Research Exchange to the University of Patras and Mediterranean Marine Fish Hatcheries and Attendance at Larvi 2009 and the LARVANET Workshop

Jennifer Cobcroft and Stephen Battaglene

AUSTRALIAN SEAFOOD COOPERATIVE RESEARCH CENTRE

Project No. 2009/720

ISBN: 978-1-925982-21-3

2009/720: Research Exchange to the University of Patras and Mediterranean Marine Fish Hatcheries and Attendance at Larvi 2009 and the LARVANET Workshop

PRINCIPAL INVESTIGATOR: Jennifer Cobcroft and Stephen Battaglene

ADDRESS: University of Tasmania, Tasmanian Aquaculture and Fisheries Institute, Marine Research Laboratories, Private Bag 49, Hobart TAS 7001.

OBJECTIVES OF RESEARCH TRAVEL GRANT

1. Observation of operating procedures in a large commercial hatchery (65 million fry p.a.) and quality control methods at this scale.

2. Develop the existing relationship with Ass Prof Giorgos Koumoundouros (University of Patras) and build research linkages between Australia, Greece and the broader European hatchery research community.

3. Increase understanding of malformations in hatchery produced marine fish by visiting the University of Patras and Mediterranean marine fish hatcheries in conjunction with attendance of Larvi 2009 and LARVANET workshop.

NON TECHNICAL SUMMARY:

Dr Jennifer Cobcroft and Assoc Prof Stephen Battaglene were invited to visit the aquaculture research laboratories of the University of Patras, Greece and collaborating research and commercial marine fish hatcheries in Greece (1-4 Sept 09). This followed a visit to Australia by Ass Prof Giorgos Koumoundouros, international expert in malformations in marine fish and a lead researcher in the EU „FineFish" project, who also attended the Seafood CRC sponsored workshop „Advances in marine fish hatchery technology in Australia" in Brisbane in August 2008. The visit enabled the development of this existing relationship and to build research linkages between Australia, Greece and the broader European hatchery research community. The laboratory and hatchery visits in Greece coincided with Larvi 09, 5th Fish and Shellfish Larviculture Symposium, the premier international event specialising in larval rearing research, the FineFish Final Workshop and a LARVANET workshop. These events took place in Ghent, Belgium (6-11 Sept 09).

In Greece, Ass Prof Koumoundouros hosted our visit to the Laboratory of Zoology, University of Patras, where he demonstrated methods used by his team for assessment of fish samples for skeletal malformations and body shape, including rapid clearing & staining of larvae, reference guides for identification of different malformations, soft tissue x-ray for juveniles and image analysis software assisted geomorphometric analyses. These methods have direct applicability in the rapid processing and thorough classification of fish samples for quality assessment in

Australian hatcheries. We also visited two facilities that collaborate with Ass Prof Koumoundouros, including the largest marine fish hatchery in Greece, Andromeda SA, producing 65-75 million sea bass and sea bream fry per year. Stringent process control, strict biosecurity and a focus on staff training and development have underpinned the company"s expansion from 2 to 65 million fry p.a. in 8 years. The company have also integrated independent scientific expertise into monitoring of fry quality, production-scale trials and committee decisions to modify hatchery protocols based on replicated and repeated trials. At the Institute of Aquaculture, AquaLabs in Heraklion, Crete, we observed research and production scale facilities for intensive and extensive larval culture. AquaLabs has a unique relationship with the adjacent public aquarium, Thalassocosmos, which funds a large proportion of the research activity. The research team have an active interest in developing aquaculture methods for large pelagic fishes including wreckfish, greater amberjack, and bluefin tuna. They are interested in developing collaborative research with international groups.

OUTCOMES ACHIEVED TO DATE

Based on the information collected in this visit, we have provided information to CST to be considered in changes to larval rearing methods and prioritisation of factors to be tested in research. Several areas for potential collaboration were identified with Ass Prof Koumoundouros and the research team at the Institute of Aquaculture, with the most likely in the short-term being a collaborative student project.

