Training Course on Development of Aquaculture Production and Technologies for the INOC member states

15-20 May 2017, Monastir-TUNISIA

compiled by
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Mustafa ERGÜN
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Scope of the Workshop/Training:

Aquaculture plays an important role in the countries of the region in terms of contribution to economic development, employment for coastal communities and as an important source of food. Harvests of wild aquatic species or matching demand through commercial fishing interests would eventually result in overfishing and the loss of those species entirely. Therefore, while aquaculture is required to meet the human demand, it also relieves the strain on wild species to allow them to continue to be a significant source. In the most of the INOC member states, the production from capture fisheries stabilized in the early 1990s and many stocks are considered now fully or overexploited. In response, marine and brackish water aquaculture grew steadily during the last decades.

The need for increasing supplies of aquatic foods to meet the growing demands of an expanding population is recognized as an important problem of the world. Closely related is the concern over the increasing pollution of the coastal areas, with potentially serious effects upon the aquatic environment and its ability to produce acceptable foods. At last, the sustainability of the sector is increasingly challenged by old and emerging issues which require innovative techniques to be successfully managed.

Consequently, in order to achieve this goal, it is important to develop new modern environmentally friendly aquaculture techniques, to know the different disciplines of this industry and their management.

The Inter-Islamic Network of Technology and Science (INOC) is a reference point for its catalytic role regarding cooperation between member countries on various topics that deserve to be valued. INOC, with the technical collaboration of the Institute of Marine Sciences and Technology (IMST) from Turkey, the National Institute of Marine Science and Technology (INSTM), from Tunisia and other institutions, plans to set up a training course of one week entitled 'Development of Aqua-culture Production and Technologies in the Islamic Countries '. This course aims to help countries of the region and its surroundings to own the latest technological developments in the marine and continental aquaculture, in its various areas of intervention, optimal production techniques and infrastructure involved in this industry.

The Aims and objectives of the workshop:

As part of the Training Course, several objectives are targeted:

* Reinforce the capacities of INOC member’s institutions about the modern techniques of marine and inland aquaculture;
It’s known that very many of the INOC member states are the main (inland and marine) producing countries. The average annual growth for the period from 2009–2014 for marine and brackish water aquaculture is estimated at 9 per cent. The objective here is to help all the other INOC member states to reach a satisfying level of production.

 Contributing to the development of aquaculture production using sustainable practices that help stabilize aquatic resources, improve ecological conditions and maintain bio-diversity;

In order to solve those environmental and social concerns, it is necessary to call for a swift inclusion of aquaculture within integrated coastal zones management and maritime policies. In this respect, space limiting factors, administrative and local conflicts are real and need a collaborative approach to be solved.

* Ensure a better monitoring of aquaculture industry in the INOC Member Countries;

In the World, it isn’t easy to talk about a real existence of a common marketing strategy in the sector to better ensure price stability, product traceability, exploitation of emerging markets, the increase in domestic consumption, improving the sector's public image and increasing the competitiveness of the industry. Here, the course aims to help participants of the countries concerned to improve their data collection methods, evaluation and forecasting of production.

**Beneficiaries of the Training Course:**

The INOC member states will participate in this workshop. These countries include: Algeria, Azerbaijan, Bahrain, Bangladesh, Cameroun, Egypt, Indonesia, Iran, Iraq, Jordan, Kazakhstan, Kuwait, Lebanon, Malaysia, Mauritania, Morocco, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, Senegal, Syria, Tunisia, Turkey, Turkmenistan, United Arab Emirates and Yemen.

Schedule of the training course and its program:

Aquaculture Science

Introduction

Hatchery Technology

Brood stock management

Theory: photo period, temperature, food, selection, reproduction)

Practice: Injection of hormones for both grey mullet and sea bass to be made prior to & during the course week. If needed, theory matter can be practiced at a private hatchery in Sousse.

Production of the larvae of sea bass and grey mullet as a practical activity.
Theory: Larval production in closed system.
Practice: Egg, larvae and “vessinatatuar” to be shown under microscope. Larval production in closed system will be shown.
Zoo-technique, Live-feed, and protocol for the development of the larvae under physical, chemical and biological conditions.
Practice: Rotifer and artemia production will be shown.
Larvae quality.
Theory: Nutritional, management of stress, welfare, harvest protocol
Shell-fish (Ruditapesdecussatus) larvae production
Theory: Brood stock, larvae production, release to lagoons, pathology and eco-toxicology. Documentary will be shown.
Practice: Lab visit.
Micro algae production
Theory: Lagoon specific micro algae isolation and production for shell fish, and toxic algae.
Practice: Micro algae isolation, isolated micro algae (including toxic algae) to be shown under microscope
Pathology (prevention, diagnostic, treatment)
Theory & Practice: Bacteria identification by means of PCR and classical method. Parasite identification.
Off-shore cage culture technology
Site selection (physical parameters)
4.2 Off-shore types depending on off-shore sites (engineering)
4.3 Feeding quality (nutrition) and techniques
4.4 Sorting technique
4.5 Welfare
4.6 Multitrophic
5. Genetics
6. Practical lab work for basic monitoring: Temperature, oxygen, nitrogen, phosphorus, other biological indicators (benthic index) in the sediment around the cage.
Aquaculture Management

Site selection (AZA concept)

Site selection with the ICZM concept

Aquaculture and environment interaction

Water quality

Food

Exotic organisms and their impact on ecosystem

Escape (genetics)

Impact on flora (e.g. Posidonia meadows) and fauna (e.g. marine tetrapods)

Environmental parameters monitoring (sampling method, optimum frequency, EIA (risk assessment & social impacts) and evaluation

In sediment

Practice: Granule size. Sulphide bacteria to be shown.

In water

Practice: NO2, NO3, NH3, PO4, Organic phosphate, chlorophyll. Bacteria to be shown.

Economy and Marketing

Sea food processing

Stock management

Species diversity

5-day practical work

Hatchery: Fish book stock & larvae; Hatchery: zoo- technique; Shellfish/micro algae; Environment/pathology; Visit to cage and feed factory.
Notes:

All practical works performed in groups of 5 to 10.
Participants presented an overview of aquaculture in their countries on power point for 10 minutes.

