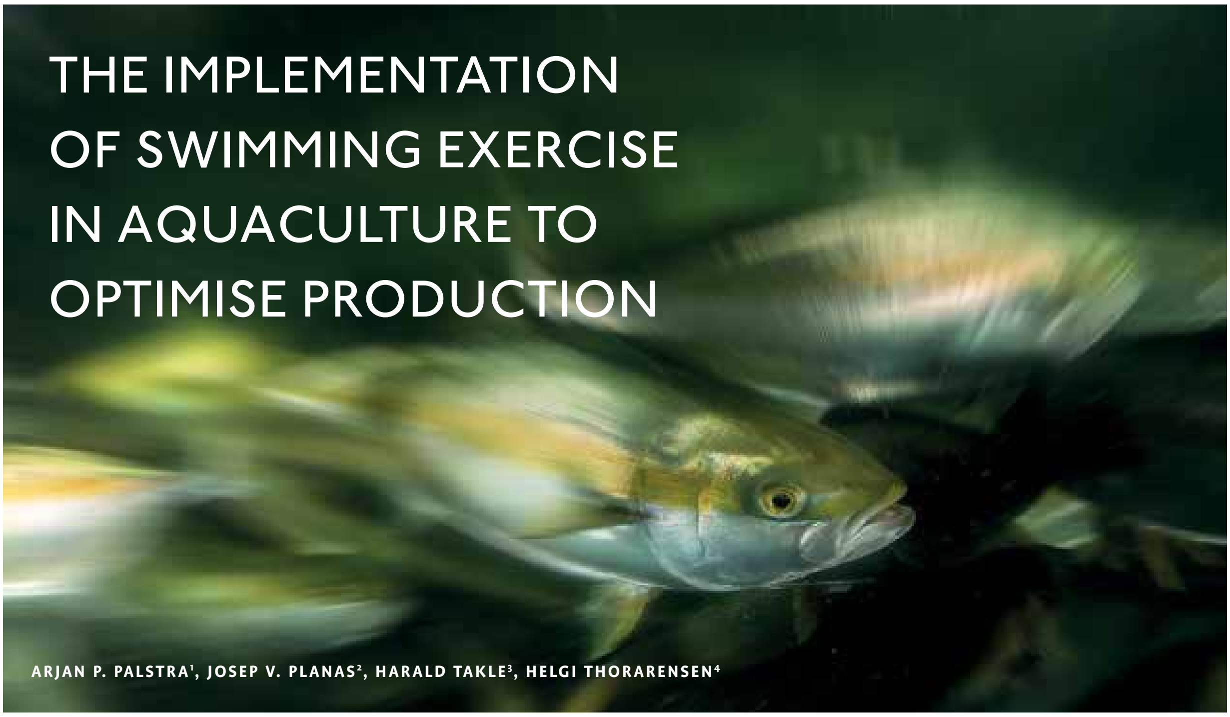
PvU, (2010). Plan van Uitvoering Convenant transitie mosselsector en natuurherstel Waddenzee

Stralen, M. van 2014. Invang van mosselzaad in MZI's. Resultaten 2013. MarinX rapport 2014.136

More information (in Dutch)
http://www.wageningenur.nl/nl/Expertises-Dienstverlening/Onderzoeksinstituten/imares/Projecten/Show/Effecten-Mosselzaad-Invanginstallaties-MZIs.htm

THE IMPLEMENTATION OF SWIMMING EXERCISE IN AQUACULTURE TO OPTIMISE PRODUCTION

ARJAN P. PALSTRA[1], JOSEP V. PLANAS[2], HARALD TAKLE[3], HELGI THORARENSEN[4]



Swimming yellowtail kingfish. *(Photo by Y. van Es).*

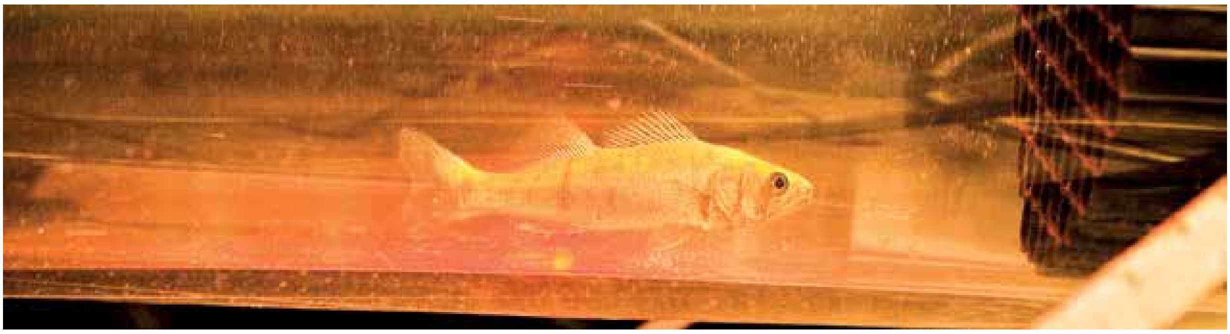
Aquaculture plays an important role in securing our future by supplying the increasing demands for animal protein. Poor fish health and welfare are a challenge for the growth of aquaculture. Aquaculture should aim to produce fish that are physically fit and robust (i.e. having the ability to maintain homeostasis under changing conditions and the capacity to mount a strong disease resistance). For fish, swimming is an essential characteristic that is intimately linked to their ability to develop, survive, grow and reproduce successfully. Current farming conditions, however, often do not allow fish to fully display their normal swimming behaviour. Therefore, farmed fish cannot experience the physiological benefits that swimming gives their wild counterparts. Exercise represents a tool in aquaculture to improve growth, health, welfare and filet quality (Jobling et al., 1993; Davison, 1997; Palstra & Planas, 2011; 2013).

The level of exercise for aquaculture fish is optimal at swimming speeds where the fish reap the benefits of the exercise without wasting energy on aggressive behavior (at speeds which are too low) or using excessive energy for swimming (at speeds which are too high). This level of exercise depends on the species, life-stage and the physiological fitness of the fish; on environmental conditions (water quality, oxygen); on the system design (RAS or flow through, tanks or raceways) and on how exercise is induced which can be accomplished by creating a current or by using the optomotor response of the fish (Herbert, 2013). Optimal exercise may be beneficial not only for athletic fish but also for species that are less known for their swimming abilities in their natural habitat. Species-specific exercise protocols that vary in duration and intensity may, therefore, be developed. Effects of optimal exercise may include: 1) Improved feeding efficiency, growth rates and skeletal muscle mass; 2) Changes in muscle composition leading to higher flesh quality; 3) Increased survival by increased robustness or fitness; 4) Increased welfare by lowered stress; 5) Improved immune capacity, and 6) Control of reproduction. Furthermore, swimming exercise can be applied to select fish on the basis of their swimming performance e.g. to select out weak or abnormal fish.

At IMARES we have six swim-tunnels, 123 L each, to perform respirometry of individual fish or small groups of juveniles while swimming at speeds up to 1 m/s (Fig. 1). These tunnels were originally designed to study the migration performance of eels (van den Thillart et al., 2004). Now we mostly use them for determining the optimal swimming speed, where the cost of transport (energy spent on swimming over a certain distance) is lowest and the energetic efficiency is highest. Importantly, the optimal swimming speed reflects very well the swimming speed for optimal growth in a variety of salmonid species and *Seriola* sp (reviewed by Davison and Herbert, 2013). A recently built 3600 L oval flume, where currents that reach 1.2 m/s can be created by a propellor driven by an electric motor (Fig. 2), is used to swim groups of fish, either to select them on their swimming performance (good vs bad swimmers), to study effects of long-term swim-training or to simulate migration. A semi-industrial RAS set-up consisting of 6 systems with each 3 tanks has been modified to study the effects of increased flow on fish and system. Over the last four years, we had eight national and EU projects running together with the aquaculture industry to apply exercise in order to solve a range of biological bottlenecks for most major aquaculture spe-

[1] The Institute for Marine Resources and Ecosystem Studies (IMARES), Wageningen University and Research Centre, Korringaweg 5, 4401 NT Yerseke, Netherlands
[2] Departament de Fisiologia i Immunologia, Facultat de Biologia, University of Barcelona, Av. Diagonal 643, 08028 Barcelona, Spain
[3] Nofima, Osloveien 1, 1430 Aas, Norway
[4] Holar University College, Holar, 551 Saudarkrokur, Iceland

Pikeperch in the swim-tunnel during a swimming test. *(Photo by R. Blonk)*.



cies. We have applied exercise to stimulate uniform muscle growth in yellowtail kingfish (Palstra et al., 2015; Fig. 3), pikeperch (Fig. 4) and seabream; to relate exercise parameters with genetic selection in seabream and Atlantic salmon; to stimulate maturation in eel and trout; and to improve welfare of Claresse. Together with the University of Barcelona we have applied exercise to prevent precocious maturation in seabass. With the Universities of Barcelona and Leiden we study the underlying physiological mechanisms using our comparative exercise model zebrafish (Palstra et al., 2010, 2014).

The swim-flume at IMARES has been used for simulated migration of eels, long-term swim training of yellowtail kingfish, pikeperch, seabass and seabream, and selection trials with seabream and Atlantic salmon. *(Photo by Y. van Es)*.

Nofima has specialised in exercise systems for salmonids. Twenty-two fresh water rearing tanks were built for automatic and exact control of swimming speed in a wide range of water velocities and for direct measures of oxygen consumption and feed utilisation of salmon smolts. For the post-smolt stage of salmonids, up-graded industrial tanks for accurate swimming speed control are present at the Norwegian centre for recirculation in aquaculture. These tanks are also used to model the effects of exercise in closed containment system in combination with different water qualities. To study exercise in open net-pens, a system with large propellers was developed to create currents similar to those in the most exposed sea cages. In recent studies we have focussed on salmon cardiology and immunity using four large swimming flumes with respirometers which are combined with physiological measures of oxygen consumption capacities, heart rate and in-depth molecular studies of mechanisms underlying robustness and disease resistance (Castro et al., 2011, 2013, Ytteborg et al., 2013; Takle & Castro, 2013; Anttila & Jørgensen et al., 2014). The applied interest of the salmon aquaculture industry in utilising exercise to optimise production is high and Nofima is involved in a number of projects funded by farming, feeding and breeding companies as well as aquaculture research funds.

"FitFish" aims to promote research on the swimming physiology of fish and to increase fundamental knowledge on exercise mechanisms as well as applied knowledge that can be used for implementation of exercise for aquaculture purposes, e.g. swimming to optimise production. In 2010, Dr. Arjan Palstra and Dr. Josep Planas organised the first FitFish workshop in Barcelona and related symposia at the Int. Congress on the Biology of Fish (Barcelona 2010; Madison 2012; Edinburgh 2014). A special issue of the journal "Fish Physiology and Biochemistry" was edited as well as the book entitled "Swimming Physiology of Fish. Towards using exercise to farm fit fish in sustainable aquaculture" (Springer). Recently, a Frontiers special issue was edited on the "Physiological adaptations to swimming in fish". In April 2014, the COST Action FA1304 on the swimming of fish and implications for migration and aquaculture (www.fitfish.eu) was started. Already 23 countries are participating in this network action that has the objective to further develop the research network in which fish swimming in the wild and in aquaculture is studied for the first time under a multidisciplinary perspective. The Action will provide the basis for technological breakthroughs (e.g. more accurate monitoring of migrant fish; design of exercise-"friendly" fish farming facilities), for establishing swimming as an essential factor determining welfare and for demonstrating that swimming can benefit quality production. The Action will add value to independent, nationally funded research activities by providing the means to exchange information, promote industrial

continued on page 22

Seabream waiting in swim-tunnels at IMARES to be tested on their swimming performance. *(Photo by A. Palstra)*.

activities and influence policies at a European level. Activities in FITFISH also include the training and exchange of early stage researchers in the area.

At AE2015 in Rotterdam we will organise a session on swimming to optimise production as a part of the COST Action. This is a meeting of the Action's Working Group 3 "Exercise in Aquaculture" lead by Dr. Harald Takle and Dr. Helgi Thorarensen. The aim of this WG is to gather scientific information on swimming of aquaculture fish, to identify potential gaps in our knowledge for targeting future research efforts and to design optimal swimming protocols for specific species and conditions. Also appropriate for your potential interest, Working Group 1 lead by Dr. Paolo Domenici and Dr. Gudrun De Boeck studies the functional mechanisms behind the beneficial effects of swimming. A meeting is organised by Dr. David McKenzie during the Aquaculture conference in Montpellier.

Acknowledgments: This publication is supported by COST Action FA1304 "Swimming of fish and implications for migration and aquaculture (FITFISH)." ■

References

Anttila, K., Jorgensen, S.M., Casselman, M.T., Timmerhaus, G., Farrell, A.P., Takle, H. (2014). Association between swimming performance, cardiorespiratory morphometry, and thermal tolerance in Atlantic salmon (*Salmo salar* L.). Frontiers in Marine Science 1:76.

Castro, V., Grisdale-Helland, B. Helland, S.J., Kristensen, T., Jørgensen S.M., Helgerud, J., Claireaux, G., Farrell, A.P., Krasnov, A., Takle, H. (2011). Aerobic training stimulates growth and promotes disease resistance in Atlantic salmon (*Salmo salar*). Comparative Biochemistry and Physiology, Part A. 160, 278-290.

Castro, V., Grisdale-Helland, B., Helland, S.J., Torgersen, J., Kristensen, T., Claireaux, G., Farrell, A.P., Takle, H. (2013). Cardiac molecular acclimation mechanisms in response to swimming induced exercise in Atlantic salmon. PLoS ONE, 8(1): e55056.

Davison, W. (1997). The effects of exercise training on teleost fish, a review of recent literature. Comparative Biochemistry and Physiology, Part A. 117, 67-75.