OUTPUTS DEVELOPED AS RESULT OF TRAVEL GRANT:

There are two current outputs from the travel grant:

1. Presentation of photographs of hatchery systems and discussion summarising the visits to Greek hatcheries and research presented at Larvi09 on 13th and 16th October 2009 to CST staff at Arno Bay and Port Augusta. Verbal discussion of visits to Greek hatcheries with SARDI members of the CST Larval Research Steering Committee on 12th October 2009.
2. This written report of hatchery visits for the Seafood CRC, particularly for members of the CST Larval Research Steering Committee, including a summary of discussions in relation to potential future collaborations.

BACKGROUND AND NEED

There are very few researchers in Australia with expertise in malformations of hatchery produced fish, and there is a critical mass of scientists working in Europe on projects such as EU Framework 6 project FineFish. This visit to Greece was a unique opportunity to increase our understanding of malformations and techniques being employed in Europe to improve larval quality. Ass Prof Koumoundouros plays a lead role in this research and has a network of colleagues in other countries (e.g. UK, France, Spain). In Belgium, the FineFish project reported major findings on the causative factors of skeletal malformations in several species at its Final Workshop, and we were invited to participate and attended the EU COST Action Larvanet workshop as international representatives.

In Greece, we presented an overview of the Australian finfish aquaculture industry, striped trumpeter research in Tasmania and a brief summary of Seafood CRC research results (presentation approved by CST) that described jaw development and malformations in yellowtail kingfish, enabling input and advice from international peers with both research and commercial production experience. Marine fish hatchery technology has been developed and applied in Europe for over 40 years and the visit provided us with the opportunity to observe state-of-the-art facilities and methods. In addition, we gained an understanding of the approach to collaboration and communication between researchers and industry in Greece, particularly in relation to malformation assessment, and have presented relevant practical techniques to the Seafood CRC and CST in this report and at meetings.

In addition to the expert appraisal of our scientific approach to understanding malformations in kingfish, this visit provided the opportunity for international peers to suggest „most likely" factors that can be incorporated in ongoing Seafood CRC research on kingfish larval culture to increase survival and improve quality. Observations of both large-scale intensive commercial hatcheries (Andromeda SA) and research facilities applying extensive „mesocosm" techniques (Institute of Aquaculture, Crete) are communicated in this report to the SfCRC/CST Kingfish and Southern Bluefin Tuna Larval Research Committees. We were interested in any relevant methods observed in the hatcheries that could be applied at a research or commercial scale at CRC Participant hatcheries to assess the effects on larval survival and quality. We also discussed opportunities for more formal collaborative research between Greece and Australia, with a view to making the most of the significant research investment developed in Europe by being trained in their methods and applying their results and expertise in Australia.

RESULTS

Stephen Battaglene and Jennifer Cobcroft were hosted by Ass. Prof. Giorgos Koumoundouros in Greece from 1-4 Sept 2009 (see itinerary in Table 1).

Table 1. Itinerary of activities in Greece

Date	Location	Activity
Tues, 1 Sept 2009	Athens to Patras	Initial meeting with Ass Prof Koumoundouros in Patras.
Wed, 2 Sept	Patras to Andromeda	Visit Andromeda SA marine fish

2009	hatchery, Vonitsa	hatchery, Vonitsa – meet with the General and Production Managers to discuss hatchery operations, tour facilities.
Thurs, 3 Sept 2009	Patras and return to Athens	Visit Laboratory of Zoology, University of Patras – presentation by SB to research team (20 people attended); discussion & observation of laboratory techniques
Fri, 4 Sept 2009	Athens to Heraklion, Crete	Visit Institute of Aquaculture, Heraklion - presentation by SB (14 people attended); meet with researchers; discussion & observation of mesocosm & laboratory techniques

Andromeda SA hatchery at Vonitsa

Background

- Hatchery purchased by Andromeda SA (http://www.andromeda-aquaculture.gr/EN/main.html) in 1999 with an annual production of 2 million fry. Hatchery expanded with construction complete in 2006. Production has been increased to 65 million fry per year for the last 2 years, with a target of 75 million in 2010. (>30x production increase in less than 8 years)

- Most efficient hatchery in Europe in terms of system volume available (540 m^3 larval rearing and 2,800 m^3 nursery recirculation systems), number of staff (80 people) and fry produced (65 million).