Trainers

Experts from Intergovernmental Oceanography Commission (IOC) and Inter Islamic Science and Technology Network for Oceanography (INOC).

Sponsors:

Inter Islamic Science and Technology Network for Oceanography (INOC);
National Institute of Marine Sciences and Technology (INSTM), Tunisia
Islamic Development Bank (IDB);
Ministerial Standing Committee on Scientific and Technological Cooperation (COMSTECH) of the OIC (Organization of Islamic Cooperation)
IFS, International Foundation for Science

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Bismilahirrahmanirrahim, Merhaba,

Dear Participants, Ladies and Gentlemen

The Inter-Islamic Network of Technology and Science (INOC) is a reference point for its catalytic role regarding cooperation between member countries on various topics that deserve to be valued. INOC, with the technical collaboration of the Institute of Marine Sciences and Technology (IMST) from Turkey, the National Institute of Marine Science and Technology (INSTM), from Tunisia and other institutions, plans to set up a training course of one week entitled 'Development of Aquaculture Production and Technologies in the Islamic Countries '. This course aims to help countries of the region and its surroundings to own the latest technological developments in the marine and continental aquaculture, in its various areas of intervention, optimal production techniques and infrastructure involved in this industry.

This course has been supported by the Institutions of:

- Inter-Islamic Science and Technology Network on Oceanography (INOC)
- National Institute of Marine Science and Technology (INSTM)
- Islamic Development Bank (IDB)
- Ministerial Standing Committee on Scientific and Technological Cooperation (COMSTECH)
- International Foundation For Science, Sweden (IFS)

Aquaculture plays an important role in the countries of the region in terms of contribution to economic development, employment for coastal communities and as an important source of food. Harvests of wild aquatic species or matching demand through commercial fishing interests would eventually result in overfishing and the loss of those species entirely. Therefore, while aquaculture is required to meet the human demand, it also relieves the strain on wild species to allow them to continue to be a significant source. In the most of the INOC member states, the production from capture fisheries stabilized in the early 1990s and many stocks are considered now fully or overexploited. In response, marine and brackish water aquaculture grew steadily during the last decades.

The need for increasing supplies of aquatic foods to meet the growing demands of an expanding population is recognized as an important problem of the world. Closely related is the concern over the increasing pollution of the coastal areas, with potentially serious effects upon the aquatic environment and its ability to produce acceptable foods. At last, the sustainability of the sector is increasingly challenged by old and emerging issues which require innovative techniques.
to be successfully managed.

In this context I would like to remember of Henry Kissinger (1976):

WITH OIL YOU CONTROL STATES
WITH FOOD YOU CONTROL PEOPLE

Therefore the “FOOD SECURITY CONCEPT” is very important for the developing world.

Consequently, in order to achieve this goal, it is important to develop new modern environmentally friendly aquaculture techniques, to know the different disciplines of this industry and their management.

As part of the Training Course, several objectives are targeted:

- Reinforce the capacities of INOC member’s institutions about the modern techniques of marine and inland aquaculture;
- Contributing to the development of aquaculture production using sustainable practices that help stabilize aquatic resources, improve ecological conditions and maintain bio-diversity;
- Ensure a better monitoring of aquaculture industry in the INOC Member Countries.

Specific action plans and strategies should take place for preservation and health maintenance of the Aquaculture in the Islamic World. My sincere wish is that you will be very successful giving further in lights in this issue.

Thank you very much for your kind attention.

Prof. Dr. Mustafa Ergun
Executive Director of INOC
Prestigious and Honorable Guests

Ladies and Gentlemen

Good morning to every one

First of all, I would like to convey the apology from Pr. Hechmi Missaoui General Director of the INSTM for not being able to come to this opening of the TC.

We are delighted and honored to host this TC on Development of Aquaculture Production and Technologies in the INOC Member States. I wish to extend a warm welcome to the participants from the various countries.

I also wish to specifically thank Pr Mustafa Ergun, executive director of the INOC, and his colleagues for efficiently coordinating the preparation of this training course. All of them have been working efficiently with us since the beginning of the planning stage. I must thank you for your proposition that this TC held in Tunisia, for your patience, responsibility and all effort, without which, this training course could not have taken place

I would like to thank Mr Abdel Melek Sellemi, General Director of the regional office of agriculture development for funding time from his very busy schedule to attend this opening ceremony and for continuous support to our regional INSTM center.

I take this opportunity to thank the joint organizers IDB, COMSTECH and the IFS for providing the necessary funding. This training course could not have been made possible without their support and contribution.

I wish to express my gratitude to all lectures for their full cooperation and contribution to this TC.

Aquaculture and extractive fishing are complementary activities that must face the challenge of the increasing needs for marine products. and as you know the extractive fishing reached its highest levels at the end of 1980 and since that time has fluctuated around the same level, indicating that the oceans are exploited near to their maximum production. At this situation future increases of the products can only come from the aquaculture, as has been happening in the last 20 years. In fact, aquaculture has grown and diversified, and has registered enormous technological improvements. in this context we are today here to share experiences between our countries.

I think that, this TC will provide us not only essential knowledge but also a great and an invaluable opportunity to share experiences both technical and scientific issues and thus for networking for fruitful contacts between countries with the aim of achieving mutual benefits.

In closing, I wish to the participants a very fruitful and productive TC, and also that you have a pleasant stay in Monastir.

Thank you.

Mohammed Salah AZAZA
Honorables invités,
Mesdames et messieurs,

Il m’est particulièrement agréable d’être parmi vous aujourd’hui pour cette importante manifestation que l’INSTM et l’INOC organisent conjointement avec l’appui d’autres organismes internationaux à savoir :

« Training Course on Development of Aquaculture Production and Technologies »

Je voudrais remercier tout particulièrement Mr. le Professeur Mustafa Eurgin, directeur Exécutive de l’INOC qui a bien voulu participer en personne à cet événement. Ceci démontre bien l’intérêt que donnent nos deux institutions au secteur de l’aquaculture pour une exploitation durable et soutenue des ressources halieutiques des pays membres de l’INOC.

Mesdames et messieurs, chers collègues

La Tunisie est un petit pays qui compte 11 millions d’habitants ; ses richesses naturelles ne sont pas nombreuses ni diversifiées et son climat est très irrégulier. Néanmoins et grâce à la dynamisme de son peuple, elle a réussi son défi de modernisation et de développement. elle a misé sur l’exploitation rationnelle des ressources de notre pays pour rendre cette marche vers l’avant possible et placer la Tunisie du début du 3ème millénaire parmi les pays émergeants.