Davison, W., Herbert, N.A. (2013). "Swimming-enhanced growth," in: Swimming physiology of fish: towards using exercise to farm a fit fish in sustainable aquaculture, eds. A.P. Palstra, J.V. Planas eds (Berlin: Springer) 172-202.

Herbert, N. A. (2013). "Practical aspects of induced exercise in finfish aquaculture," in Swimming Physiology of Fish: Towards Using Exercise to Farm a Fit Fish in Sustainable Aquaculture, eds A. P. Palstra and J. V. Planas (Heidelberg: Springer), 377–406.

Jobling, M., Baardvik, B.M., Christiansen, J.S., Jørgensen, E.H. (1993). The effects of prolonged exercise training on growth performance and production parameters in fish. Aquaculture International 1, 95-111.

Palstra, A.P., Planas, J.V. (2011). Fish under exercise. Fish Physiology and Biochemistry. 37, 259-272.

Palstra, A.P., Planas, J.V. (2013). Swimming Physiology of Fish: Towards using exercise to farm a fit fish in sustainable aquaculture. Heidelberg: Springer, pp. 429.

Palstra, A.P., Rovira, M., Rizo, D., Torrella, J.R., Spaink, H.P., Planas, J.V. (2014) Swimming-induced exercise promotes hypertrophy and vascularization of fast skeletal muscle fibres and activation of myogenic and angiogenic transcriptional programs in adult zebrafish. BMC Genomics 15:1136.

Palstra, A.P., Mes, D., Kusters, K., Roques, J.A.C., Flik, G., Kloet, K., Blonk, R.J.W. (2015). Forced sustained swimming exercise at optimal speed enhances growth of yellowtail kingfish (*Seriola lalandi*). Frontiers Physiology 5: 506

van den Thillart, G., van Ginneken, V., Körner, F., Heijmans, R., Van Der Linden, R., Gluvers, A. (2004). Endurance swimming of European eel. Journal of Fish Biology 65, 312-318.

Ytteborg, E., Torgersen, J., Pedersen, M., Helland, S.J., Grisdale-Helland, B., Takle, H. (2013). Exercise induced mechano-sensing and Substance P mediated bone modeling in Atlantic salmon. Bone 53, 259-268.

Takle, H., Castro., V. (2013). "Molecular adaptive mechanisms in the cardiac muscle of exercised fish," in Swimming Physiology of Fish: Towards Using Exercise to Farm a Fit Fish in Sustainable Aquaculture, eds A.P. Palstra and J.V. Planas (Heidelberg: Springer), 257-274.

Dutch Aquaculture Experts create 'one stop shop' for Global aquaculture development

The Dutch Aquaculture Experts (DAE) is founded in January 2015. DAE is a new organisation where longstanding experience and expertise joined forces in the area of aquaculture and its related businesses. Dutch products and expertise are now easily accessible through a one-stop shop approach. DAE allows the world to benefit from an accumulation of the best products and services that The Netherlands has to offer.

BACKGROUND

The Netherlands is a small country surrounded by the sea and always threatened by water. It has prioritised a modern, economical profitable and sustainable fishing and aquaculture industry. The Dutch aquaculture industry is exclusively applying closed water RAS technology in indoor fish farming systems. RAS is recognised by sophisticated systems and sustainable production. In addition, The Netherlands plays a significant role in seafood processing, quality & safety control, traceability and international trade.

A number of world-class companies with a proven track record in both national and international aquaculture research and businesses now voluntarily pool resources and offer their products or services through the Dutch Aquaculture Experts (DAE).

OBJECTIVES OF DAE

The Dutch Aquaculture Experts (DAE) are committed to promote sustainable development of the world aquaculture industry and its supply chains. DAE is continuously working on improving environmentally friendly solutions and raising the healthiest seafood while reducing the impact on the ocean's resources.

BENEFITS OF A ONE-STOP SHOP

DAE aims at accelerating sustainable aquaculture development worldwide. The Dutch experts, all with their specific specialisations, join forces to create innovations and set new standards for sustainable aquaculture farming.

The strength of this organisation is the better accessibility of products and services through one contact point and short communication lines. Serving as a 'one-stop shop', will also save time and money due to the greater efficiency of finding solutions from the wide range of products and services that DAE has to offer.

The combined efforts can accelerate sustainable aquaculture development when required. At the same time, leaving the DAE members free of acting in small groups or individually when this would be more suitable for a specific project.

ACTIVITIES OF DAE

The open approach to combine the collective aquaculture expertise of the Dutch companies allows a wide variety of projects. DAE can deliver all requirements for complete aquaculture farming and supply chain projects. Services include contract research, farm design, fish health and welfare services, quality assessments, preparation for certification and training. Products include equipment and building, fish feeds, fish stocks & broodstock. The activities are grouped into the following areas;

- Hatchery and production technology
- Processing, market and logistics
- Health, quality and certification
- Engineering and equipment
- Feed formulation and production
- Research, education and services

Members of DAE successfully implemented large or complex aquaculture projects. However, small-scale production facilities are also welcome. Clients may include aquaculture producers, governmental bodies, international organisations, but also individual producers and companies in any of the supply chains.

ILLUSTRATION PROJECT

Before DAE was officially launched, members occasionally found each other for diverse cooperation projects. One example is FoodTechAfrica (FTA: www.foodtechafrica.com), a public-private initiative combining the strengths of Dutch agro-food companies (mainly DAE members), knowledge institutes, governmental agencies and their East-African counterparts to improve food security in East Africa.

This 5-year project started in 2013. Five DAE members (Skretting, Imares, Viqon, Holland Aqua and Fishion) cooperate with other partners such as the Kenya Marine and Fisheries Research Institute (KMFRI), The Roost, Almex BV, Dinnissen BV, Ottevanger BV, Unga Farm Care, the Dutch Ministry of Foreign Affairs and the Royal Dutch Embassy in Nairobi.

FTA aims to improve food security in East Africa through the establishment of a fully integrated aquaculture value chain. FTA offers an integrated approach for developing sustainable high quality inputs (feed, fingerlings), productive yet sustainable farming methods and finally safe and efficient processing and cooled logistics.

Contact for more information

DAE members are committed to drive developments in aquaculture; to improve environmental performance, increase aquatic animal health and welfare and to drive down costs.

The ambition of DAE is to make a valuable contribution to the sustainable development of aquaculture worldwide.

For more information and contact visit: http://www.dutch-aquaculture-experts.com ■

LUMPFISH

THE SALMON FARMER'S NEW BEST FRIEND

BY ALBERT. K.D. IMSLAND, AKVAPLAN-NIVA, TROMSØ, NORWAY AND UNIVERSITY OF BERGEN, NORWAY

SALMON AND ITS FOE – THE SEA LICE

Infestations by the sea lice *Lepeophtheirus salmonis* Krøyer, is a major health problem facing the Atlantic salmon industry. The parasite grazes on the skin and mucosal tissue of the fish and leaves the fish open to secondary infections and osmotic stress which may ultimately result in death. This ectoparasitic copepod has a large impact on the economy of fish farmers in the form of costly treatment procedures, reduced growth, feed waste and the downgrading of the final product. It is expected that the cost of sea lice alone to Norwegian fish farmers is more than 150 m€/year. The problem also extends beyond aquaculture, with wild fish stocks (predominantly Atlantic salmon) acting as a natural reservoir of the parasites, and the effects of parasitism has been linked to wild population declines. There are also other ectoparasites that may pose a threat to Atlantic salmon e.g. *Caligus curtus* and *Caligus elongatus*. *C. elongatus* has been found on over 50 marine species, many of them with aquaculture potential.

Lumpfish from below (the sucking disk can be seen).

The aquaculture industry has been struggling with the issue of sea lice for many years and has relied heavily upon the use of chemotherapeutic treatments either as bath treatments (such as hydrogen peroxide and organophosphates) or, more recently, synthetic pyrethroids (Cypermethrin and Deltamethrin) or using an in-feed treatment with emamectin benzoate (SliceTM). Sea lice medications available to the salmon farming industry are limited, and the continuous and frequent use of cypermethrin and emamectin benzoate can potentially lead to the development

Front view of a juvenile (approx. 10 g) lumpfish.

of resistance in lice. Reduced efficacy and increased proportion of ineffective treatments have risen from zero in 2002 to 50% of reported cases in 2006 and recent Norwegian data indicate that the numbers are now much higher. The fundamental problem is that current methods of sea lice control are proving ineffective and unsustainable. Accordingly, a cost-effective and environmentally sustainable alternative to chemotherapeutic treatments is an urgent priority for the aquaculture industry.

BIOLOGICAL CONTROL OF SEA LICE WITH CLEANER FISH

The biological control of sea lice through the use of "cleaner fish" has recently become a feasible option due to the increased occurrence of resistant lice, and the reduced public acceptance of chemotherapeutic use in food production and the urgent need for an effective and sustainable method of parasite control in Atlantic salmon aquaculture. Up to now the main cleaner fish in use have been the wrasses. Currently, some farms are using wrasse species to aid in the control of sea lice. Of those, the Ballan wrasse (*Labrus bergylta*) has the greatest potential for large scale biological delousing, particularly for use on larger production grade salmon, being the biggest and most robust of the available wrasse species. However, the wrasse species currently in use for biological delousing are temperature sensitive, making them unfit for use under low temperatures. As a cold-water alternative, the common lumpfish (*Cyclopterus lumpus*) has been suggested.

BIOLOGY OF LUMPFISH

Lumpfish is found through a wide geographical area, both in the north-east and north-west Atlantic, where it occurs in temperate and cold waters, mainly at high latitudes. The species is common from January-September along the northern European coast. In the north-eastern Atlantic, lumpfish occurs in the North, Baltic and Barents Seas, extending from the English Channel to the Arctic. It has, however, recently been recorded in Galicia and in the Mediterranean Sea and southward range extension has been identified along the coast of Portugal. The lumpfish is primarily a benthic species found on rocky bottoms, living close or attached to the seabed, but it is also found as a pelagic species in the open sea. Lumpfish aggregates and moves inshore in late spring or early summer to spawn and leaves for deeper water in late summer. Observations have further shown that lumpfish spends most of its life over great depths, only visiting the sea bed to spawn. The lumpfish migrates to the coast in the spring to spawn. The male lumpfish guards the eggs until hatching.

The appearance of the lumpfish is highly characteristic (Fig. 1). The head is thick and short, with a blunted nose, and a high dorsal crest that covers the first dorsal fin entirely. The body is covered in scale-less skin, with rows of dark tubercles longitudinal of the body. The pelvic fins constitute a ventral suction disc, allowing fish to rest on rocky substrate, algae and vegetation. Lumpfish display a sexual dimorphism in size, skin color and blood plasma. Mature females range from 35-45 cm and are often bluish gray or green in color, while males are 17-38 cm and display nuptial colors of pink, orange and deep red. One year old juveniles are brown, dark purple red, brown spotted or red in colour, assumed to be a function of background colour and reflecting habitat choice.

PRODUCTION OF JUVENILE LUMPFISH

Pilot scale experiments in the 1990ies confirmed that adult lumpfish could with ease be reared and would spawn in captivity, and from 2010 there has been a steady increase in production of juvenile lumpfish in Norway, the Faroes Island and in Iceland. The larvae can be weaned directly on dry feed making large scale production of lumpfish juveniles possible. It is estimated that in 2016 as much as 16 million lumpfish juveniles may be produced in Norway. Figure 2 shows a schematic overview over production of juvenile lumpfish.

THE USE OF LUMPFISH TO CONTROL SEA LICE INFESTATIONS IN FARMED ATLANTIC SALMON

To assess the efficacy of lumpfish grazing on attached sea lice on Atlantic salmon, we performed a small scale trial in Northern Norway (see also Imsland et al. 2014a). Six sea cages (5x5x5 m) were each stocked with 120 Atlantic salmon with a mean (± SD) weight of 619 ± 49 g. Two of the cages were further stocked with 12 lumpfish (10% density), and two with 18 lumpfish (15% density) with a mean (± SD) weight of 54.0 g ± 7.2. Two cages without lumpfish acted as control cages. There were clear signs of lumpfish grazing of sea lice with significantly lower average numbers of pre-adult, mature males and females stages of *L. salmonis* per salmon. Lumpfish supressed the mature females stage of *L. salmonis* to levels equal to or lower than the pre-treatment counts recorded prior to the start

continued on page 26

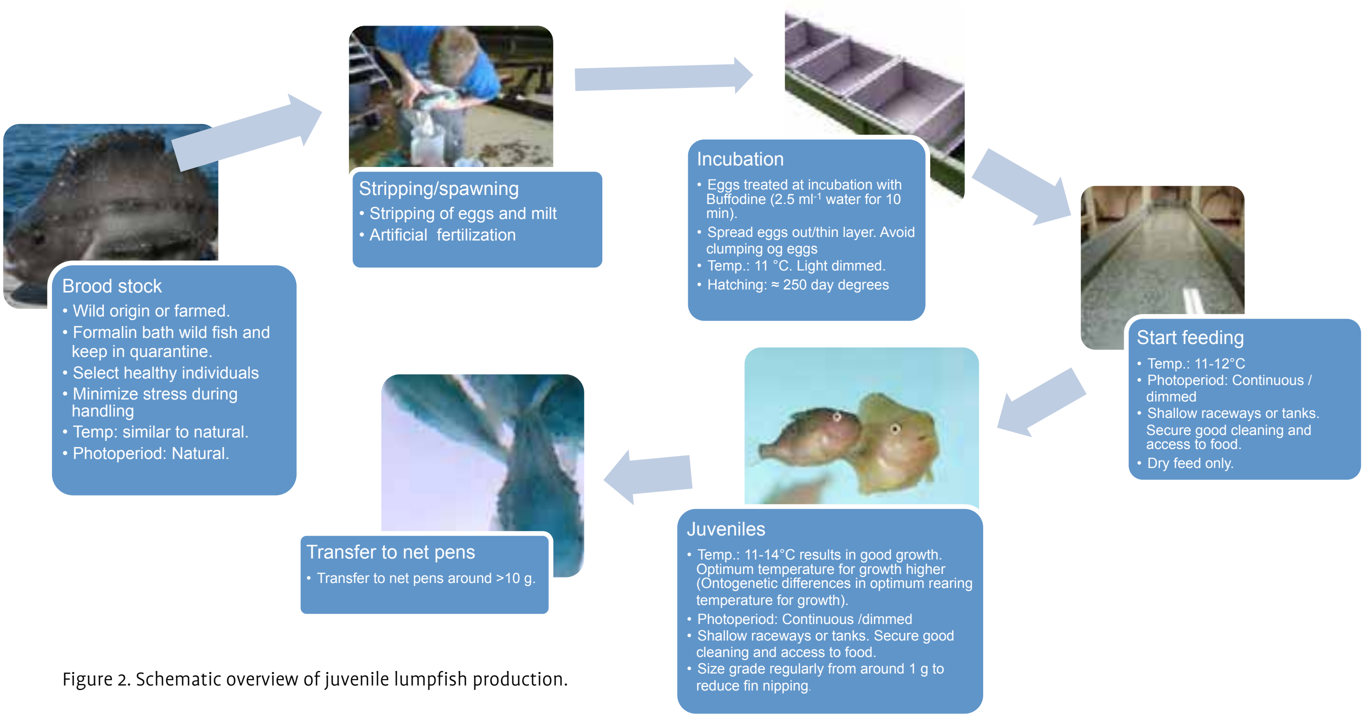


Figure 2. Schematic overview of juvenile lumpfish production.