- Produce Gilthead Sea Bream (*Sparus aurata*), Sea Bass (*Dicentrarchus labrax*). Have an active research & development unit involved in the major species and with other species including some production of Senegalese sole (*Solea senegalensis*). Previously looked at 10 other species (including Puntazzo (*Diplodus puntazzo*), Pandora (*Pagellus erythrinus*), Corvina/Shi drum (*Umbrina cirrosa*), and Pagrus (*Pagrus pagrus*).

- Selective breeding program commenced in 2002. Need to limit return of fish ongrown on farms to the hatchery to avoid nodavirus.

- Hosted by Nickos Katribouzas (Production Manager – Greece, Albania & Spain) and Gabriel Moukas (Hatchery Manager). Also met with George Spiliopoulos (Fish Pathologist) in Patras 3/09/09.

Features

- Facility laid out in 3 biosecurity zones – 1st zone, outside gates, where transport trucks collect fish from nursery to ship-out and 2 quarantine tanks where all new fish are held for 2 months prior to moving into the 2nd zone. 2nd

zone, office facilities, broodstock tanks, small hatchery with 30 million fry capacity, all experiments and new species in this zone. 3rd zone, hatchery with 30-40 million fry capacity for sea bass & sea bream production.

- Water source is bore water with temperature 17-21 °C. Air lifts used to achieve pH of 7.8 and add chemicals to the water for broodstock to increase pH. Some pre-conditioning of water (1-2 days) before use. 30% of infrastructure investment in water quality – bores and UV (150-400 m^3/h depending on number of UV lamps). Oil powered heaters to heat to 80 °C, then heat exchange to get seawater to 23 °C. Commercial chillers (100 m^3/h)
- Enclosed lagoon off the hatchery is used for some of the company"s growout. 8-30 °C temp fluctuation and 1 water exchange every 100 years.
- Emergency generator with 170% capacity of hatchery power requirements & automatic start-up.
- Live algae – *Nannochloropsis* and T *Isochrysis*
- Rotifers – Max production 20 billion/day, with a 20 billion standing stock. 9 x 2,000 L and 12 x 1,000 L tanks. Batch culture system starting at 1-2000/mL to 6-7000/mL, 1200% production at end. Based on commercial algal pastes. pH adjustment with water exchange & salinity at 25 ppt. Small strain 170-180 µm. Red Pepper for rotifer enrichment.
- Rotifers – 4 harvests per day for 4 feedings.
- Artemia – Max production 8.5 billion/day. 8 x 5,000 L tanks. Decapsulate cysts. Separate hatch and enrichment tanks. Ceramic airstones. INVE stainless screens for rinsing.
- Artemia – 4-5 feeds/day, with cold storage of harvested Arts.
- Sea bass – 6 x 6,000 L and 8 x 4,000 L – room dark and temperature controlled
- Eggs stocked directly into larval tanks (bream @ 1.5 million in 16 m^3 = 94/L; bass stocked at lower density), but only stock eggs >90% normal development.
- No current egg disinfection, however information on ozonation equipment and treatment was requested from TAFI following the visit.
- Larval tanks in dark or very low light until start feeding.
- All larval tanks and lines disinfected with chlorine between runs.

- Monitoring larvae by scoop in a glass jar, twice daily, for feeding activity and gut contents. Also used for residual rotifer and Artemia counts.
- Stable survival achieved.
- Record sheets for most daily activities, e.g. to record every incidence of surface skimming.
- Nursery – recirculation systems. Raceway-style tanks, original a Dutch design – hanging screens in the tanks to reduce swimming movement. Good size distribution at 1st grade. Three sizes of fish – at least two grades in the nursery. Newer system 1000 m^3. Total system volume 2,800 m^3.
- Hand-feed in nursery to control behaviour, improve efficiency, health, appetite and water clarity. Have a growth model to allow daily feed adjustments.
- Hand monitoring of O_2 every 3 hours and constant O_2 injection. Manual addition of O_2 in an emergency. Daily ammonia monitoring in recirculation system – 5 ppm okay for short-term but aim for <1 ppm.
- With better feeding management in the nursery, efficiency was doubled.
- Biggest hatchery issue – stability of juvenile fish sales.
- Production scale trial/experiment facility of 4 x 20,000 L larval tanks. These are stocked with ~1.5 million eggs per tank (~75/L). Two tanks are run with the treatment (e.g. larval diet) and 2 using standard protocol. If the treatment has a positive effect the trial is repeated to confirm before the hatchery manual is updated to adopt the new treatment.