Ainsi, conscientes de l’importance du rôle que peut jouer l’Aquaculture dans l’assurance des besoins accrus en protéines animales tant sur le plan mondial que régional et surtout national, et dans le but de relancer ce secteur qui a connu des difficultés et des résultats peu convaincants dans ses débuts, les autorités tunisiennes ont élaboré, une nouvelle stratégie pour le développement de l’Aquaculture en Tunisie. Parmi les recommandations mentionnées dans cette stratégie, en plus des encouragements administratifs et financiers, le renforcement de la formation et de la recherche aquacole afin de remédier aux insuffisances et résoudre les difficultés rencontrées.

C’est dans ce contexte que rentre l’objet de l’organisation de cette formation. Ainsi, lors de cette rencontre nous sommes appelés à partager les connaissances acquises dans un domaine où les avancées scientifiques et techniques sont très rapide

Mesdames et messieurs, honorables invités

Avant de terminer, il est m’est agréable de rendre hommage à la collaboration et à la solidarité qui nous unit. Je renouvelle mes remerciements aux organisateurs de cet importante rencontre à laquelle je souhaite un plein succès, je souhaite encore une fois la bienvenue à nos honorables hôtes ainsi qu’un excellent séjour parmi nous à Monastir.

Bonne continuation et Merci à tous.
Honorable Guests,

Ladies and Gentlemen,

I am particularly pleased to be here today for this important event that INSTM and INOC are organizing jointly with the support of other international organizations, namely:

"Training Course on Development of Aquaculture Production and Technologies"

I would especially like to thank Professor Mustafa Ergun, Executive Director of INOC, who took part in this event in person. This demonstrates the interest of our two institutions in the aquaculture sector for sustainable and sustained exploitation of the fishery resources of INOC member countries.

Ladies and gentlemen, ladies and gentlemen,

Tunisia is a small country with 11 million inhabitants; its natural resources are not numerous or diversified and its climate is very irregular. Nevertheless, thanks to the dynamism of its people, it has succeeded in its challenge of modernization and development. It has relied on the rational exploitation of the resources of our country to make this march forward possible and place Tunisia at the beginning of the 3rd millennium among the emerging countries.

Conscious of the importance of Aquaculture’s role in ensuring the increased need for animal proteins at global, regional and, above all, national levels, with a view to reviving this sector which has experienced difficulties and of the results unconvincing in its beginnings, the Tunisian authorities have elaborated, a new strategy for the development of Aquaculture in Tunisia. Among the recommendations mentioned in this strategy, in addition to administrative and financial incentives, the strengthening of aquaculture training and research in order to remedy the shortcomings and to solve the difficulties encountered.

It is in this context that the object of the organization of this training falls. Thus, during this meeting we are called to share the knowledge acquired in an area where the scientific and technical advances are very fast.

Ladies and gentlemen, honorable guests

Before concluding, I am pleased to pay tribute to the collaboration and solidarity that unites us. I would like to reiterate my thanks to the organizers of this important meeting, which I wish you all a very successful, welcome to our honorable guests and an excellent stay with us in Monastir.

Good continuation and thanks to all.

Abdel Melek SELAMI
AQUACULTURE STATUS
CURRENT STATE AND FUTURE PROSPECTS OF THE AQUACULTURE ACTIVITIES IN ALGERIA

Djamel Eddine ZOUAKH and Abderrafik MEDDOUR
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Abstract

Since 1999, the Algerian aquaculture development program was improved through various steps of implementation of experimental extensive and intensive production on the basis of imports of fingerlings of the freshwater species Aristichthys nobilis, Hypophthalmichthys molitrix, Cyprinus carpio, Ctenopharyngodon idella, Micropterus salmoides and Sander lucioperca. However, this procedure lead to the accidental introductions of 9 species of fishes; Alburnus alburnus, Abramis brama, Carassius gibelio, Carassius carassius, Lepomis gibbosus, Gymnocephalus cernua, Perca fluviatilis, Pseudorasbora parva and Scardinius erythrophthalmus. Indeed, the various imports of live fishes lead to the translocation of many pathogen agents in Algeria. Moreover, the strategies of development of the aquaculture sector are facing difficulties at different levels, from the installation of the projects to the supply of products to the local markets. If the actual fish farming is mainly focused on the freshwater inland dams, lakes and small reservoirs, the sea farming remains very low with two mussel farms and five sea farming units of sea bass Dicentrarchus labrax and sea bream Sparus aurata in off-shore cages. On the other hand, initiated in 2001, the National Plan for Aquaculture Development with its component “Fish Culture in Saharan Areas” was targeting both extensive and intensive farming of Oreochromis niloticus, Clarias gariepinus and of the king shrimp Litopenaeus vannamei in the semi-arid and arid areas in the Southern Algeria. We consider that a sustainable aquaculture should be insured through efficient administrative organization and regulations as well as through vulgarization, professional training, continuous research programs, national and international cooperation and investments in the annex industries of the fish-farming activities.

Keywords: Marine farming, Aquaculture, Saharan fish-farming, Algeria.

1. Introduction

In many Mediterranean countries, fish farming is considered as a new activity within the fisheries sector. Regarding the increasing demand in the supply of food with high level proteins at reasonable quality/price ratio, the aquaculture sector represents a solution for providing various products to the markets. In Algeria, the fish farming industry is emerging through a policy of sustainable development within the natural coastal and wetlands potentialities. Measures were taken by the government classify this activity as the centre of priorities of the National Plan for the Development of Aquaculture (NPDA). To support and promote the fish farming projects, various instruments were provided through legal devices and financial subsidies.
2. Current situation of aquaculture in Algeria

The Algerian experience in the fish farming industry is in its early stages, but it is undergoing through a nationwide developing program with the implementation of fish farms within the natural richness in wetlands. The diversified natural potentialities are represented by an inland surface area of more than 100 000 ha including the wetlands in the National Park of El Kala which offer considerable possibilities of fish production resources:

- Lagoon El Mellah (800 ha): Yield/hectare: 46.5 kg/year (Eel, Sea bass, Sea bream and Mullet),
- Lake Tonga (2 700 ha): Eel fishing,
- Lake Oubeira (2 200 ha): Eel fishing and Cyprinids extensive farming.