of the study i.e. removing 93-97% of adult female lice (Fig. 3). There was clear evidence of grazing from the results of gastric lavaging with 28% of all lumpfish found to have ingested sea lice on the last sampling day. Overall, the findings clearly indicated that lumpfish is a suitable cold-water option for biological delousing of Atlantic salmon. Based on those initial findings the interest in using lumpfish for biological delousing of salmon has rocketed in Norway with the production of lumpfish going from thousands to millions in less than three years. Lumpfish is now being used, or considered for use, by most of the major Norwegian salmon farmers.

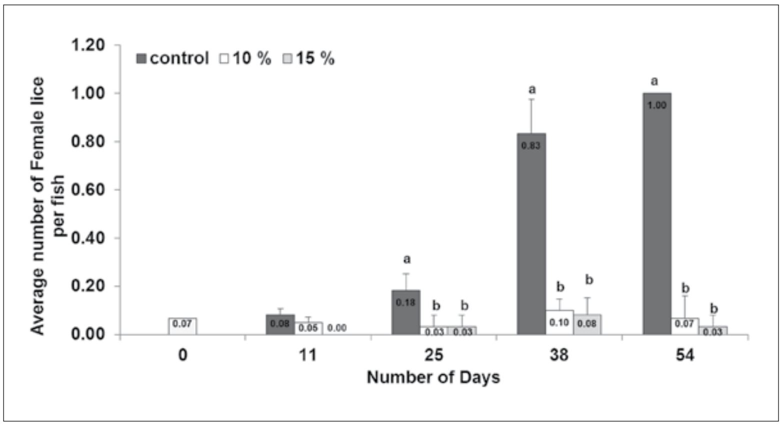


Figure 3. Lumpfish is effective in delousing salmon.

HAS CLEANING BEHAVIOUR EVOLVED BETWEEN LUMPFISH AND ATLANTIC SALMON?

Cleaning behaviour is considered to be a classical example of mutualism. Very limited information exists on the stomach content of wild lumpfish, but *L. salmonis* have been reported in the stomachs of wild juvenile lumpfish and other copepods are a substantial part of the diet of juvenile lumpfish. Moreover, wild Atlantic salmon in the sea can have a large number of adult *L. salmonis* attached on their surface during winter. Given the opportunity lumpfish will effectively graze on *L. salmonis* on Atlantic salmon (see above) and it may be speculated that this parasite grazing behaviour has developed between the two species in a similar way as seen for parasite cleaning fish in the tropics. This is an exciting research avenue that we will try to investigate further.

In general the feeding behaviour of lumpfish in sea pens (see also Imsland et al., 2014b) can be classified as strongly opportunistic and the fish do not restrict themselves or rely on a single food source if others are present. Our findings show that the majority of daylight time is spent foraging for food and if not feeding or foraging, the fish were found to be either resting within the floating seaweed within the cage or hovering just under the weed. In the absence of Atlantic salmon lumpfish spent more time resting. ■

Further reading

Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Foss, A., Vikingstad, E., Elvegård, T.A. 2014a. The use of lumpfish (*Cyclopterus lumpus* L.) to control sea lice (*Lepeophtheirus salmonis* Krøyer) infestations in intensively farmed Atlantic salmon (*Salmo salar* L.). *Aquaculture* 425-426, 18-23.

Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Nytrø, A.V., Foss, A., Vikingstad, E., Elvegård, T.A. 2014b. Notes on behaviour of lumpfish in sea pens with and without Atlantic salmon. *Journal of Ethology* 32, 117-122.

Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Nytrø, A.V., Foss, A., Vikingstad, E., Elvegård, T.A. 2014c. Assessment of growth and sea lice infection levels in Atlantic salmon stocked in small-scale cages with lumpfish. *Aquaculture* 433, 137-142.

Nytrø, A.V., Vikingstad, E., Foss, A., Hangstad, T.A., Reynolds, P., Eliassen, G., Elvegård, T.A., Falk-Petersen, I.B and Imsland, A.K. 2014. The effect of temperature and fish size on growth of juvenile lumpfish (*Cyclopterus lumpus* L.). *Aquaculture* 434, 296-302.

Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Nytrø, A.V., Foss, A., Vikingstad, E., Elvegård, T.A. 2015. Feeding preferences of lumpfish (*Cyclopterus lumpus* L.) maintained in open net-pens with Atlantic salmon (*Salmo salar* L.) *Aquaculture* 436, 47-51.

Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Nytrø, A.V., Foss, A., Vikingstad, E., Elvegård, T.A. 2015. Assessment of suitable substrates for lumpfish in sea pens. *Aquaculture International* (in press).

ORGANIC TROUT OVA/FRY ALSO AVAILABLE FROM DANISH HATCHERIES

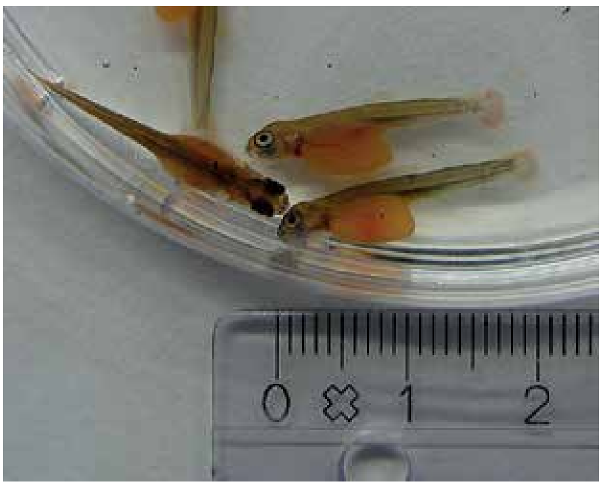
One year ahead of the deadline for implementation of complete organic aquaculture life cycle - organic trout ova/fry is available from Danish hatcheries.

BY ALFRED JOKUMSEN, SENIOR ADVISORY SCIENTIST, TECHNICAL UNIVERSITY OF DENMARK, DTU AQUA, THE NORTH SEA RESEARCH PARK, HIRTSHALS. DENMARK.

Organic aquaculture production is one of the most dynamic food production sectors in Europe and the production has increased rapidly in recent years. Denmark is among the leading European organic aquaculture producers. The Danish annual production in organic aquaculture is currently about 1000 MT of rainbow trout and about 400 MT blue mussels and additionally production of organic seaweed and crustaceans has been initiated.

According to Commission Regulation (EU) No 1364/2013 the life cycle of all animals in organic aquaculture must be 100 % organic by 1st January 2016. The hitherto national organic rules in force have also been harmonized.

Fry (above) and yolk-sac fry. *Photos Lone Madsen.*



Organic fry of rainbow trout from Danish hatcheries. *Photo V.J. Larsen*

This request of exclusively organic fry from 2016 entails big challenges to the organic farmers. The organic rules only allow very limited treatments against diseases to keep the organic certificate. Fry is vulnerable to diseases and hence the robustness of fry to diseases is crucial. In particular this concerns one of the most serious trout fry diseases in Danish aquaculture, Rainbow Trout Fry Syndrome (RTFS).

To further strengthen and develop Danish organic aquaculture, a national funded research project, RobustFish (2014-2017) has recently been launched. The project focuses on organic robust trout fry to prevent disease and medical treatments. The project will also provide knowledge about market conditions for organic aquaculture products, consumer attitudes and development potentials for organic aquaculture. Further information at the project website: http://www.icrofs.org/Pages/Research/ORG_RDD2_Robustfish.html

The basic hypothesis of RobustFish is that there is a relation between the time of absorption of the fry yolk sac followed by swim-up/searching for feed at the water surface – and the robustness and growth potential. Thus it is assumed that the first fry at the water surface (”early swim-up”) will perform better during grow out than the last swim-up fry (”late swim-up”). Using a specific developed sorting device the fry is sorted into fractions (”Early” – ”Medium” – ”Late”) as they are swimming up.

The project will investigate the robustness of the various fractions of fry. This includes investigations of the influence of the dietary content of essential Ω-3 fatty acids (HUFAs), which are important for growth, health and welfare of the fish, as well as testing robustness to stress.

continued on page 36

Juvenile geoduck nursery float and trays.
Photo: Yves Harache

DEVELOPMENTS IN SHELLFISH CULTURE IN WASHINGTON, U.S.

DUANE FAGERGREN, CALM COVE OYSTER LLC (INVITED SPEAKER AT THE 1ST WORLD OYSTER CONGRESS, ARCACHON, 2012)
AND BILL TAYLOR, TAYLOR SHELLFISH FARMS

BASIC OVERVIEW OF THE WASHINGTON SHELLFISH PRODUCTION

According to 2009 production data generated by the Pacific Coast Shellfish Growers Association (http://www.pcsga.org), the total tonnage (MT) and dollar value ($ USD, farm gate value) for shellfish produced and sold in Washington State are:

Oysters	Clams	Mussels	Geoduck	Totals
27,727 MT	4,327 MT	1,250 MT	750 MT	34,055 MT
$ 57,750,000	$ 19,550,000	$ 3,162,500	$20,100,000	$ 107,562,500

These data are six years old and need to be updated to reflect current production. Also these figures do not include a considerable "sport" (non-commercial) shellfish harvest enjoyed by recreational harvesters.

Nine commercial shellfish hatcheries operate on the Pacific Coast- Washington (6), Oregon (1), British Columbia (1), Canada, and Alaska (1); they produce ~ $ 9 M USD seed and setting-sized larvae for the industry.

Most of the commercial industry relies on hatcheries for its seed supply because of its technology is predictable and provides single oyster seed or seed set on cultch for a wide range of economically important bivalve species. Many growers buy 'eyed larvae' from hatcheries and set their own seed in setting tanks on their own farms.

Periodic natural sets of Pacific oysters occur in Willapa Bay, Hood Canal, and along the East coast of Vancouver, British Columbia, and these natural sets on oyster shell are used primarily for the shucked, "oyster meat" market. Higher market value per oyster can be attained by selling single oysters in the shell, either for raw consumption or for various "top-off" cooked presentation. The market is trending toward single oysters, although the shucked market continues to be strong. Many of the large (> 15 cm) single oysters are highly prized in China and in the domestic U.S. Asian market. Most small single oysters sold for raw consumption in domestic oyster bars are ~ 6- 10 cm.

Historic perspective of the Washington Shellfish Industry:

The oyster industry on the West Coast of North America dates back to the mid 1800s. In 1889 at the time of statehood in Washington, logging and fishing formed the backbone of small rural communities, and Native Americans long relied on wild natural resources, including mussels, clams the native oyster, later termed "Olympia" or *Ostrea lurida*.

In order to promote commerce and encourage natural resource development, Washington State sold some of its intertidal tidelands to early pioneers for use in shellfish culture. This early practice of selling these tidelands to promote the oyster industry was unique in the United States and fostered a strong, cohesive industry for small and large growers alike. Ownership also provides certainty for farming the intertidal tidelands and makes it possible for growers to borrow money from the bank based on their asset.