Malformation monitoring

- Some early assessment for caudal fin issues (missing or double) at start of flexion (~12 days). Routine quality control for bream at ~35 days (8-10 mm) of 100 fish randomly sampled from every production tank. Water level is dropped in the larval tank and sampled fish are anaesthetised before fixation (≤0.2% malformation). These are processed by G. Koumoundouros.
- 1st „sort" of fish at 0.2-0.5 g (20-30 mm) in the nursery with a swim bladder float (anaesthetised fish in high salinity) and also removal of opercular malformations at this stage.
- 2nd „sort" isconducted over a light table for all fish at ~1 g.
- Handsorting – 2-phenoxyethanol for anaesthesia, net onto large light table (no running water) for hand-sorting. Sorters are seated around the table, and each scorer has 2 buckets, 1 for discards and 1 for good fish. Wet weight of fish from both buckets are recorded from each scorer at regular intervals to

monitor quality control. Also assess 100 fish checked per sorter to check for effectiveness of grading.

Overall impressions

- Strong emphasis on rigidly complying with hatchery manual and standard protocols at all levels of the organisation. Improvements and innovations are encouraged but through a very rigorous testing process. Staff who do not follow this approach are not retained.
- Large focus on staff training (including succession planning) and water quality, with simple systems operated in labour intensive (e.g. hand feeding) but very efficient way. Most management staff are from technical schools of ichthyology and aquaculture and are trained within the hatchery starting as junior managers.
- Close relationship with larval research expert advising on in-house research trials and hatchery manual modifications and engaged in collaborative EU projects.
- Company focus is investing in personnel in one big hatchery rather than several smaller facilities.

Take-home ideas for Australian industry

- Staff training and development and strict adherence to hatchery manual.
- Systematic approach to changing production protocols in the manual, through repeated replicated production-scale trials.
- Light tables to enhance hand-sorting.
- Assess effect of alternative commercial enrichment products on malformations.

AquaLabs, Institute of Aquaculture, Hellenic Centre for Marine Research (HCMR), Heraklion, Crete

Background

- The Institute of Aquaculture, Hellenic Centre for Marine Research (HCMR), has two sites in Athens with programs „food for fish" and „fish for food" and pathology, while the site in Crete is focussed on larval culture. www.hcmr.gr
- About 20 staff in Athens and 21 staff at AquaLabs.
- Facility tour was provided by Dr Pascal Divanach, Director of the Institute of Aquaculture, and Dr Sterioti Aspasia, Director of Thalassocosmos (the Crete Aquarium).

- The Institute of Aquaculture has an aquaculture research facility known as AquaLabs, located adjacent to a public aquarium, Thalassocosmos. The public aquarium funds the maintenance of many species in AquaLabs.
- 2 million fry per year production of sea bass and sea bream from intensive culture at AquaLabs (sale of which provides 20-30% of AquaLabs income).
- The Institute of Aquaculture has a cage system for growout.
- The Institute of Aquaculture has a history of research comparing extensive (mesocosm) and intensive culture systems for new finfish species for aquaculture.
- AquaLabs has a close working relationship with the University of Crete.
- Following Stephen"s presentation of Australian aquaculture, striped trumpeter research in Tasmania, and kingfish research, we had a meeting with several researchers from the facility including: Dr Divanach, Dr Nikos Papandroulakis (intensive and semi-intensive larval culture, incl. tuna), Dr Pantelis Katharios (fish pathologist).

Features

- Many of the fish on display at Thalassocosmos were cultured at AquaLabs. Many behavioural studies are carried out in the aquarium facility.