3. The marine farming

The marine culture was initiated on the basis of imports of larvae and fingerlings of various species (Tab.1) for the local intensive farming (concrete raceways and sea cages). In the past, the oyster *Crassostrea gigas* was introduced in the Lagoon El Mellah but its farming is not any more undertaken since more than a decade. The shrimp culture concerned two species *Penaeus monodon* and *Litopenaeus vannamei*.

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<th>Imported species</th>
<th>Country</th>
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<tr>
<td>Oyster <em>Crassostrea gigas</em></td>
<td>France – Italy</td>
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<tr>
<td>Sea bream <em>Sparus aurata</em></td>
<td>Spain – Italy</td>
</tr>
<tr>
<td>Sea bass <em>D centrarchus labrax</em></td>
<td>Spain – Italy</td>
</tr>
<tr>
<td>Tiger shrimp <em>Penaeus monodon</em></td>
<td>Egypt</td>
</tr>
<tr>
<td>King shrimp <em>Litopenaeus vannamei</em></td>
<td>South Korea</td>
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Table 1: Origin of imported species for marine farming in Algeria

The five main sea farms are dispatched along the coast (Fig.1):

- **Aquasol** (Ain Temouchent district): Intensive breeding of sea bass, sea bream and meagre (*Argyrosomus regius*) in inland raceways and in six offshore cages. Production in 2014 was 700 T.

- **Aquatafna** (Ain Temouchent district): Intensive breeding of sea bass, sea bream and meagre. The total first production in 2013 was 300 T. Targeted production is 1 600 T and 2 millions of larvae/Year.

- **Azeffoun "M’lata"** (Tizi Ouzou district): Targeted production is 1 200 T/ Year of sea bass and sea bream by intensive breeding.

- **Sarl Hypone Aquacole of Zemmouri** (Boumerdes district): Intensive breeding of sea bream in 6 offshore cages and sea bass in 2 offshore cages. Total production in 2014 was 600 T.

- **ONDPA Cap Djenet farm** (Boumerdes district): Intensive breeding of sea bream in inland raceways.
Beside that, there are 2 private structures (*Seam* and *Orca Marine*) involved in the farming of the mussel *Mytilus galloprovencialis* (**Fig.2**) in open sea (Average production 15 T/Y) and a small farm at El Marsa (Skikda district) dedicated to the breeding of shrimps and where successful reproduction of *Penaeus monodon* and *Litopenaeus vannamei* were recorded (**Fig.3**).

**Figure 1:** Location of the main marine farming along the coast of Algeria

**Figure 2:** Mussels species cultivated in 2001 in the Lagoon of El Kala

**Figure 3:** Giant Tiger prawn in raceway at El Marsa shrimp farm
4. The freshwater fish farming

During 1985, 1986, 1991, 1997 and 2000, a total of 36 millions of fingerlings, mostly Cyprinids were imported from Hungary and introduced in various lakes, dams and small reservoirs of the country (Meddour, 2009; Meddour et al., 2011). Globally, 7 species were concerned: *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Ctenopharyngodon idella*, *Micropterus salmoides*, *Sander lucioperca* and *Silurus glanis*. However, several accidental introductions of 9 species of fishes occurred through these transfers of live fishes: *Alburnus alburnus*, *Abramis brama*, *Carassius gibelio*, *Carassius carassius*, *Lepomis gibbosus*, *Gymnocephalus cernua*, *Perca fluviatilis*, *Pseudorasbora parva*, and *Scardinius erythrophthalmus*.

On the other hand, artificial spawning was successfully carried out on *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Aristichthys nobilis* (Meddour et al., 2005, Meddour, 2009), on *Sander lucioperca* (Meddour et al., 2005; Bouali et al., 2006; Zouakh and Meddour, 2010), on *Clarias gariepinus* (Zouakh and Meddour, 2010) and on the Black bass *Micropterus salmoides* (Zouakh and Meddour, 2008; Zouakh and Meddour, 2017).

4.1. The Tilapia farming in the Saharan area

The breeding of *Oreochromis niloticus* has been proved to be reliable in many countries of the world and it represents 85% of the world Tilapia farming. In order to achieve one of the NPDA targets, the Tilapia farming within the arid and semi-arid areas started in 2002 with the first wide operation concerning a total of 4 670 fingerlings and 210 adult specimens of *O. niloticus* and the Red Tilapia (*O. mossambicus* x *O. niloticus*) (Tab.2) that were imported from Egypt (Zouakh et al., 2006). Fishes were distributed to the fish farmers having sufficient infrastructures and water supplies. *O. niloticus* was targeted because of its rusticity to the particular climatic conditions in the Algerian Sahara and its resistance to unfavourable conditions. The breeding with artificial food supply is very easy allowing a rapid growth rate.

Actually, there are three main intensive farming poles of *O. niloticus* and Red Tilapia:

- **Fatstep** (Saida district): Intensive breeding. Targeted production: 100 tons/year.
- **Pesca de da duna** (Ouargla district): Intensive breeding. Total capacity = 14 400 m³. Expected production: 1 000 tons/year.