The industry has diversified greatly since 1889 when the state sold about half of its intertidal tidelands. This sale of the state's intertidal tidelands gave shellfish farmers the right and the responsibility to use this class of tidelands exclusively for shellfish production. Today about 150 companies farm shellfish in Washington, Oregon, California, British Columbia, and Alaska. About 85% of the West Coast production comes from Washington and most of the intensive growing areas

continued on page 30

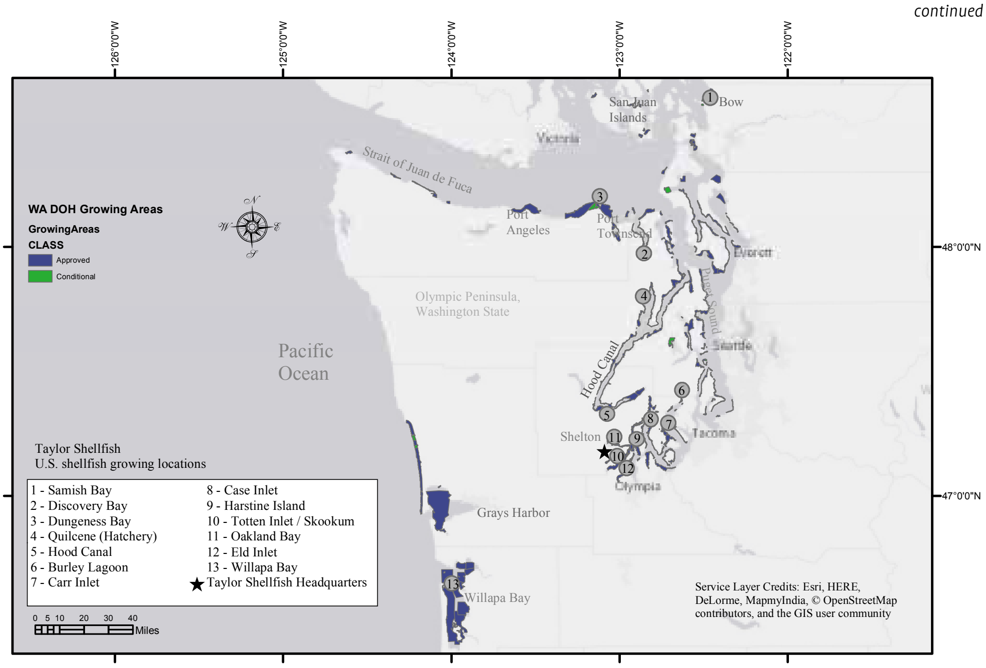


Fig. 1: TSF operation locations.

are in Willapa Bay, North and South Puget Sound and Hood Canal. Willapa Bay produces the highest volume of oysters, mostly sold as shucked product. (Figure 1)

Taylor Shellfish Farms: A West Coast shellfish success story

Taylor Shellfish Farms (TSF or 'the Company') is a leader in the shellfish industry in Washington and in the United States. Justin Taylor (1921-2011) and Edwin Taylor (1914-1984) pioneered the family shellfish Company and had the wisdom and financial resources to purchase tidelands in South Puget Sound, Hood Canal, Samish Bay near Bow, and Willapa Bay. The family runs this business as a vertically integrated corporation, now in its fifth generation. (http://www.taylorshellfish.com)

Justin Taylor's sons, Bill and Paul Taylor, and their brother-in-law Jeff Pearson now direct the activities of the largest producer of farmed shellfish in the United States. They manage growing operations in Washington State and British Columbia, Canada, and seed production operations in California and Kona, Hawaii. They also own a wholesale and distribution operation in Hong Kong, and four restaurants and oyster bars in Seattle and Shelton, Washington, and a pearl oyster farm in Fiji.

TSF employs about 700 staff: 550 in the U.S., 80 in British Columbia, and 45 in Hong Kong. In all, they own and farm about 4,450 hectares.

In the early 1990s, over half of the Company's revenue resulted from the sales of manila clams (*Ruditapes*

Fig. 2: TSF harvest/dive boat built by TSF. *Photo by Brian Omdahl*

phillipinarum), slightly less than half resulted from oysters (primarily Pacifics (*Crassostrea gigas)*, and a small fraction came from Mediterranean mussels (*Mytilus galloprovincialis*). Shucked Pacific oysters accounted for about 95 percent of these oyster sales, with about five percent sold as half shell oysters for raw consumption or other specialty "top off" presentation.

In 2014, annual Company revenues exceeded $60 M USD. Oysters topped the list of sales revenue (45%), manila clams were second (25%), geoduck clams third (15%), mussels fourth (10%) and seed sales fifth (5%). Specialty half shell oysters, both live and frozen in the shell, make up about 80 percent of oyster sales, and less than 20 percent of sales come from shucked Pacific oysters. In all, over 36 M oysters were sold in the shell, and about 20 M were shucked and sold as meat. Other bivalve products tip the scales at: Manila clams- 5M pounds (2270 MT); geoduck- 1 M pounds (450 MT); and mussels- 1.5 M pounds (680 MT).

The change from shucked to half-shell oyster production reflects advancements in the shellfish industry and a response to what the domestic and broader world markets prefer. Other important changes come from new growing methods and greatly improved mechanization and harvest equipment, including large vessels that the company designs and now builds. (Figure 2)

Another important change in the industry, which TSF has embraced and in many cases pioneered, is the production of high quality single oyster seed for a variety of species in shellfish hatchery and nursery systems employing various grow-out methods.

Hatchery and nursery Innovations

In 1989 TSF built their first major shellfish hatchery on Quilcene Bay on Hood Canal. An early emphasis for the hatchery was manila clam seed, since wild sets in important growing areas were sporadic. Keeping markets strong for manila clams requires certainty in seed availability and exceptionally clean growing waters.

Soon, the Company improved hatchery production of other bivalve species, which coincided with an upswing in demand for half shell oysters, specifically for the Pacific (*Crassostrea gigas*) oyster, the native Olympia (*Ostrea lurida*), the European Flat (*O. edulis*), the Kumamoto (*C. sikamea*), and the Eastern oyster (*C. virginica*). Modifications in hatchery practices led to successful rearing and setting larvae of these species, as well as Mediterranean mussels and the native giant clam species, the geoduck (*Panopea generosa*).

Another benefit of the hatchery results from an ability to produce a sterile triploid oyster. This allows high quality oysters to be harvested and marketed year-round.

As the hatchery successfully produced high quality seed, a need developed for an intermediate step to raise juvenile post-set bivalves before planting directly onto beaches or into bags or on racks on beaches. This intermediate juvenile rearing method, termed a Floating Upwelling System (or "FLUPSY") helped increase size and survival of juvenile stages before out-planting of animals and later harvest. (Figure 3)

Another pioneering breakthrough came when TSF ventured across the Pacific Ocean to Kona, Hawaii to benefit from ideal water and abundant sunshine to grow algae as food for early shellfish life stages. Since setting-sized bivalve larvae were easily flown to Hawaii from Washington State hatcheries, the new facility in Kona was ideal to raise young seed to a larger size that capitalized on the exceptional conditions there during Washington State's the winter season.

Flying small seed back to the Northwest proved highly feasible, and allowed TSF and other growers to get a jump start on the early spring growth in bays and inlets up and down the coast for a variety of half shell oysters and clams. Further refinement in FLUPSY

Floating upwelling system for young seed. Top left: float with rainbow in background *Photo: Steve Jones*. Top right: seed sorter in operation *Photo: Bill Dewey*. Below: longer view of FLUPSY *Photo: Duane Fagergren*

technology allows growers to use native plankton growing in productive bays and inlets, such as South Sound's Oakland Bay near Shelton. The seed could be economically raised to various screened, uniform sizes for out-planting.

Advances in Grow-out Technology expand opportunities

Early introduction of rack and bag culture began in the 1970s in Willapa Bay, pioneered by Dr. Randy Shuman of Shoalwater Bay Oyster Company. This method originated in France, but its use in Washington State was possible as a result of single oyster seed becoming available from Kuiper's Hatchery in California. Use of this culture technique also opened a new way to look at otherwise unusable tidelands that were too soft and muddy, or riddled with burrowing shrimp that tend to smother oysters grown by typical on-bottom methods.

This early innovation led to more efficient and economical growing methods. John Lentz (1955-2014) of Chelsea Farms (http://www.chelseafarmsllc.com) was one of the early pioneers in experimenting with modified bag culture to "flip" the bags on most tide exchanges. (Figure 4) This method employs a fixed

Fig. 4: TSF Flip bag culture in Samish Bay, WA *Photo: Duane Fagergren*

continued on page 32

Fig. 5: Bag grown- "Shigoku" oysters on ice. *Photo: Bill Dewey*

Fig. 6: Geoduck intertidal harvest. *Photo: TSF staff*

ground line that is suspended above the bottom, with one side of the bag affixed to the line, and a float tied to the opposite side of the bag that raises and lowers with tidal exchanges.

This tide-flipping process serves two very important purposes: it keeps oysters tumbled in the bag, so singles remain singles, and it also rounds the shell margins of Pacific oysters, which is attractive to chefs and consumers alike. The oyster shells become deeply cupped, meats are full, and market size is achieved more quickly than oysters on the ground or in bags that need to be physically handled.

TSF and Chelsea Farms among other oyster growers use this method in several of their growing areas. TSF patented a company name, "Shigoku" (Jananese translation: "Ultimate") identifying their unique specialty half-shell product. This oyster is highly prized by chefs domestically and overseas. Similarly TSF's "Totten Inlet Virginicas" earned high acclaim and won blind taste tests on the East Coast of the U.S., where this species is native. (Figure 5)

Pioneers and Innovators in Intertidal Geoduck Culture

Historically, a robust commercial diving industry, involving both Native American and non-tribal divers, harvested wild geoduck. This giant clam, native to the West Coast of North America, grows in large numbers in subtidal areas of Puget Sound. These subtidal areas are managed and regulated by the state Department of Natural Resources limiting harvest in a depth zone from minus 10 meters to minus 25 meters. Divers harvest about 5 M pounds (2300 MT) annually in Puget Sound.

By the mid 1990s, TSF began producing geoduck seed from its Quilcene hatchery. In 1996, they planted their first commercial crop on a few of their lower intertidal areas with suitable substrate and tidal elevation.

A few years ago, TSF and other farms realized one life-stage limited the overall viability of geoduck culture. Between the hatchery stage and planting size, small juvenile seed significantly benefited from a few months in sandy substrate before they were transplanted to the beaches for final grow-out.

TSF turned to their internal engineering services and fabrication plant to develop a high tech floating system, with a traveling hydraulic framework of trays filled with sandy substrate for the geoduck to grow. The trays can be vertically lifted from the water for easy access at any tide stage (See photo on page 30). After a few month living in this system, the juvenile geoducks attain a size of 30-50 mm at which point they are washed from the sand-filled trays and out-planted to lower intertidal beaches in Puget Sound where ideal water quality, substrate and tidal elevation coincide.

To improve survival, workers plant juvenile seed inside 20 cm diameter PVC tubes that provide safety for the juvenile seed before it digs down to depths of almost a meter. The tubes are typically removed after about 18-months; clams reach market size of ~ 1kg in about 5-8 years total. (Figure 6)

Challenges and Proactive Approaches for the Shellfish Industry

The Pacific Shellfish Growers Association (http://www.pcsga.org) leads the shellfish industry in engaging in public policy discussions at local, state and federal levels on topics such as shoreline management and development and environmentally protective agriculture practices.

Based on delegated federal authority, the Washington Department of Health Shellfish and Water Protection Program closely monitors, regulates and manages shellfish growing waters for bacteria and biotoxin with assistance from local (county) health departments so depuration is unnecessary. DOH works with the industry to regulate other safe storage, processing, and shipping procedures to protect public health.

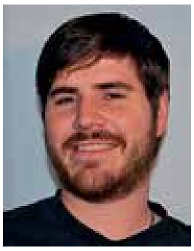
TSF and the entire shellfish industry contributes greatly to other topics of increasing importance:

- Ocean Acidification (OA) and hatchery methodology to mitigate the effects of OA

continued on page 36

EUROPEAN PERCID FISH CULTURE (EPFC) WORKSHOP 2014 – SUMMARY

BY FABIAN SCHÄFER[1], TOMAS POLICAR[2] AND STEFAN TEERLINCK[3]
WITH A COMMENT BY STEFAN MEYER[4]

1


2


3


4


The third workshop of the European Percid Fish Culture (EPFC) thematic group within EAS was held on October 14th 2014 in San Sebastian. This year's topic was "Genetic improvement approaches in percid fish & country experiences in percid culture"

The workshop attracted 71 participants from all over Europe, including a considerable number of participants with a background in primary production of pikeperch and perch, as well as scientists from applied research institutes. In total, eight presentations were given within the two workshop topic areas. The initial ice-breaker and the coffee break proved to be lively opportunity to chat and network.

All presentations can be downloaded from the EPFC website: www.epfc.net

1. **Genetic improvement approaches in percid fish**
   1.1. **Selective breeding of fish for dummies**
   1.2. **Design of a practical breeding program for pikeperch in the Netherlands**
   1.3. **DIVERSIFY project and pikeperch related activities**
   1.4. **A cost action proposal to provide a meeting point for European initiatives on emerging aquaculture species**

2. **Development of Commercial Percid Culture – Country Experiences**
   2.1. **New percids hatchery: Project PERCAFRANCE**
   2.2. **Perch production in Ireland, a success, but what next?**
   2.3. **Is Turkey a good place to produce pikeperch?**

1. Genetic Improvement Approaches in Percid Fish

1.1. *Selective breeding of fish for dummies (M. Vandeputte)*

Marc Vandeputte (INRA, FR) opened the session with an overview presentation on the origins of domestication of poultry, cattle and pigs, highlighting the aims and underlying mechanisms of selective breeding. Following this historic overview, the presentation was oriented along the lines of questions starting with "Which trait(s) to improve?" and the according evaluation methodology. Secondly, Marc highlighted the threat of inbreeding and how it can be avoided. As recommendation, only a high number of broodstock (minimum 50+, better 100+ or even 200+ animals, with higher numbers necessary for selected populations) with an equal sex ratio effectively minimizes inbreeding. In this context, the introduction of "new blood" to the stock needs to be seen as a consequence of failure, not as a solution. It will be necessary to share the effort of keeping different populations over a period of several years in order to achieve progress. Next up, Marc outlined different breeding types such as individual selection, Norwegian family-based and French genotype-based schemes. He also addressed the obstacles coming along with the thorough implementation

continued on page 34

of a breeding program, such as the costs (private and/or public investment) and the necessity of combined, long-term (years to decades) efforts by scientists and farmers. He concluded by emphasizing that economy is the key to sustained investment and hence any breeding program needs to achieve economically relevant goals. Until its return of investment though, the costs for such a program need to be compensated by an appropriate model of cooperation and research.