At AquaLabs…

- Cobia culture, initial batches with high malformation rates, most recent batch stocked 7000 eggs (estimate ~4000 good eggs) into a megacosm (~120,000 L) and obtained 3500 good quality juveniles (~90% survival).
- Tuna culture in mesocosm tanks (~80,000 L), with few surviving juveniles. Anticipate using the megacosm system next time.
- Broodstock of several species held in 5, 10, 20 and 60 tonne tanks.
- Several systems of bioreactors (bio-fence) for microalgae production, mainly *Tetraselmis* and *Chlorella*, and creating paste by flocculation.
- *Artemia* culture system – 800 L cones with automated enrichment addition.
- Rotifers produced in 1,600 L tanks at 200 to 400/mL on Cuture Selco – contemplating use of algae.
- Intensive larval culture systems for research (16 x 500L and others 2000L) and behaviour system with self-feeders installed.
- From discussion:

- larval walling behaviour called the „mirror" effect in Greece as larvae apparently attracted to the surface as a mirror, and they have also looked at tank colour.

- Species of interest in Greece with potential for collaboration: wreckfish (*Polyprion americanus*) (same genus as NZ groper, hapuku, *Polyprion oxygeneios*); greater amberjack (*Seriola dumerili*); bluefin tuna (*Thunnus thynnus*); spiny rock lobster

- Collected parasites from Atlantic stargazer (not aquaculture species) – have *Chondracanthus* (copepod) specimens and monogeneans – study done on competition between the parasites, including pathology, but not yet published. *Zeuxapta* is an issue in kingfish in Greece. Copepods/*Caligus* in some species but not all.

- Researchers interested in pursuing funding to support collaboration (eg. A bilateral arrangement between Greece and Australia – see Australian Academy of Science http://www.science.org.au/aashome.htm; FEAST www.feast.org/; CORDIS www.cordis.lu/en/home.html). Discussed option to use COST for travel for short-term activity. Option of a research MOU between the Institute and University of Tasmania, and potential to seek "Island" funding.

- Would like to establish the facility as a „hotel of research and education" – intent to develop an international program for researchers to come to the facility to conduct research trials.

Overall impressions

- Dynamic research team and excellent facilities for replicated small-scale and large-scale research.

- Relatively less experienced/progressed in kingfish and tuna culture compared to CST and other Australian facilities.

- Ass Prof Koumoundouros will be moving to the University of Crete in 2010, increasing opportunities for research in malformations.

Take-home ideas for Australian industry

- Consider collaborative research and technical exchanges, possibly comparative studies of the same genus.

Following the visits in Greece, Stephen and Jenny attended the FineFish Final Workshop, Larvi09 – Fish & Shellfish Symposium, and LARVANET activities in Ghent, Belgium (6-10 Sept). A report summarising the major developments in fish

hatchery research, particularly in relation to causative factors of skeletal malformations, will be provided to the CST Larval Rearing Research Committee, but is not a required output from this travel grant that funded activities in Greece.

EXTENSION ACTIVITIES

Presentation of photographs of hatchery systems and discussion summarising the visits to Greek hatcheries and research presented at Larvi09 on 13th and 16th October 2009 to CST staff at Arno Bay and Port Augusta. Verbal discussion of visits to Greek hatcheries with SARDI members of the CST Larval Research Steering Committee on 12th October 2009.

Proposed discussion of travel activities and observations at the next meeting(s) of the CST Larval Rearing Research Committees, specifically in relation to prioritisation of factors to investigate in replicated experiments and production-scale trials.

Proposed summary of travel findings to marine fish hatchery industry representatives at Australasian Aquaculture 2010.

PROJECT OUTCOMES (THAT INITIATED CHANGE IN INDUSTRY)

Table 2. Potential outputs from the travel as listed in the travel grant application and the current status of potential industry application.