The extensive breeding of Tilapias in irrigation ponds is also well developed ensuring small quantities of productions to the local farmers. This kind of breeding is now integrated to the agriculture and water of fish farming, rich in natural organic materials, is also used for the land irrigation and contributes to improving the agricultural production (Zouakh et al., 2016). Actually, several other projects of *O. niloticus* farming are either still being implemented or in the phase of production implying extensive, semi-extensive or intensive breeding systems. The few examples cited in this survey indicate the importance given to the Tilapia farming activity in the Saharan areas.
<table>
<thead>
<tr>
<th>District</th>
<th>Nature of the sites</th>
<th>Quantity (A = Mature adults)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2002</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bou Ismaïl</td>
<td>CNDPA</td>
<td>600+200 A</td>
</tr>
<tr>
<td>Ain Defla</td>
<td>Irrigation pools</td>
<td>500</td>
</tr>
<tr>
<td>Ain Temouchent</td>
<td>Private investment</td>
<td>200</td>
</tr>
<tr>
<td>Relizane</td>
<td>Merdjet El Amel Pond</td>
<td>100</td>
</tr>
<tr>
<td>Tebessa</td>
<td>Irrigation pools</td>
<td>530</td>
</tr>
<tr>
<td>Ghardaïa</td>
<td>Private investment</td>
<td>600</td>
</tr>
<tr>
<td>El Oued</td>
<td></td>
<td>370</td>
</tr>
<tr>
<td>Djelfa</td>
<td></td>
<td>450</td>
</tr>
<tr>
<td>Biskra</td>
<td></td>
<td>150 + 10 A</td>
</tr>
<tr>
<td>Sidi Bel Abbes</td>
<td></td>
<td>700</td>
</tr>
<tr>
<td>Ouargla</td>
<td></td>
<td>700</td>
</tr>
<tr>
<td>Bechar</td>
<td>Djorf Torba Dam</td>
<td>200</td>
</tr>
<tr>
<td>Adrar</td>
<td>Private investment</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>4,670 fingerlings + 210 broodstock fishes (A)</td>
</tr>
<tr>
<td><strong>2003</strong></td>
<td></td>
<td></td>
</tr>
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<td>300</td>
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<tr>
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<td>1,500</td>
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<td>Setif</td>
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<td>2,000</td>
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<tr>
<td>Relizane</td>
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<td>1,500</td>
</tr>
<tr>
<td>Guelma</td>
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<tr>
<td>Ouargla</td>
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<td><strong>Total</strong></td>
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<tr>
<td><strong>2004</strong></td>
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<td>Djelfa</td>
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<tr>
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<tr>
<td>Setif</td>
<td></td>
<td>100</td>
</tr>
<tr>
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<td></td>
<td>60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>15,410 fingerlings</td>
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</table>
4.2. The socio-economic impacts of the Tilapia culture

If compared to the average consumption in the Mediterranean area (12 kg/inhabitant/year) or in the Maghreb (7.5 kg/hab./year), Algeria is characterized by a very low level of fish consumption with a food ratio reaching 3.02 kg/inhab./year in 1999 and 5.10kg/inhab./year in 2005 whereas the minimum threshold standard of the World Health Organization (WHO) is 6.2 kg/inhab./year. For the Saharan population, the recent estimated average level of fish consumption is 0.05kg/inhab./year (M.P.R.H., 2006) which is far below the WHO standard. Within the prospects of the various projects of Tilapia farming, it is expected that this rate of consumption should rise up to 0.4 kg/inhab./year but still remaining very low.

In the South of Algeria, the local population concerns can mainly be defined as the needs to ensure food self-sufficiency and to have food of good nutritional quality. The integration of the Tilapia farming activity with the traditional agriculture and livestock farming is a new challenge that is expected to provide solutions to the predominant deficiencies of fresh fish in the local markets. Setting up such activity in the arid and semi-arid areas represents an opportunity to boost a new professional dynamism that will generate considerable dividends.

4.3. The catfish farming in the Saharan area

The African catfish *Clarias gariepinus* (Clariidae) is the most adapted species to the Saharan fresh-water farming. This species has various ideal breeding characteristics such as a high growth rate, a high stocking density tolerance, a good food conversion rate, a good flesh quality and a high annual profitability rate. Recent intensive breeding of *C. gariepinus* is successfully conducted at "*Ezzahra*" and "*Pesca de la duna*" fish farms.

The artificial reproduction of *C. gariepinus* is a perfect solution to avoid the costly import operations as well as the transfer of pathogenic agents. Our experiments on the induced reproduction of *C. gariepinus* were successfully performed through easily applicable procedures (Zouakh and Meddour, 2010).

4.4. The shrimp culture in the Saharan area

Since July 2016, the whiteleg shrimp or King prawn *Litopenaeus vannamei* is cultivated in the shrimp farm at Ouargla. This project is carried out as a part of Algerian-South Korean cooperation, funded by the Korean side at about 5 millions USD. The project aims at guaranteeing the sustainable development of industries related to the shrimp aquaculture as well as the transfer of the Korean knowledge and experience to the Algerian operators, with the implementation of the farming infrastructures, management and marketing plans.

The shrimp farm has a total surface area of 10 hectares with various units: ponds, breeding raceways, food processing unit and a laboratory. In the first experimental step, this farm is expected to produce 5 tons/year before reaching a production of 10-20 tons/year, after completion of extension works during 2017 (Fig. 4 & 5).
5. The deficiencies in the Aquaculture National Program

* The various imports of live fishes lead to the translocation of many pathogen agents in Algeria including the Viral Encephalopathy and Retinopathy (VER) or Viral Nervous Necrosis (VNN) in *Sparus aurata* (Fig. 6) and the Flexibacteriosis (*Flexibacter maritimus*) in *Dicentrarchus labrax* (Fig. 7) (Meddour, 2016 GTVA), the Spring Viraemia of Carp and more than 15 species of parasites mostly of freshwater fishes (Meddour and Meddour-Bouderda, 1999; Meddour and Bouderda, 2001; Meddour et al., 2007a ; 2007b, 2010, 2011).
6. Conclusion and prospects

Regarding the considerable financial volume of investments (more than 60 millions USD), the new Algerian experience in the fields of aquaculture will certainly lead to very important changes at various levels of technical and the socioeconomic aspects. However, the additional annex industries of the fish-farming activities have not yet been taken into consideration by the investors despite the fact that they are essentials and although integrated into the NPDA.

Even though, the actual levels of production of the aquaculture sector remain insufficient in regard to the high demand for fish products in the local markets. Hence, the WHO standard of fish consumption will not yet to be reached soon. Besides that, the Saharan fish-farming will also have to face the growing demands of the markets. We believe that the Tilapia and the African catfish farming will provide solutions for the local market with supplies of fresh and highly nutritive products. This can be realised only if the specific artificial food industry is well developed to provide efficiently the intensive fish farming activities.