1.2. *Design of a practical breeding program for pikeperch in the Netherlands (R. Blonk, A. Kamstra, H. Komen)*

Andries Kamstra (IMARES, NL) gave an overview of the main bottlenecks for pikeperch production in the Netherlands. At present, there are several grow-out farms, but only very few hatcheries either producing fingerlings in pond or RAS-based production. Andries pointed out that pond-raised fingerlings are typically well conditioned and exhibit a good quality in terms of malformation and swim bladder inflation. But due to their very limited seasonal availability (typically only once per year) this source is insufficient for a year-round RAS-production. Opposed to this, RAS-fingerlings are generally available year-round as off-season induction is no longer considered a major issue, but quality can be quite erratic and variable between batches. This unfavorable situation is likely to be caused by the lack of structured breeding programs possibly accompanied by suboptimal production protocols. Therefore, to improve this situation a breeding program is needed, which addresses questions regarding the specific rearing environment (pond/RAS) and respective selective pressure of the environment.

1.3. *DIVERSIFY project and pikeperch related activities (P. Fontaine)*

The DIVERSIFY program is a European FP7 project aiming towards "Exploring the biological and socio-economic potential of new or emerging candidate fish species for expansion of the European aquaculture industry". It started in December 2013, will run for 5 years, includes 31 partners in 10 countries and a budget of 9 M€. 10% of the budget is reserved for pikeperch as one of the six targeted species. The pikeperch relevant workpackages include reproduction & genetics (genetic variability in RAS broodstock and comparison to wild fish to define a genetic breeding program), nutrition (first feeding, enrichment products), larval rearing (protocol optimization, cannibalism), grow out (stress, immune & physiological status, domestication) and socioeconomics (product development, market strategies etc.). Regarding pikeperch genetics, the objectives are designed to avoid the loss of genetic variability and to maintain the potential of adaptation. Over 1000 samples have been collected so far that will be analyzed for population genetics parameters.

1.4. *A COST action proposal to provide a meeting point for European initiatives on emerging aquaculture species (N. Duncan)*

Neil Duncan from IRTA (ES) presented general information related to previous COST action proposal entitled "Realising the potential of production of new aquaculture finfish species in Europe through collaboration in scientific and technological innovation (NEWFINFISH)", which was not positively evaluated during past project call. Neil added other useful information and ideas for preparation of a new COST project proposal related to aquaculture of emerging species in Europe, where percid fish should be included such as interesting and promising fish species for diversification and new development of European inland aquaculture sector. The added value of a COST network, besides promotion of exchange and mobility among the scientific community, is the opportunity

---

Workshop announcement:

Big is beautiful – isn't it?

Upscaling of percid fish culture in Europe

Organized by the European Percid Fish Culture (EPFC) thematic group on the culture of **pikeperch, perch and other species of the family percidae** for human consumption, stocking and conservation.

Topic-related contributions are invited from all fields of technology, biology, market and supply chain research as well as case study reports and investment models.

The scope of the workshop is to bring together percid fish aquaculture insiders and experts from continental Europe and other regions and to provide a basis for exchange on industry and research relevant topics.

Costs: **FREE workshop participation** for registered Aquaculture Europe conference delegates
Date: **20th October 2015**, 13-17 PM
Venue: **De Doelen Congress Centre, Rotterdam, Netherlands**

Please **register** no later than **15th September** by sending an email to info@epfc.net

More info can be found on www.easonline.org and www.epfc.net

"BIG IS BEAUTIFUL – ISN'T IT?": UPSCALING OF PERCID FISH PRODUCTION IN EUROPE

A COMMENT BY **STEFAN MEYER** FOUNDING MEMBER OF EPFC

The European Percid Fish Culture (EPFC) thematic group was established in 2012 and since then built an ever growing network of scientists and practitioners from all over Europe. It is a pleasure to see that EPFC has managed to sustain itself for this time period despite a very limited budget. This was (and still is) only possible due to substantial voluntary input from many active members. A big Thank You to all who contributed and still contribute to this success! EPFC will continue in this direction and will do its best to provide an added value for all participants and the sector.

In my opinion, pikeperch and perch truly are THE aquaculture diversification species for continental Europe. Both species are well-known from their fisheries and extensive production background and both of them exhibit a great biological potential for production in larger and more intense systems (e.g. RAS, split pond, etc.). There are definitely still a lot of bottlenecks that need to be overcome before "the big breakthrough", i.e. leaving the candidate-status behind and becoming fully grown and established European aquaculture species. Genetics and breeding (topics addressed in 2014 edition of the EPFC workshop), cost reduction and market access among other technical and biological obstacles (previous and future workshops) will be addressed and solved in the near future. It just has to be like that, because there are so many extremely well qualified and determined people working on it. So let's assume for a minute that percids will have their major breakthrough within the next five years' time…

…what happens then? What is the consequence of growing out of the candidate-status and becoming a fully renown and established aquaculture species? I have ambiguous associations with this thought: Consolidation to key players? Vertical integration from broodstock to ready product? Large RAS farms all over the place? Or is "big" not the only way forward? Will we see also alternative production methods? And is there still a niche for traditional extensive pond production? Nobody can tell at the moment! But it is certainly worth thinking about it.

EPFC therefore invites everyone from the percid sector to share his/her personal thoughts and prepositions for the future of the sector in the next EPFC workshop entitled "Big is beautiful – isn't it?: Upscaling of percid fish production in Europe". Topic-related contributions are invited from all fields of technology, biology, market and supply chain research as well as case study reports and investment models. Participation will be free of charge, but a registration is mandatory. The workshop will take place on the registration day of Aquaculture Europe in Rotterdam, Tuesday, 20th October 2015, from 13 – 17 pm. Please register yourself by sending an email to info@epfc.net and check www.epfc.net for regular updates.

also for SMEs and other industry-based stakeholders to get involved in training activities and workshops and to influence the main fields of research in the respective field.

2. Development of Commercial Percid Culture – Country Experiences

2.1. *New percids hatchery: Project PERCAFRANCE (J. Saint-Sevin)*

Located in Northern France, PERCAFRANCE owner Julien Saint-Sevin has built up a hatchery for perch and pikeperch in 2014 based on a former ornamental fish farm. The farm features a 500 m^2 production unit, seven temperature and light controlled rooms and an effluent control to ensure sustainable production. The presentation highlighted important aspects to consider when starting a company in the percid sector. In Julien's opinion, ambitious production volumes and high expected retail prices are likely to put an early end to such start-ups. PERCAFRANCE is set to serve different markets (e.g., fingerling and filet production) and in addition is offering a range of services regarding RAS farms with a focus on percids. At present, both species are being reproduced twice per year. Finally, Julien summarized the bottlenecks the production is facing and highlighted differences in-between the species, with pikeperch being more susceptible to stress and cannibalism, while size homogeneity, gamete quality and survival rate are smaller issues than in perch.

2.2. *Perch production in Ireland, a success, but what next? (D. Toner)*

Serving mainly Swiss markets, pond-based perch production has been quite a success in Ireland, as Damien Toner (BIM, IE) points out. To further improve this, ongoing work is dedicated to a genetic approach in order to quantify and map levels of variation within the species across Europe and to test if growth might be improved by selective breeding measures. First results from in total 100 fast/slow growing fish are promising, revealing a good potential for selection. For example, it was possible to detect two out of eight perch "families" with fast growing offspring. Damien underlined the necessity of an increased efficiency of perch production in Ireland with reduction of production cost and provision of stable marketable perch production. Damien presented one possibility how to achieve this aim - using the split pond system as a tool for effective and stable perch production in Ireland. In such a system, fish are kept in only a small compartment of a larger, semi-artificial pond and herewith combine intensive production and the benefits of a large water body. Future testing of this system is necessary in practice for future wide use in perch commercial farms.

continued on page 36

2.3. Is Turkey a good place to produce pikeperch? (T. Bodur)

Türker Bodur from Akdeniz University in Antalya (TR) presented the current status of freshwater fish production, the history and present state of pikeperch fishing and possible future developments regarding this species in Turkey. With trout being the major fish species produced in Turkey in over 1200 enterprises, more than 280 of which produce over 500 t per year, and carp being another freshwater species of less importance, percid fish may be a promising addition. Pikeperch have been introduced in large numbers already during the 1950s and today can be found in several lakes and basins almost all over the country, where they are fished commercially. Especially Eğirdir Lake and Beyşehir Lake in South-West Turkey are promising production locations for pikeperch, due to an existing infrastructure including 15 fish processing plants, 2 fisheries faculties and 2 research institutes in this region.

3. Conclusion and final remarks

Generally a high interest in participating in the EPFC workshop was recorded including a rich discussion among participants. Again EPFC thematic group obtained new members and their interest to work within EPFC thematic group. New information or plans about percid production progress in France, Ireland and Turkey was spread during the EPFC workshop. Basic information about current research and development work of workshop participants related to reproduction, hatchery operation, larval and juvenile culture, production of ongrowing and marketable fish including fish quality in perch and pikeperch were extended and discussed among all active partners. During this fruitful discussion, joint request arose to propose and established new European active COST project related to percid fish, which should associate all research and production partners interested in percid fish in Europe. The aim of this activity is better coordination of research and development of percid aquaculture and market sector in Europe which has generally high socio- economic potential. ■

ORGANIC TROUT OVA/FRY ALSO AVAILABLE FROM DANISH HATCHERIES

continued from page 27

Stress and RTFS tests are going to be performed to investigate if these two factors can be included in strategies to increase the robustness of the fry. Further, the effect on health and welfare of water treatments using approved agents in organic aquaculture are tested. However, the outcome of RobustFish can as well improve the productivity of the conventional trout farming by lower prevalence of RTFS, reduced medication and lower environmental impact.

The perspectives of the RobustFish project is that Danish organic hatcheries will be able to produce even stronger more healthy and stress resilient organic trout fry to underpin increased European organic trout production.

The project is carried out in cooperation between Technical University of Denmark (DTU Aqua and DTU Vet), University of Copenhagen (Dep. of Food & Resource Economics), University of Aalborg (Dep. of Development and Planning) and The Danish Aquaculture Organisation.

RobustFish is part of the Organic RDD 2 programme, which is coordinated by International Centre for Research in Organic Food Systems (ICROFS). It has received grants from the Green Growth and Development programme (GUDP) under the Danish Ministry of Food, Agriculture and Fisheries. ■

DEVELOPMENTS IN SHELLFISH CULTURE IN WASHINGTON, U.S.

continued from page 32

- Third-party certification of sustainable seafood,
- Advocacy for monitoring and research of water quality,
- Ecosystem services provided by shellfish,
- Brood stock development and disease resistance,
- Regulations, model ordinances and best practices related to naturally-occurring pathogens, such as *Vibro parahaemoliticus*.

Geoduck juvenile seed ready to plant.
Photo by Brian Phipps

A current challenge facing the industry is the public perception that standard practices used by the industry are harmful to the environment. A small, but very vocal and well-organized group of opponents fight what they perceive as "industrialization" of the tidelands. Opponents target the most visible activities such as mussel and geoduck nursery rafts and intertidal geoduck PVC tubes. An expanding universe of regulations at the federal, state and local levels also challenges growers in all Pacific Coastal states.

Despite these challenges, the Pacific Shellfish Growers Association remains positive and hopeful about the growth in demand for quality seafood that farmed shellfish can satisfy. ■

Nucleated pearl production in *Pteria penguin* and *Pinctada margaritifera* with onshore culture in India

AJAI KUMAR SONKAR

An independent research project to produce pearls in marine waters with black lipped pearl oysters were initiated in early 2003 in Andaman and Nicobar Islands. Numerous batches of experiments were undertaken and huge numbers of different shapes and sizes of pearls are produced in locally available specie of pearl oyster *Pinctada margaritfera.*

A big natural stock of oysters were available in at the seaward side of the project.

In the floating rafts numbers of cages were hung with the ropes, and it was very encouraging to observe that numerous spats were settled on the underwater installations including ropes and cages. most interestingly the spats of *Pteria penguin* were also settling with almost same density as black-lipped oysters *P. margaritifera.*

Here we had been producing pearls in *Pinctada margaritifera* with high efficiency, but these wing oysters which were available plenty were not utilized to produce pearls, however these oysters are very big in size and interior of the shells are exceptionally lustrous and vibrant in colours. (Pic-6)

NEW TECHNOLOGY:

Initially experiments carried out to explore the possibilities to produce blister pearls in *Pteria penguin.* For which different shapes including semi spherical nuclei were designed and fabricated. in the series of experiments we implanted 42 mm size of Ganesha shape of nuclei below the mantle of the oysters. These nuclei were cut and carved from the thick portion of shells of edible rock oysters(Pic-1)).

P. penguin formed very nice Ganesha image pearls (Pic-2) and the same time during the implantation a natural free pearl encounters in *Pteria penguin* (Pic-3), the size and quality of the natural pearl gave a hope that the free nucleated pearls can be cultured in this species. This natural pearl had opened the new road of experiments to introduce nuclei in new locations other than gonad region.

Several experiments to introduce foreign body in different locations were carried out, and recently breakthrough came when one experiment got success to produce free nucleated pearls, most importantly in *Pteria penguin* which is usually not know as the specie produce nucleated cultured pearls. (pic-4), this way a most advanced technique to produce free nucleated pearls in *Pteria penguin* has been developed.

THE CHALLENGES:

The tsunami in 2004 destroyed all the setup of pearl culture including seaward side floating installations situated at North Bay, South Andaman. The land at the Project site sank more than a meter, which reduced the intertidal area; now the major portion of the area was under water during low tide. We were having more shallow sea bottom to place the oyster cages. However, an unwelcome occurrence changed everything.

It was observed that the behaviour of some fishes had changed after tsunami. The parrot fishes (*Scarus ceruleus)* had started preying on the shells of the oysters. It was hard to believe that they were preying on the oysters because they had always been there with the oysters below the floating rafts, but had never harmed them before.