Specific take-home 'inputs' from the visit	**Potential industry application 'outputs'**	**Current status of industry application 'outcomes'**
Critical evaluation of SfCRC research approach to assessment of kingfish malformations	Improvement of research approach – modified research plan if required in consultation with Research Committee(s)	Current monitoring of YTK production and experiments is similar to that used in Europe and is appropriate. Recommendation that factors influencing larval performance are examined in a controlled way at a production scale and that one factor be tested at a time. Allocation of resources (outside of production) to test and validate factors at commercial CST facilities.
Most likely causative factors of jaw malformations seen in kingfish (e.g. nutrition, light, water flow dynamics)	Testing factors in replicated research experiments or in a commercial scale trial, as applicable	Several factors of interest discussed at the Final FineFish Workshop: 1. temperature (more commonly associated with spinal, stargazer and opercular malformation but may affect jaw) 2. live feed enrichment (jaw malformation in grouper involving similar bones to those affected in kingfish; mineral and

		vitamin contents also possible factors) 3. oxygen saturation (Atlantic salmon and cod best practice recommendation < 140% DO) 4. larval density 5. Water current velocity (role in severity of spinal lordosis)
Observation of hatchery operations in commercial and research facilities, including photographs and documented procedures	Report and presentation to industry and adoption of relevant commercial methods in the hatchery	Photographs and procedures discussed with CST staff Oct 2009. Discussed benefits of staff training, adoption of strict adherence to and monitoring of adherence to „hatchery manual".
Mesocosm extensive methods for testing new species	Culture of kingfish with modified extensive methods (where infrastructure permits) to examine effect on jaw deformity. Potential application of techniques with SBT.	Systems observed. Potential for collaboration with Institute of Aquaculture in Heraklion in Seriola culture. Crete system used for tuna larviculture in 2009.
Collect most recent information on malformation research in Europe (Larvi 2009 and LARVANET)	Report to industry and adoption of relevant research results in the hatchery	Report to CST in October 2009. Planned presentation at Australasian Aquaculture, May 2010. Potential factors for investigation as listed above.
Identify opportunities for ongoing collaboration (joint projects, staff and/or student exchanges)	Increased training (specifically input to training carried out as part of 2008/902) and exposure to recent advances in improving larval quality	Manuals will soon be available from FineFish on the assessment and characterisation of malformations in Atlantic salmon, rainbow trout, Atlantic cod, sea bass and sea bream. Many methods are currently in use with YTK, with additional transfer of methods recommended in other species sectors, and additional methods suggested for YTK (eg. Radiography of 5g juveniles).

SUMMARY OF CHANGE IN INDUSTRY (WHAT IMMEDIATE CHANGES ARE EXPECTED)?

As mentioned above, prioritisation of factors to be assessed in research trials will be ongoing through the CST Research Committees.

Application of improved staff training, monitoring of protocols and adherence to a hatchery manual was recommended and adoption is at the discretion of commercial companies.

WHAT FUTURE AND ONGOING CHANGES ARE EXPECTED?

A more systematic approach to testing and adoption of „new protocols" in larval culture prior to adoption in the hatchery manual.

Ongoing commitment to data collection from larval culture and monitoring of fish survival and quality.

FURTHER ACTION REQUIRED IN REGARDS TO COMMUNICATION?

Brief report prepared for Seafood Stories, Seafood CRC newsletter (published early 2010).

Discussion of travel activities and observations at the next meeting(s) of the CST Larval Rearing Research Committees (anticipated early 2010), specifically in relation to prioritisation of factors to investigate in replicated experiments and production-scale trials.

Summary of travel findings to marine fish hatchery industry representatives at Australasian Aquaculture 2010.

FURTHER ACTION REQUIRED IN REGARDS TO COMMERCIALISATION? (IP PROTECTION, LICENSING, SALES, REVENUE ETC)

None

LESSONS LEARNED AND RECOMMENDED IMPROVEMENTS?

The visit to Andromeda SA, the largest marine fish hatchery in Greece (65-75 million sea bass and sea bream fry p. a.) revealed that stringent process control, strict biosecurity and a focus on staff training and development have underpinned the company"s expansion from 2 to 65 million fry p.a. in 8 years. The facilities are large but have minimal automation and the 30 fold increase in production was achieved by ensuring high quality water quality and well-defined hatchery protocols. The company have also integrated independent scientific expertise into monitoring of fry quality, production-scale trials and committee decisions to modify hatchery protocols based on replicated and repeated trials.