In order to diversify Algerian economy and to promote and develop the aquaculture activities in the south of the country, as a promising joint program (DIVECO 2) has been set between the Algerian Ministry of Agriculture, Rural Development and Fishing and the European Union. The programme aims at establishing a diagnosis on the state of the fish farming sector and identifying the potentialities to boost the aquaculture activities in the Saharan area. This cooperative partnership programme revolves around three main lines:

* The lack of specialized training courses in fish farming: The university academic programs are mostly directed towards marine biology courses and this fact is leading to the deficiency of specialized personnel in the aquaculture industry.
* The lack of specialized training courses in fish pathology in the veterinary academic programs.
* The lack of concern about the environmental impact of the alien species, the risks of translocation of pathogen agents and the very low health monitoring of the imported fishes.
- The strengthening of leadership capacities in this area,
- The support for the promotion and the development of all aquaculture fields, including inland fishing practiced particularly in lakes, dams and Saharan fish breeding ponds,
- Encouraging the integration professionals and specialized associations.

Presently, the aquaculture production did not exceed 4,000 tons/year. The goals for 2017 are expecting an aquaculture production of 17,000 tons through 2,100 projects (public and private) of which 70% are related to fish farming in irrigation basins.

In regard to all these aspects, at the Badji Mokhtar Annaba University, the research team of the Aquaculture and Pathology Research Laboratory (AQUAPATH) is giving high priority to the following fields:

* Artificial spawning of freshwater and marine fishes,
* Monitoring of the global pathogen threats to the fish farming activities and the application of intelligent therapeutic and prophylactic treatments,
* Assessment of the negative environmental impacts of the alien fish pollutions,
* Backing up a sustainable exploitation of the aquatic environments,
* Development of research programs to the related fields,
* Improvement of regional and international cooperation.

References


AQUACULTURE IN EGYPT

Mohamed Souady, Suzan Hassan, Mai Wassel
National Institute of Oceanography and Fisheries (NIOF)

Importance of aquaculture in Egypt

There is shortage in animal protein in Egypt, so the logical solution to that problem is aquaculture. Aquaculture is currently the main source of fish protein and the best option for reducing the gap between production and consumption of fish in Egypt.

Aquaculture history in Egypt
Fig. 1 Total aquaculture production of the Arab Republic of Egypt (FAO FishStat)

Fig. 2 Aquaculture vs. Fisheries in Egypt

Fig 3 Per Capita consumption of fish in Egypt 2002-2015 (GAFRD and CAPMAS)
Fig. 4 Cultured species in Egypt (aquaculture vs. fisheries)

Fig. 5 Fish type production (%)

Table 1 World top producers by selected measurements of aquaculture productions (Unit: tonnes, fish weight) (FAO 2016)
Farming systems distribution and characteristics

Most aquaculture activities are generally located in the Northern Nile Delta Region, fish farms usually found clustered in area surrounding Delta Lakes (Maruit, Edko, Boruls and Manzala).
Table 3 Practices/systems of culture

<table>
<thead>
<tr>
<th>Practices/systems of culture</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi intensive</td>
<td>645169 ton.</td>
</tr>
<tr>
<td>Intensive</td>
<td>2412 ton.</td>
</tr>
<tr>
<td>Cage culture</td>
<td>172632 ton.</td>
</tr>
<tr>
<td>Poly-culture in rice</td>
<td>17537 ton.</td>
</tr>
</tbody>
</table>

Semi-intensive aquaculture

- Farms Location: northern and eastern part of Nile Delta
- Total land area: 159,191 hectares
- Production: between 2.8 to 8 ton./ha.
**Intensive systems**

Intensive pond aquaculture is now expanding to replace large areas of the semi-intensive ponds.

- **Total area**: 19,938 ha.
- **Average production**: 14 – 25 ton./ha. (mainly species are tilapia, and mullets).

**Cage culture**

There are 4500 cages in the northern branches of Nile Delta.

![Cages in the Nile Delta](image)

**New projects of aquaculture in Egypt**

The target production of aquaculture in 2018 is 2.1 mt.

- **Area**: 8000 ha.
- **Species**: European sea bass, sea bream, mullet, lott and shrimp

![The National Project for Developing East Port Said](image)

- **Area**: 7,857 ha.
- **Species**: European sea bass, sea bream, mullet, lott and shrimp

![Gillon Lake Project in Kafir El Sheikh](image)

- **Area**: 2,100 ha.
- **Species**: European sea bass, sea bream, mullet, lott and shrimp

![The National Project for Marine Aquaculture in the Suez Canal](image)

Fig.10 The new aquaculture projects and their properties
Aquaculture production in the world

According to FAO report in 2016, aquaculture produced almost 74 million tonnes of aquatic animals in 2014 and almost 28 million tonnes of aquatic plants. Globally, aquaculture supplies more than 50 percent of all seafood produced for human. Global per capita fish consumption has risen to above 20 kilograms a year for the first time. And in Iran was 10 kg. According to word bank prediction in 2030, 62% of the fish consumed will come from aquaculture.

Aquaculture development in Iran-History

Real efforts to develop the aquaculture industry in Iran have just been taking place over the last three decades with good growth reported particularly since 2003. Aquaculture development began in the early 1980s along the Caspian Coast and in some of the southwestern provinces. The first aquaculture experiment was conducted with rainbow trout (Oncorhynchus mykiss) culture near Tehran in Mahisara (Karaj) in 1959. The first farm for warm water aquaculture was established in the Gilan Province by the Sefidrud company Rasht) and the Abzi company in Khuzestan Province (Shooshtar) in 1971. In 1973, efforts began for the culture of sturgeon fingerlings in the province of Gilan. After the Iran-Iraq war in 1988, the Iranian government began paying more attention to its fisheries and aquaculture industry. Bony fish stocks decreased dramatically in those years, primarily due to overfishing, environmental pollution and illegal fishing. As a result, farms for fry and fingerling culture were developed with the purpose of re-stocking the sea with commercially important species. The sector developed fast after the Islamic Revolution of 1979 with production increasing from 5,000 tonnes in 1978 to 125,000 tonnes in 2005.
- **Semi-intensive aquaculture:**

In Iran this includes production of carp in earthenponds, rainbow trout in raceways (approximately 20kg/m² in 2008) and shrimp farming. Raceways are made of concrete and water runs through continuously. Trout farms have been developed mainly in mountainous areas along the centre, north western and western parts of the country where winters are cold and summers are cool.

- **Intensive and super intensive aquaculture**

108 licenses have been issued in recent years for the development of recirculation production systems. Out of these, 32 are known to be operational with a capacity of 2,400 tonnes. In 2002, 430 tonnes of rainbow trout were produced using this method (3% of total Rainbow trout production). Equipment inadequacy has been the main reason for lower productivity levels and the costs associated with this method are still higher than raceway systems.