Investigation revealed that Tsunami not only destroyed the corals but buried them below the sand carried from the depths, causing a food constraint for the parrot fishes as they used to feed on the algae within the coral polyps. The parrot fishes then started preying on the available shellfish there such as pearl and rock oysters. The most Productive harbour North Bay was no longer safe for the oysters as a new killer was in the water. From the initial stage itself, they were preyed upon by the parrot fishes.

The crisis created a very adverse situation for the project, now we had to find some way to protect our oysters in the sea and to explore the possibility to rear operated pearl oysters out of sea with onshore culture technique. On the one hand we experimented different cages at seaward side which could provide protection from the new predator, (pic-5) and on the other other hand experimented to rear several batches of oysters onshore with various parameters to determine the most suitable environmental conditions.

ONSHORE CULTURE STUDY:

Four batches of oysters were maintained in fiberglass conical tanks of capacity 2000 lit each. One biological filter of 1200 lit/hour filtration capacity was installed in each tank. The bottom was fully covered with calcified stones conically so that wastes and discharges of the oysters could be gathered at the central drain of the conical bottom. Aerators and wave maker devices were installed in each tank.

Sixty oysters were then scattered over the bottom of each of the four tanks in this way, a total of 240 oysters which were grafted and implanted with 6mm nuclei, were reared in the four tanks. The parameters of each tank are shown in table 1. A microalgal culture unit was set up to culture *Nanochloropsis salina, Chaetoceros calcitrans and Isochrysis galbana* for the feeding of the oysters. Oysters were fed periodically at 50 000 cells/ml. Algal culture was done using two different protocols, one with Walne medium and the other without using medium but with only filtered and autoclaved seawater being used.

continued on page 38

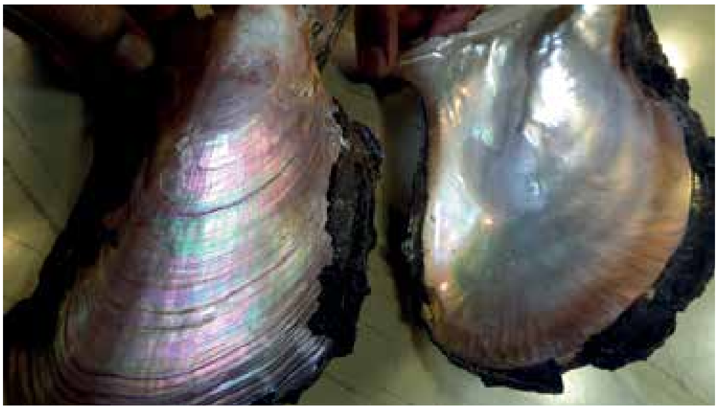
Pic 1: Nuclei in the shape of Lord Ganesha.

Pic 2: Pearls produced in Pteria penguin.

Pteria penguin.

Pic 3: Natural pearl from Pteria penguin.

Above and left, Pic 5: cages of oysters in protecting net



Pic 6: color and lustre of the shell of Pteria penguin

Oysters in batches 1, 3 and 4 were fed with the algae cultured with Walne medium protocol while in batch 2 the algae were cultured without the medium. However, no detectable impact was identified due to algal culture method. Ten percent (200 lit) of the water was exchanged daily in batches 1, 2 and 4. The water was biologically filtered before adding to the tank in batches 1, 2 and 3. In batch 4, however, 200 lit of apparently clean natural sea water was added/transferred directly. Water was exchanged daily in batches 1, 2 and 4; however, 500 lit of water was changed in 15 days in batch 4.

Frequent water exchange is required in land-based oyster rearing, the carbonate minerals calcite and aragonite are available in the water in trace amounts; the oyster utilizes these for shell formation and growth by secretion. That is why new aseptic water was added every day to maintain the availability of these trace elements for better pearl formation.

Water chillers were installed in batches 2, 3 and 4 to maintain a uniform temperature range of 20-22°C whereas the temperature of batch 1 was left to natural variation; at night it was about 27°C and in the daytime it was 2-4°C higher.

Ammonia and other contaminants, which were produced by uneaten food and other decaying organic matters, were monitored frequently but since oysters consume nitrogen-containing compounds (nitrates and ammonia), phosphates, plankton, detritus, bacteria and resolved organic matters, no contamination was detected in the water column. Water chemistry was the same in batch 3 in which water was transferred in 15 days.

Wave maker devices were installed in the tanks to create waves to simulate the natural sea environment for the oysters. All the oysters were attached to stones below them as they would be in the natural condition. The waves also helped to mix the micro algae quickly and uniformly.

Biological filters were functioning 18 hours a day, helping to reduce the algal density and remove decaying matters. This reduced the need for entire water exchange. A seawater salinity of over 31 ppt was maintained. The pH of the water was maintained at 8.2 to 8.5. During the whole operation, all four tanks were covered with black poly-sheets to avoid unwanted photosynthesis.

Table 1: Parameters of each batch

Batch	Number of oysters	Density of algal cells (n/ml)	Temp range (Degree Celcius)	Water Transfer
1	60	50000	27-31	200 ltr/day
2	60	50000*	20-22	200 ltr/day
3	60	50000	20-22	500 ltr/15 days
4	60	50000	20-22	200 ltr/day **

**Cultured without medium, **without filtration*

RESULTS AND OBSERVATIONS:

It was observed that aseptic condition of water, optimum algal density and adequate oxygen play important roles in the rearing of the oysters in the tank onshore. However, uniformity of pearl formation and luster of the pearl are determined by water temperature and food quality.

The results of the experiment are shown in Table 2. Survival rate in onshore rearing is very high; there was no mortality in batch 2 and 3. Higher temperature causes poor of the oysters; 27 oysters were dead during 7 months in batch1. Pearl quality was also compromised in this batch. Most of the pearls were dull in luster and formation of pearl sacs was not uniform.

Sixteen oysters were dead in batch4; this indicates that without a filter direct use of seawater is not good enough for onshore pearl oysters. Pearls of the best quality were formed in batches 2 and 3. Batch 3 produced a total of 49 pearls with 11 implantation rejections. Out of 11 rejections, 7 oysters had rejected both nucleus and graft tissue, and 4 contained graft pieces that formed irregular pearls.

Rearing the oysters in the sea under floating raft have several draw backs such as there are several predators of oysters and numerous marine organisms (biofoulants) grow on the shells of the oysters. Some of them bore the shells causing the oysters to repair the shell by secretion. This affects the quality of the pearls. to overcome this problem, oysters and their cages in the sea need to be cleaned very frequently. The cleaning process of scrubbing the outer surface of the shells causes shock to the oysters, affecting the normal formation of pearl. However, in onshore rearing, no such growth on the shell is detected and oysters were not required to be cleaned.

Finally, the results of the experiments indicate the bright scope for mass pearl production with low operational cost. In onshore pearl culture, major expenses are involved in microalgal culture, but when it is done without using medium, the cost goes down substantially. This can open the possibility of producing pearls in any part of coast, although in the conventional pearl culturing operation, a protected harbour is needed, if large expensive pearls are produced onshore, it would be a highly lucrative and environmentally friendly project. ■

Table 2: Results of the experimental onshore culture

Batch	Mortality out of 60 oysters	Pearls formed	Lustre of the Pearls	Uniformity of pearl surface
1	27	9	Mostly poor in lustre	Most had stains and tails
2	0	37	Deep metallic	21 uniform, 16 with tails
3	0	49	Deep metallic	42 clean and uniform, 7 with stains
4	16	22	Deep metallic	7 uniform, 15 with stains

AQUAEXCEL: E-INFRASTRUCTURES AS A TOOL FOR ENHANCING EUROPEAN AQUACULTURE RESEARCH

M. FØRE[1,2], G. SENNESET[1], B. F. TERJESEN[3], E. EDING[4], W. ABBINK[5], A. KAMSTRA[5], M. ALVER[1,2], N. PAPANDROULAKIS[6] AND P. CISAR[7]

MOTIVATION AND BACKGROUND

The European aquaculture industry features a wide variety of species that are produced using very diverse production methods. Consequently, physical infrastructures and laboratories aimed at aquaculture related research tend to be designed for studying a particular species and/or phenomenon in detail rather than covering aquaculture in a broader sense. To achieve the best possible outcome of an experiment, it may therefore in some cases be useful for researchers to conduct their experiments at facilities other than their own if these infrastructures are better suited to study the problem at hand. This has been the main motivation behind the system for Trans National Access (TNA) employed in the AQUAEXCEL-project, where personnel from European research facilities may apply for financial support to cover the costs of conducting experiments at the research infrastructures of participants in the TNA system.

Researchers receiving TNA support will generally be required to set up their experiments themselves, and may need to follow up on the project throughout its execution to ensure that it is progressing as planned. In some cases, it may be practical to travel to the hosting facility both when setting up and monitoring the project. However, this will increase the costs and time consumption associated with travelling in the project, especially if the process needs to be monitored at a regular basis. The main objective of WP 6 in the AQUAEXCEL project is to develop and implement an e-infrastructure system supplying the TNA-system with technical solutions for remote access to research infrastructures within the AQUAEXCEL consortium (Figure 1). Furthermore, the e-infrastructure should be sufficiently flexible to be easily implemented for any additional research infrastructures, and not require large changes in the local systems at the hosting facilities. Potential uses of

[1] SINTEF Fisheries and Aquaculture, AS, NO-7465 Trondheim, Norway

[2] Norwegian University of Science and Technology, Department of Engineering Cybernetics, NO-7491 Trondheim, Norway

[3] Nofima, NO-6600 Sunndalsøra, Norway

[4] Aquaculture and Fisheries Group, Wageningen University, P.O. Box 338, 6700 AH Wageningen, The Netherlands

[5] IMARES Wageningen UR — Institute for Marine Resources and Ecosystem Studies, Department of Aquaculture, P.O. Box 77, 4400 AB Yerseke, The Netherlands

[6] Institute of Aquaculture, Hellenic Centre of Marine Research, Heraklion, Greece

[7] Institute of complex systems, CENAKVA, Faculty of Fisheries and Protection of Waters, University of South Bohemia in České Budějovice, Zámek 136, 373 33 Nové Hrady, Czech Republic

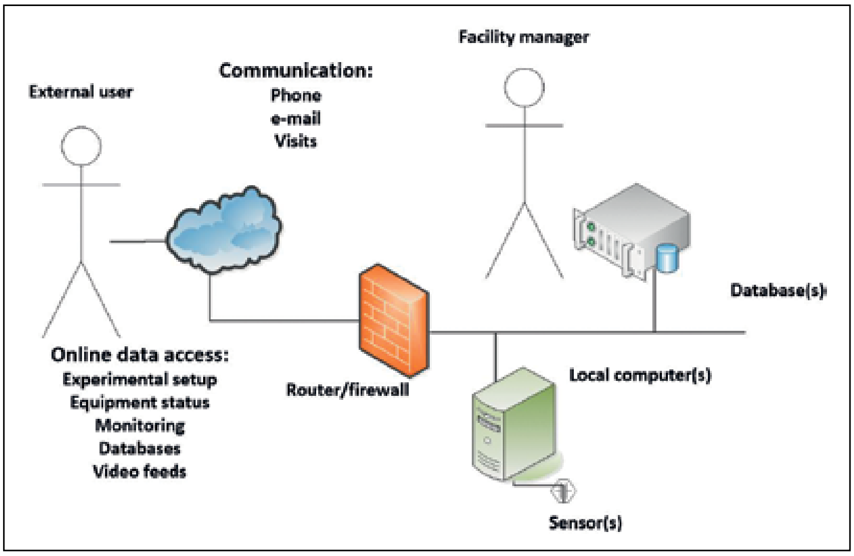


Figure 1: Outline of a generic e-infrastructure system describing how an external user is able to access the resources at a facility through remote operations.

the e-infrastructure system range from active remote control, where the setup, monitoring and manipulation of experiments is conducted through the e-infrastructure, to passive remote monitoring of ongoing experiments.

DEVELOPING THE REQUIREMENT SPECIFICATION

The first step in developing the e-infrastructure system was to conduct a survey among the managers of all 23 research facilities included in the TNA arrangement. Since all TNA facilities were considered eligible candidates for implementation of the e-infrastructure, a full description of the technical infrastructures in all facilities was requested. Furthermore, the managers were queried on which functional requirements and features they would want and expect from an e-infrastructure.

The questionnaire form used in the survey was divided into three segments, the first of which was intended for input on the instruments and systems available at the particular site. Required information in this segment included subjects such as instrumentation type, automation level, data format, user interface and required bandwidth. In the second segment, each respondee had to rate a set of generic use-cases (e.g. video conference, document sharing, version logs, online access for control systems) for the e-infrastructure based on their expected usefulness in cooperative research projects within the consortium. The third segment of the questionnaire was optional, and allowed the managers to describe use-cases specific to their laboratory or research that they would wish the e-infrastructure to support.

A requirement specification for the e-infrastructure was formed based on the aggregated replies from the survey participants. Briefly summarised, the e-infrastructure needed to adhere to a set of main technical requirements:

- Accommodation of a wide range of different technical systems
- Handling of a wide range in bandwidth
- Handling of various data formats

In addition, two groups of functional requirements were identified:

1. Document sharing and version control
    - Version control for procedures and protocols
    - Experimental log
2. On-line access (including user access control)
    - Measurement data
    - Control systems
    - Data analysis applications

These technical requirements were found to cover most of both generic and specific use-cases proposed for the e-infrastructure.