In Crete, the close association of a public aquarium in a popular tourist destination with the research facility has allowed the Institute of Aquaculture to be substantially funded through the aquarium income. This was an interesting model with potential for application in Australia.

ACKNOWLEDGEMENTS

We thank the Seafood CRC for funding of activities in Greece, and the Australian Research Council for funding travel and attendance of FineFish Final Workshop, Larvi09, and LarvaNet Workshop. Ass Prof Giorgos Koumoundouros is thanked for arranging visits to Andromeda and Institute of Aquaculture, Heraklion and his hospitality in Greece.

APPENDIX 1. Selected photographs of visit

Andromeda, Vonitsa

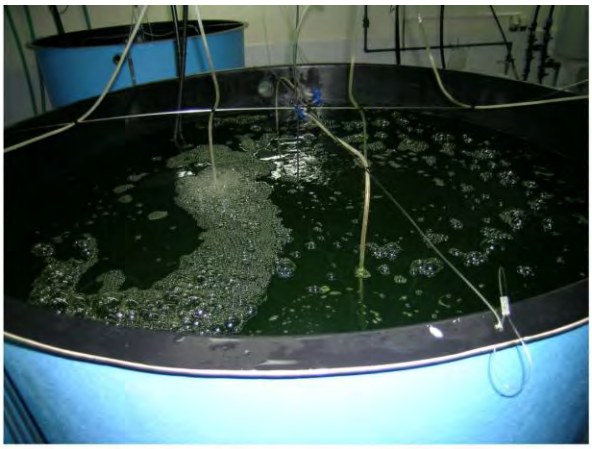
Andromeda fish hatchery, Vonitsa

Growout cages in Greece

Growout cages in Greece

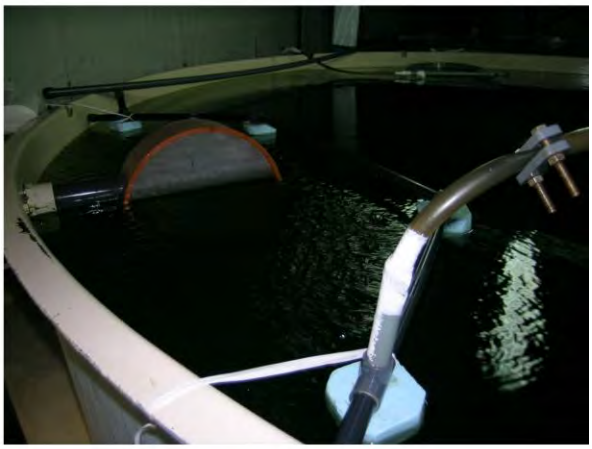
Andromeda, Vonitsa

Artemia culture tanks



Rotifer culture tank

Larval culture tank



Larval culture tank - outlet screen

Larval culture tank - surface skimmer

Nursery tanks

Andromeda, Vonitsa

Manual grading in the nursery

Estimating numbers with wet weight

Handsorting for malformations

Handsorting for malformations

Handsorting for malformations

Sorted sea bass - lower fish with upper jaw malformation. Note - vertebral bends can be visualised on light table.

University of Patras, Biology Department, Patras

Cranial bones of a fish in Giorgos' lab

Cleared and stained specimens in Giorgos' lab

Jenny with students in Giorgos' lab

Stephen discussing zebrafish with Giorgos

Family lines of zebrafish in Giorgos' lab at University of Patras

Zebrafish - a model species for assessment of temperature effects on body shape and sex differentiation.

Institute of Aquaculture, AquaLabs, Heraklion

Cultured greater amberjack in aquarium

Wild caught and cultured fish in aquarium

AquaLabs - Pascal Divanach showing cobia juveniles to Stephen

Megacosm tank (~120,000 L)

Juvenile tuna tank

Microalgae bio-fence

Institute of Aquaculture, AquaLabs, Heraklion

Intensive larval rearing replicated system

Intensive larval culture production system

Mesocosm tanks

Empty mesocosm tank