- **Integrated farming systems**

Although not a common method, the Iran Fisheries Organisation has received funding with the purpose of introducing new techniques to increase the productivity of both water and soil resources in the agriculture sector. Fish culture in paddies following the harvesting of rice and irrigation reservoirs have brought considerable benefits to rural families including food security. Around 2,100 tonnes (13%) of the total rainbow trout production is produced using integrated systems as are 740 tonnes of Chinese carp (1.3%). There are extensive rice paddies in the northern part of Iran which would allow for further development and expansion of this system.

- **Fish cage culture**

Most fish cages are located in lakes and dams with rainbow trout production from cages being 754 tonnes in 2014. A development plan is underway in the Caspian Sea, the Persian Gulf and the Gulf of Oman for the development of marine cage culture. According to a reliable Norwegian company report in 2003, Iran has a capacity for 900 thousand tonnes of aquaculture in the Persian Gulf, the Gulf of Oman and the Caspian Sea. Marine cage culture is expected to increase to 1 million and 500 thousand tonnes at the end of the sixth development plan.

**Seafood production in Iran – Fisheries vs Aquaculture**

The total fishery production was 983.897 tonnes in 2015. In this year, 582.349 tonnes (59% of total fishery production) of fish production were obtained from the capture fisheries and 401.548 tonnes (41% of total fishery production) of production was obtained from the aquaculture production. Iran fisheries plan to increase production of aquaculture from 401,548 tonnes in 2015 to 811,000 tonnes in 2021, which will increase aquaculture production proportion to fisheries of 39.2 percent to 45.8 percent (2021, 39.2 to 45.8). In 2014 there were 213 million pieces of ornamental fish produced.
Consumption per capita in Iran

Consumption per capita in the world is 20Kg (10Kg in Iran). Expansion of aquaculture throughout the country, together with an increase in people’s knowledge of fish as a healthy food, is helping to change people feeding attitude to fish and development of the seafood processing industry through better quality methods and technologies and more appealing packaging. Seafood consumption is expected to increase to 18kg per capita by 2025.

Number of fish & shrimp farms in Iran

There are 14 stock enhancement government hatcheries aimed at rehabilitation of fisheries particularly in the Caspian Sea. These focus mainly on Caspian kutum and 5 species of sturgeon including: *Acipenser guliendaeid*i - Russian sturgeon, *A. persicus* - Persian, *A. stellatus* - Sevruga, *A. nudiventris* - Ship sturgeon, Beluga - *Husohuso*. Sea farming is comprised of 18 Cages.
Human resources

The total number of people employed in fisheries has risen from 93,213 in 1993 to 208,472 by 2014 of which the number directly employed in aquaculture and aquaculture-based fisheries was 68,287. It is expected that aquaculture investment will result in a growing number of jobs during the sixth development plan period (2016 - 2020).

Investment in aquaculture subsector

The Islamic Republic of Iran has only given serious attention to this activity during the last three decades where investment in aquaculture development began in the early 1980s along the Caspian Sea coasts regions and in some of the south-western provinces. It is part of the main responsibilities of the IFO within the aquaculture sub-sector. Government investment in aquaculture infrastructure increased from 1277.1 Milliard rial in 2003 to 4989.8 Milliard rial to 2014.
Iran’s Exports by product - 2015

82,000 tons of seafood was exported with a value of $350 million, 15% more than the previous year. Out of this, 13,000 tons were shrimp. The rest consisted of sturgeon and caviar, shrimp and other fishes. Vietnam and the UAE were the main destinations for Iranian shrimp. 1.5 tons of caviar was produced, over 65% of which was exported to Japan, Germany, the UAE, Britain, Italy, Belgium, South Korea and Norway. The total value of such exports was $1.7 million.

Major aquaculture activities in Iran

Warm water fish culture

Warm water fish culture species in Iran include silver, common, grass, and bighead carps. Production of these species on fish farms has increased by 46 percent in year 2014. These species are cultured together typically in earthen ponds of approximately 1.8-2.5m depth.
- Coldwater fish culture

Trout farming started in 1959 and the production increased from 599 tonnes in 1978 to 177,950 tonnes in 2015. Rainbow trout (*Oncorhynchus mykiss*) is the main cold water fish species farmed in Iran. At present, Iran has been acquired the first rank of rainbow trout culture in fresh water of the world.

![Fig.9 Coldwater fish culture](image)

- Sturgeon culture

Recently, great sturgeon *Huso huso* has aroused interest from government and private enterprises for potential aquaculture use. The Islamic Republic of Iran has around 83 active caviar farms. Iran plan to increase sturgeon meat to 10000 tonnes & sturgeon caviar to 100 tonnes by 2021.

![Fig.10 Sturgeon culture](image)
Marine shrimp culture

In 2014, shrimp production reached almost 22475 tonnes produced from 7053 hectares of coastal ponds, located mainly in five provinces in southern and northern regions; compared to the previous year, production levels and land use increased by approximately 47.58 and 76.99 percent, respectively. The high price of shrimp on the world market has been one of the major factors for the increasing production in available ponds for shrimp culture.

Fresh water shrimp culture

Shrimp and prawn culture includes Indian white shrimp, banana shrimp and green tiger shrimp. Indian shrimp are reared in the semi-intensive earthen ponds. Shrimp is a species with high economic value that are used mainly in developing countries like Iran usually as export to other nations. Due to a white spot syndrome outbreak in 2005 and the economic loses it caused; Indian shrimp was replaced with white leg.

Fish farming in natural & semi-natural water resources

The total area of inland water bodies including lagoons, lakes, reservoirs, rivers, etc., in Iran is estimated to be about 1.5 million ha. Some of the water bodies are stocked with common, bighead and silver carps. Fresh water and Caspian Sea capture fisheries (including waters enhanced by stocking) have leveled off at around 34000 tonnes/year, with a steep drop in 2000-2003 probably due to the continuing drought conditions.
- Marine cage culture

Development of the aquaculture sector in Iran will have a focus on marine cage culture. Most fish cages are located in lakes and dams with rainbow trout production from cages being 754 tonnes in 2014. The candidate species for mariculture development in the Caspian Sea include, among others, rainbow trout (*Oncorhynchus mykiss*) and sturgeon (*Huso huso*). The Persian Gulf and the Gulf of Oman include groupers (*Serranidae*), Sobaity bream (*Sparidentex hasta*), barramundi (*Latescalcarifer*), cobia (*Rachycentron canadum*), silver pomferet (*Pampus argenteus*) and fourfinger threadfin (*Eleutheronematetradactylum*).