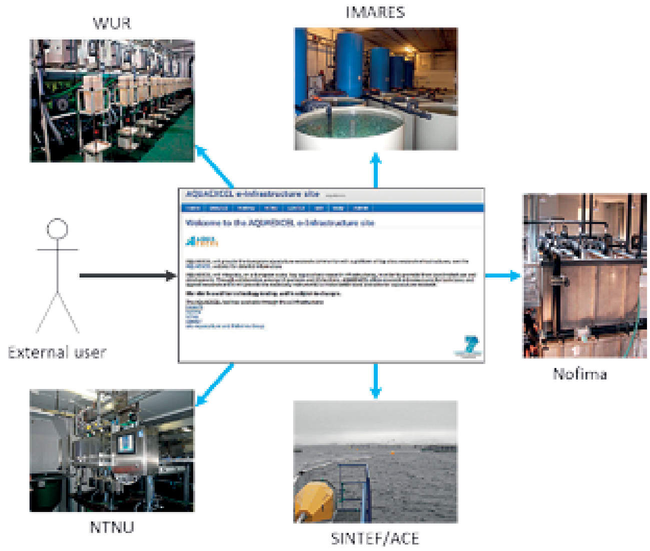


Figure 2: Conceptual description of how a user may access the five pilot research infrastructures through the common web-based portal.

PROTOTYPE DEVELOPMENT AND IMPLEMENTATION

Based on the requirement specification derived from the survey and additional non-functional requirements, a prototype e-infrastructure solution was developed. Due to the high diversity in user interface, required bandwidth and data format, the development of a stand-alone computer application handling all technical requirements while being compatible with all TNA facilities was deemed unrealistic. Consequently, a web-based solution was developed based on a set of main principles:

- Web site (www.wikidot.com) containing guides and links for remote access to facilities (login to the site is required)
- VPN or similar security measures for protecting the local network of each facility, and ensure secure access to the resources at each site
- Internal network security and access to resources at a facility will always be governed by the policies enforced at the hosting organisation/company
- Each facility is responsible for local user administration (providing username/password and access levels), technical solutions for remote access and user training.
- All data from experiments are stored locally at each facility

The prototype e-infrastructure was first implemented for five pilot facilities (DLO-IMARES, Wageningen University, Nofima, NTNU and SINTEF/AquaCulture Engineering AS) with application areas ranging from desk-scale laboratories focused on micro-biology (DLO-IMARES) to an industrial size fish farm with full-scale sea-cages (SINTEF/ACE). All five facilities were made accessible through a common website (Figure 2). During the implementation, the technical solutions used at each facility including eventual changes to local infrastructure necessary to implement

continued on page 42

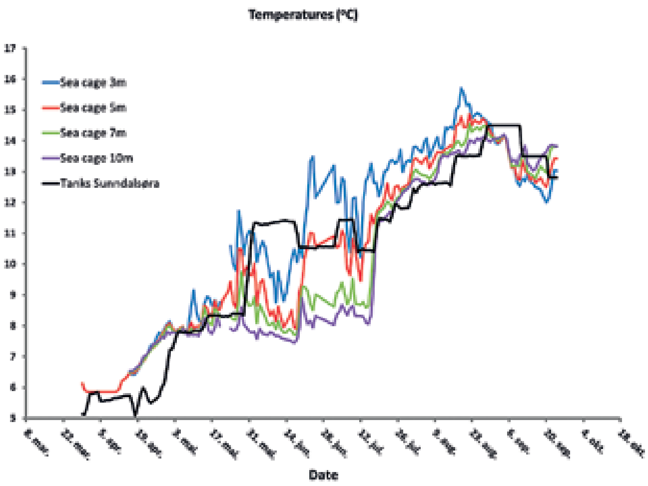


Figure 3: Water temperature during the experiment, both in the indoor tanks at Nofima (black line) and at different depths in the reference sea cage at ACE (blue, red, green and purple). Sea cage temperatures at 5m depth (red line) were used as reference in the tanks. The e-infrastructure facilitated the daily transfer of temperature data from cage to tank, a feature that was essential to enable the adjustment of tank temperatures in accordance with temperatures in the cages.

the e-infrastructure were documented and summarised. Using this as background material, a best-practices guide for implementation of the e-infrastructure was developed. The guide was intended to be a tool when implementing the e-infrastructure for other research infrastructures.

TESTING AND RESULTS

Subsequent to the installation at the five pilot facilities, the e-infrastructure implementations were subjected to user tests. The protocol for testing was derived by reaching a consensus between the WP participants on how the e-infrastructure properties should be tested, and included aspects such as digital security, user friendliness and system time response. Two separate tests were conducted at each facility, the first of which was executed by the partners responsible for implementing the e-infrastructure at the site. The second test was conducted by an external independent expert who had no involvement in the implementation of the e-infrastructure systems at any of the sites. By using the same external expert on all pilot sites, this approach allowed for an objective comparison between the e-infrastructure implementations.

In general, all e-infrastructure implementations were found to pass the testing procedures with no critical issues regarding security or other important subjects being raised. The solutions at all sites were found to implement all the most important functionality for remote monitoring of the experiments on the facilities.

A more practical test of the e-infrastructures was conducted in WP8 in the AQUAEXCEL project where an experiment featuring fish from a common genetic strain and cohort were simultaneously raised in full-scale sea-cages at SINTEF/ACE and indoor lab-scale tanks at Nofima. The main aim of this project was to investigate whether the physical scale (i.e. geometric size) of the production unit had an impact on the performance (i.e. growth and survival) of the fish. To keep conditions as similar as possible within the tanks as in the cages, the e-infrastructures at SINTEF/ACE and Nofima were set to cooperate in such a way that Nofima were able to tune the temperatures in the tanks in accordance with the temperatures measured in the sea-cages (Figure 3). This synchronisation of temperature allowed keeping the conditions at the two sites more similar than would be the case without a functioning e-infrastructure, illustrating how e-infrastructures may contribute to streamline and improve aquaculture research.

CONCLUSION AND FUTURE PROSPECTS

The outcomes from WP 6 in the AQUAEXCEL project have illustrated some of the benefits of introducing e-infrastructures as a tool for aquaculture research. Although aquaculture oriented research infrastructures and laboratories in Europe vary widely in focus area, species, technological level and security, a common web-based platform presenting the requirements and procedures for accessing the infrastructures remotely could represent an important step toward stimulating a higher degree of collaboration between research infrastructures and laboratories across Europe. This potential for collaborative research through e-infrastructures was also directly demonstrated by the conjoined project between SINTEF/ACE and Nofima, in which the e-infrastructure was an essential component. ■

NOFIMA CENTRE FOR RECIRCULATION IN AQUACULTURE (NCRA), A RESEARCH FACILITY FOR THE FUTURE SALMON PRODUCTION METHODS

BENDIK FYHN TERJESEN, SENIOR RESEARCH SCIENTIST,
NOFIMA, NO-6600 SUNNDALSØRA, NORWAY
EMAIL: BENDIK.TERJESEN@NOFIMA.NO

The basis for establishing NCRA

Before the late 80s, a few recirculating aquaculture systems (RAS) were used in Norway mostly to achieve energy savings and production of one-year smolts. In fact, some of the first research on Atlantic salmon smolt production in RAS was done at the Sunndalsøra station in Norway in the early 70s (Aquaculture paper by Risa and Skjervold, 1975). However, in the late 80s, most RAS in Norway was discontinued due to the introduction of heat pumps and exchangers, as well as lack of RAS knowledge and optimal technology. Between the end of the 80s until a few years ago, RAS was little used and flow-through systems dominated. This contrasted the development for other species in Europe and elsewhere, where RAS was used extensively. The lack of use of RAS in Norway was partly due to an abundance of fresh water, and increases in smolt production not covered by water bodies was until the late 2000s handled by oxygenation and in-tank CO_2 stripping. However, a seminal report in mid-2000s led by Arne Kittelsen at Akvaforsk, collaborating with NIVA and SINTEF, concluded that freshwater resources available in Norway would become a seriously limiting factor for future increases in salmon production, and proposed RAS as a long-term solution. Together with initiatives within the industry itself, this led to a dramatic change in technology used for smolt production in Norway. Today, several of the large salmon farming companies only use RAS when building new facilities.
At the time of the report by Kittelsen and collaborators, Akvaforsk found that there was a lack of publicly available information on RAS-specific water quality requirements, production methods, and RAS technology for salmon smolts. Most of the previous research had been done using flow-through systems, but considering the contrasting environment in RAS several aspects of smolt production should be revisited and developed. This formed the basis for the decision made by Akvaforsk in 2007 to establish Nofima Centre for Recirculation in Aquaculture (NCRA), which was opened in 2010.

Design and dimensioning of NCRA

Building a research facility calls for a different approach to that of a commercial production system.

Nofima colleagues Astrid Buran Holan and Reidun Kraugerud Lilleholt in grow-out hall 3 of Nofima Centre for Recirculation in Aquaculture, with RAS for Atlantic salmon postsmolts operated at 12 ppt salinity.
Photo: Terje Aamodt, Nofima.

First out, the research objectives of NCRA dictated the design and dimensioning. It was decided that the primary purpose of NCRA should be to facilitate studies on effects of RAS on the fish and to provide recommendations on how to achieve optimal performance, health and welfare. In addition, the centre should also be used for testing and development of new technology.

NCRA was built with a 1750 m^2 ground area, and a second storey of 550 m2. The centre features six experimental sections and has a total culture volume of 1100 m^3. The facility can use both freshwater and seawater. Cooling water is taken from a nearby hydro power station, and heat from a waste heat circuit (85°C) originating from the large aluminum plant at Sunndalsøra. Two experimental sections contains 15 pcs of 3m3 tanks in each, and a third section has 18 pcs of 0.5m3 tanks. These 48 tanks can use water from two separate medium-scale RAS (50 kg/day feed capacity each), or two other water qualities in flow-through mode. All the four water qualities can be randomly assigned to individual tanks and sections. Further, three large halls have each three 100 m^3 tanks for experiments on a large, near-commercial scale. Two of these sections have separate RAS (300 kg feed/day capacity each), while one section operates as flow-through. Feeding is fully automatic and computer controlled, and light regimes in all six sections can be programmed separately. In total, this means that an experiment can study several factors at the same time, e.g. both RAS water quality, tank-level factors (e.g. fish density, feeding, water velocity), and light-regime.

As is evident, a much larger scale approach was chosen for NCRA, compared to many existing research facilities. This was fully intended, and was done to achieve more realistic salmon production conditions, which is essential when research results are to be applied in the industry. At the time there was also anecdotal evidence that larger scale tanks improve growth rate, which was critical, since nutritional and environmental requirements of salmon can be affected by growth rate. Effects of tank scale was the focus of a work package in the recent EU-infrastructure research project, AquaExcel. In WP8, led by Nofima, it was indeed found that growth rate correlated positively with tank scale, such that the final weight of postsmolts became largest when reared in 100m3 > 3m3 > 1m3

continued on page 44

tanks. In parallel, a study was done in industrial scale sea cages, using fish of the same origin, and similar feed batches and temperature. It was found that postsmolts in the 100m3 and 2m3 in NCRA performed as well, or better than the cage reference, while fish in the 1m3 tanks showed inferior performance.

However, the large-scale approach in NCRA also had the consequence that fewer separate RAS could be built within the budget. For tank-level studies, a single-RAS experimental design may be best. However, when studying system-level questions, e.g. biofilter type, few replicate RAS are available using a large scale facility approach. This has however, been solved using other types of replication, which was for instance used in a recently published study done in NCRA on optimal RAS alkalinity for smolt production.
Since opening of the centre in 2010, NCRA has been used extensively, and the experience has in general been good. The RAS are robust, and during maximal load tests (kg feed/day) they have performed to specifications or above. There are always things to improve however, and the automation and sensor level has been much focused on. In particular, maintenance of sensor surfaces is important, and Nofima and collaborators have designed automatic probe cleaning systems. NCRA is continuously being improved, and recent plans concerns better automation as well as logistical solutions for experimental fish and feed transfer.

Research projects and future plans in NCRA

The research in NCRA since 2010 has been funded by several sources, including industry, EU, the Research Council of Norway (RCN), and The Norwegian Seafood Research Fund. During the EU-project AquaExcel, NCRA was one of the 23 selected research facilities in Europe open for transnational access (TNA), in which basic costs for experiments was funded by EU for researchers outside Norway. NCRA has been much used in TNA, such as for studies on fish monitoring systems and water treatment equipment.

During the two first years of operation, the projects mostly concerned methods and technology for freshwater smolt production in RAS. However, this quickly changed, and several experiments since 2012 have concerned rearing methods and technology for postsmolts. This was due to the several issues facing salmon farming, such as sea lice, escapees and sea phase fish mortality. Through the project OPP, funded by industry partners and RCN, two solutions to these problems were investigated, either production of postsmolts to 1 kg on-land in RAS or in floating semi-closed systems in the sea. Reducing the time salmon spend in open sea cages may reduce the problems with sea lice. Further, of the smolts stocked in sea cages, 16% on average are lost before harvest. Producing a larger and more robust postsmolt at 1 kg for stocking in sea cages, may improve sea cage survival and growth. In OPP, the optimal strategy for production of large postsmolts in RAS was studied in NCRA. Use of full-strength seawater RAS may give higher operating costs compared to freshwater/brackish water RAS, due to the lower efficiency of CO2 and ammonia removal in full-strength seawater. Thus, it was hypothesized that

Nofima Sunndalsøra aquaculture research station in North-western Norway. Nofima Centre for Recirculation in Aquaculture is the largest building in the middle of the picture, closest to the mountain behind (with peak at 1880 m above sea level). *Photo: Kjell J. Merok, Nofima.*

The central water treatment hall in Nofima Centre for Recirculation in Aquaculture, showing parts of RAS1 and RAS2 medium-scale research systems. *Photo: Kjell J. Merok, Nofima.*

producing postsmolts in lower salinity water could be a cost-efficient solution, if fish performance and health was not compromised. Exercise through increased water velocity improve growth rate and robustness of earlier salmon life stages. In OPP the combined effects of salinity and exercise was therefore studied. The results indicated that a salinity of 12 ‰ and a water velocity of 1.3 body lengths per second have a positive effect on water treatment efficiency, and salmon growth, feed conversion, and skin health in RAS. Using brackish water can be a cost-efficient strategy for postsmolt production, and the results may also be applicable to land-based production of salmon to harvest size.

Recently, Nofima was one of the 17 Norwegian research institutions to become hosts for Centres for Research-based Innovation (SFI), funded by the Research Council of Norway. The selected centres were distributed across all scientific disciplines and industry sectors. The overall objective of the 8-year long SFI program is to enhance the ability of the Norwegian business sector to innovate through close collaboration between leading industry and research institutions. The centre which Nofima hosts, CtrlAQUA (Centre for Research-based Innovations in Controlled-environment Aquaculture), is to contribute to solving some of the main challenges facing the salmon industry, such as sea lice and fish mortality. The overall goal of CtrlAQUA is to develop technological and biological innovations to make closed-containment aquaculture systems a reliable and economically viable technology, for use in strategic parts of the Atlantic salmon production cycle. NCRA will be a much used research facility for experiments in the RAS-part of CtrlAQUA. The 20-member strong CtrlAQUA consortium with 14 industry partners and six R&D partners, will from autumn 2015 and for the next 8 years focus on innovations in closed-containment aquaculture, to contribute towards a sustainable growth of Atlantic salmon farming. ■

AQUACULTURE MEETINGS

Direct links, brochures, registration form etc are linked to this information in the EAS website calendar module

This AQUACULTURE MEETINGS calendar is a summary of the new events module of the EAS web site...

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.

MARCH 2015

Aquafeed Extrusion Technology - Short course
Centre for Feed Technology (FôrTek), Ås, Norway, March 25-27, 2015
This 3-day course covers the principles of extrusion, the design of extrusion processes, and the formulation of extruded aquafeeds. Principles learned will be demonstrated using the extruder in the Centre for Feed Technology pilot plant.
Email: email training@foodstream.com.au.
Web: www.foodstream.com.au/events.

APRIL 2015

Towards sustainable aquaculture in the Middle East
Dubai World Trade Centre, April 5-6, 2015
The Middle East Aquaculture Forum (MEAF) has been created to bring together aquaculture industry experts and academics from the Middle East, to showcase the latest products and offer industry professionals a state-of-the-art platform to interact. The Organizing Committee would like to invite all ME producers/farmers, suppliers, and other industry professionals to the DWTC, Dubai, UAE to attend this unique forum.
Info at: http://www.meaf.ae/. Email: info@meaf.ae

European Algae Biomass
Amsterdam, The Netherlands, April 22-23, 2015
The conference will have a heavy focus on case study examples of latest technologies in operation in the global algae industry. Discuss the technical challenges faced when optimising the cultivation of algae.
Study the current and future commercial markets for algae products and the challenges faced during the commercialization process including the views from three different end markets.
Info at: http://www.wplgroup.com/aci/conferences/eu-eal5.asp

XXII Conference of the EAFE (European Association of Fisheries Economists)
Salerno, Italy, April 28-30, 2015
"New management issues within the reformed Common Fishery Policy: implementation and socio-economic impacts"
The conference is intended to provide a forum for the dissemination of recent advances in capture fisheries and aquaculture economics and management and to promote discussion amongst researchers, managers, policy makers and other stakeholders in the fisheries sector. The conference also aims to contribute to the ongoing discussion within the review of the Common Fishery Policy.
Contact Email: eafe2015@unisa.it;
Website: http://www.eafe2015.unisa.it/

MAY 2015

Scientific Symposium 2015 - Tools for Assessing Status of European Aquatic Ecosystems
Malmö, Sweden, May 6-7, 2015
The symposium brings together scientists and environmental managers to present and discuss state-of-the-art indicator development and assessment methods for ecological/environmental status of freshwater and marine ecosystems. The focus of the presentations will be related to the implementation of EU Water Framework Directive and EU Marine Strategy Framework Directive. For information, see: http://www.waters.gu.se/digitalAssets/1500/1500127_wdmss-flyer-141020.pdf

Advances in Flatfish Production - Course
Zaragoza, Spain, May 11-15, 2015
This course is designed to offer participants an opportunity to be updated on existing and new practices in flatfish production.
http://www.iamz.ciheam.org/ingles/cursos14-15/Peces-planos_ING.pdf

Symposium on Veterinary Medicine
Vrdnik, Serbia, May 21-23, 2015
The goal of this symposium is the promotion of the "one health" perspectives and new challenges in interdisciplinary research in all aspects of veterinary medicine and public health as well as environmental protection, addressing a wide range of research projects.
Symposium office contacts: Email: vetsym2015@niv.ns.ac.rs; Web: http://niv.ns.ac.rs/?page_id=814.

JUNE 2015

7th Conference "Water & Fish"
Belgrade, Serbia, June 10-12, 2015
Main topics are water and fish. Welcomed are all those interested in or studying aquatic environment and aquatic organisms, aquaculture, fishery… As usual, the best scientists from the sector, representatives from different countries, associations, institutions, and projects will participate as lecturers.
Info: Conference secretary: Bozidar Raskovic, E-mail: raskovic@agrif.bg.ac.rs. Institute of Animal Science Faculty of Agriculture, University of Belgrade Nemanjina 6, 11080 Zemun Serbia Telephone:+381 11 2615 315, ext. 290 Fax:+381 11 316 84 99
E-mail:ribarstvo@agrif.bg.ac.r; Website: http://www.cefah.agrif.bg.ac.rs/conference/conference.html

Fish Passage 2015 - International conference on river connectivity best practices and innovations
Groningen, The Netherlands, June 22-24, 2015
Fish Passage 2015 will be an important international forum to exchange findings and experiences on fish related passage issues. This international conference is of interest to researchers, educators, practitioners, funders, and regulators who have an interest in advancements in technical fishways, nature-like fishways, downstream passage solutions, stream restoration and stabilization, dam removal, road ecology, and the myriad of funding, safety, climate change, and other social issues surrounding watershed connectivity projects.
For info: Email: fishpassageconf@gmail.com; website: www.fishpassageconference.com

JULY 2015

39th Annual Larval Fish Conference
Vienna, Austria, July 12-17, 2015
The conference themes will cover the contribution of early life history to dispersal, recruitment, and population dynamics of fishes, as well as conservation and restoration issues. We welcome contributions from multidisciplinary fields of aquatic sciences and all environments concerned (marine estuarine and freshwater systems). A special focus on dispersal, larval ecology and life history strategies in riverine ecosystems will be part of this event.
Website: http://www.larvalfishcon.org/Conf_home.asp?ConferenceCode=39th

AUGUST 2015

9th International Symposium on Fish Parasitology
Valencia, Spain, August 31 – September 4, 2015
The scientific program will include the diversity of approaches and research fields in fish parasitology, with a special interest on the "New Challenges in Fish Parasitology" facing us for the next years: parasite diversity and development of techniques for taxonomic and phylogenetic analyses, biology of parasites and host-parasite interactions, parasites as pathogens in aquaculture and wild ecosystems, use of parasites as bioindicators of ecosystems and fish stocks, and the impact of global changes and human activities on fish and their parasites in different earth regions.
Website: www.9isfp.com

Aquaculture 2015 - Cutting Edge Science in Aquaculture
Montpellier, France, August 23-26, 2015
This conference will highlight the top scientific approaches being used to advance the global aquaculture industry. The main research themes at Aquaculture 2015 will be: Research innovations on aquaculture's interactions with the environment; -Modern methods for disease detection and control; Applications for physiology and experimental biology to improve the sustainability of aquaculture; New targets and tools for selective breeding of aquaculture species; Nutritional advances using molecular techniques; The governance of aquaculture value chains.
Website: http://www.aquaculture-conference.com/

SEPTEMBER 2015

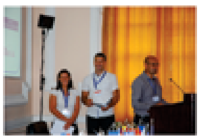
YOUMARES 6 "A journey into the blue: ocean research and innovation"
Bremen, Germany, September 16-18, 2015
Email: info@youmares.net; URL: http://www.youmares.net/

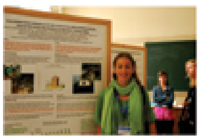
OCTOBER 2015

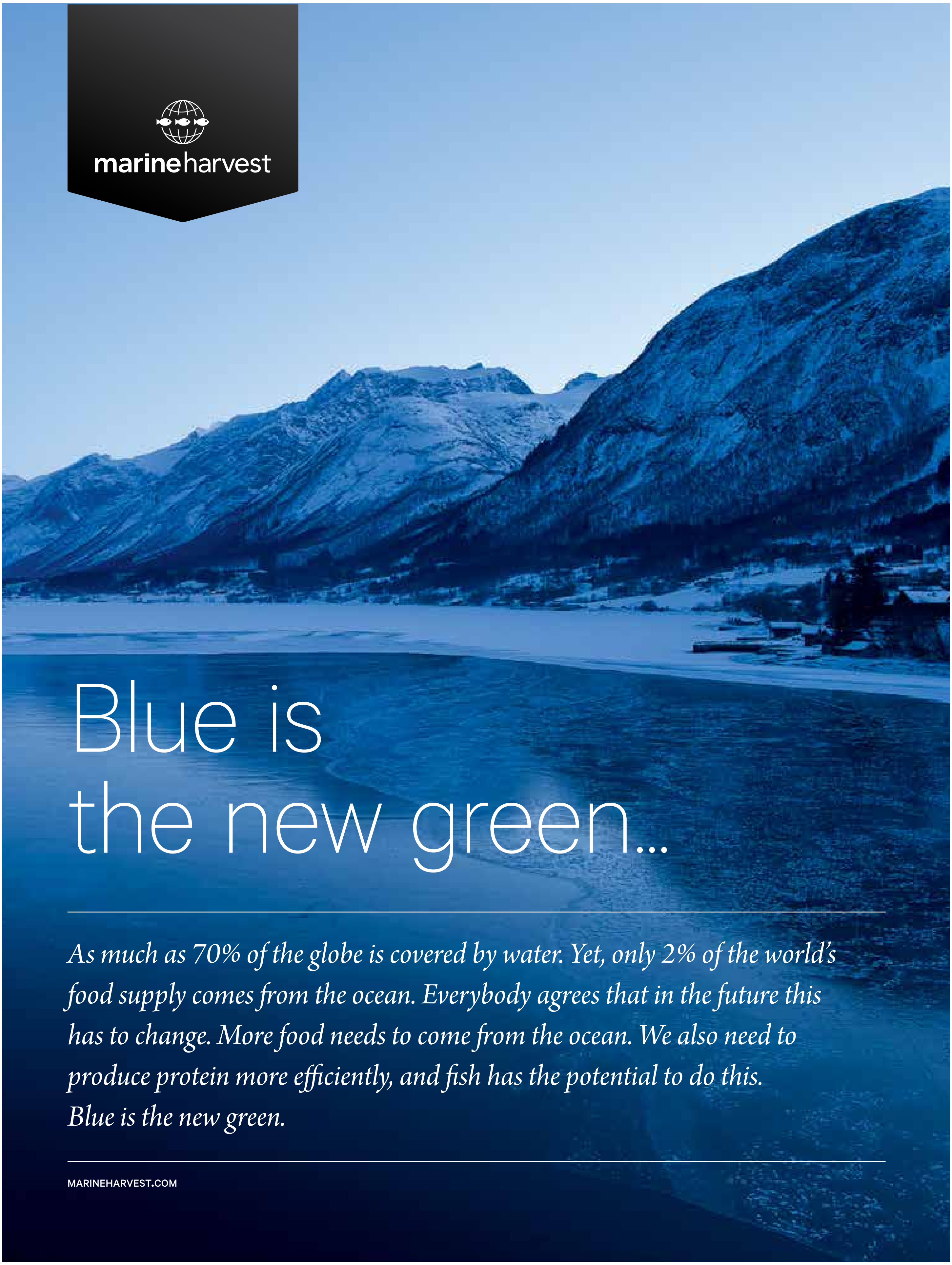
Aquaculture Europe 2015
Rotterdam, The Netherlands, October 20-23, 2015
Organised by EAS in cooperation with IMARES Wageningen UR, and Gold Sponsored by BIOMAR, the event will focus on the role and contribution of aquaculture to the management of natural resources and its importance in society through the provision of high quality, nutritious and healthy food. These are the main thematic areas that will be addressed during the plenary sessions. European and national research is providing highly innovative and integrated solutions to support development and the outputs of this research will be presented in the AE2015 parallel sessions that cover the full scope of European aquaculture and comprise submitted oral and poster presentations.
Contact for abstracts and registration: EAS Conference Organiser, John Cooksey, MF Cooksey Conference Management, AE2015 Conference, P.O. Box 2302, Valley Center, CA 92082, USA. Tel: +1 760 751 5005; Fax +1 760 751 5003;
E-mail: worldaqua@aol.com
Contact for industry and media sponsorship opportunities: Mario Stael, MAREVENT, Begijnengracht 40, 9000 Gent, Belgium. Tel/Fax: +32 9 2334912; E-mail: mario@marevent.com;
Web: www.marevent.com
General information: European Aquaculture Society, Slijkensesteenweg 4, 8400 Oostende, Belgium.
Tel. +32 59 32 38 59; Fax: +32 59 32 10 05;
Email: ae2015@aquaculture.cc. Url: www. easonline.org

SEPTEMBER 2016

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






marineharvest
Blue is the new green...
As much as 70% of the globe is covered by water. Yet, only 2% of the world's food supply comes from the ocean. Everybody agrees that in the future this has to change. More food needs to come from the ocean. We also need to produce protein more efficiently, and fish has the potential to do this.
Blue is the new green.
MARINEHARVEST.COM