- Stock enhancement

As part of a stock enhancement programme along the southern Caspian Coast, the government had established 9 hatcheries to produce bony fishes and sturgeon fingerlings. There are several stock enhancement programmes for shrimp and fish resources on the Persian Gulf and the Gulf of Oman area and indigenous species in inland waters as well. In 2014 Iran released more than 331935 thousand pieces fish fingerlings and 30000 thousand pieces shrimps through the Iranian Stock Enhancement Program.
Main concern and challenges of aquaculture development from the management and technological point of view,

- Disease management, especially when aquaculture is intensified
- Access to market management
- The species nominated to be cultured, especially marine fishes
- Lack of proper technology
- Locally limited supplies of fish seed
- Access to water and water body (Inland aquaculture)
- Lack of enough training and microcredit
- Lack of participatory decision-making
- Lack of proper investment
- Lack of enough human resource development and capacity development
- High cost for preparing infrastructures

Conclusion

Although, the history of aquaculture in Iran is young and dated back to three decades, but nowadays, the speed of aquaculture development is high, especially because the use of marine and brackish waters are under the program for development.

References

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- Iranian Fisheries year Book
- Iranian Statistic and Information Organization
- Iranian Central Bank
THE STATUS OF AQUACULTURE IN THE ISLAMIC REPUBLIC OF IRAN

Mohammad Ali Salari-Alibadi
Khorramshahr University of Marine Science and Technology

Introduction

The Islamic Republic of Iran is located in the Middle East between latitudes of 25° 00' and 39° 47' N and longitude of 44° 02' and 63° 02' E. The total area of the Country is 1 648 195 km$^2$ which includes 1 636 million km$^2$ land area and 12 000 km$^2$ of water surface. The coast line stretches for 2 700 km to the south in the Persion Gulf and the Oman Sea and in the north along the Caspian Sea (Kalbassi et al., 2013).

![Location of the Islamic Republic of Iran](image)

Table 1 Key facts

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<td>Head of State</td>
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</tbody>
</table>
Weather conditions differ greatly across the country allowing a range of different types of aquaculture to be practised. Fish farming in the Islamic Republic of Iran began with the enhancement of fish species selected from the Caspian Sea and then continued through the development of semi-intensive aquaculture utilizing various Chinese carp species, as well as the rainbow trout (*Oncorhynchus mykiss*). In recent years, shrimp culture (whiteleg shrimp - *Penaeus vannamei*) and marine fish culture such as Sabaity seabream (*Sparidenex hasta*), barramundi (*Lates calcarifer*), orange-spotted grouper (*Epinephelus coioides*), has become the main focus for government investment in the Gulf region where it has been developed in earth ponds, land bass and sea cages.

**Climate**

Summer season are long, hot and dry, winters are short and cool. In the northwest regions during December and January winters are cold with heavy snowfall and the temperatures are below zero. Weather is mild during spring and fall. Summers are dry and hot. Winters are mild and summers are very hot, with average daily temperatures exceeding 38° C in July in the south part of Iran. The average precipitation is 250mm between October and April in most of the country. It is 500mm at the higher mountain valleys of the Zagros and the Caspian coastal plain. In the western parts of the Caspian the precipitation is 1000mm or more throughout the year (Rahimikhoob, 2010).

**Geography**

Iran is a country located in the Middle East. It has a strategic location on the Persian Gulf and Strait of Hormuz, which are vital maritime pathways for crude oil export. The country has about 43 islands. The lowest point in the country is at 28m. in the Caspian Sea. The highest point is 5,610m at Mount Damavand. The coastline of the country is 2,440km. long.

Borders are; **North-West**: Armenia and Azerbaijan, **North**: Caspian Sea, **North-East**: Turkmenistan, **West**: Afghanistan and Pakistan, **South**: Persian Gulf and Gulf of Oman, **East**: Turkey and Turkey.

Iran has a very young population, with 60% being under the age of 30 and 41% under the age of 25. The ratio between sexes stands at 1.03 males/females. Median age is 29.6 years (Barthold, 2014).

**Seafood Production Overview - Fisheries**

At the end of the last Iranian year (ending March 2016), Iran produced over 1 million tons of seafood, its highest production levels so far. 82,000 tons of seafood were exported with a value of $350 million, 15% more than the previous year. Out of this, 13,000 tons were shrimp. The rest consisted of sturgeon and caviar, shrimp and other fishes. Vietnam and the UAE were the main destinations for Iranian shrimp. 1.5 tons of caviar was produced, over 65% of which was exported to Japan, Germany, the UAE, Britain, Italy, Belgium, South Korea and Norway. The total value of such exports was $1.7 million. Approximately 95% of catches come from Southern waters, the remaining comes from catches in the Caspian Sea (2013). Tuna and tuna-like species are a major component in large pelagic fisheries in Iran and one of the most important activities in the Persian Gulf & Oman Sea (Rönnbäck, 1999, FAO, 2017).
Seafood Consumption

Iran is considered to have one of the lowest seafood consumption rates in the world. Trends have been changing over the past few years however, as consumption has increased from just 4kg in 2005 to 10kg per capita in 2014. (The world average currently stands at over 20kg). The trend in consumption has changed partly due to promotion of seafood as a source of protein and government encouragement for higher seafood consumption, development of the seafood processing industry through better quality methods and technologies and more appealing packaging (Naylor et al., 2002).
Needs And Feasibility

Like other Middle Eastern countries, Iran is also concerned over food security. Aquaculture is seen as an important part of the solution. Additionally, aquaculture is seen as a means to improve the welfare of fishers and farmers, promote exports and increase fish production to meet demands. Brackish-water and saltwater aquaculture, fish production from cages and ponds, freshwater production from lakes, reservoirs and rivers are all viable methods for aquaculture in Iran. Favorable climatic conditions, suitable water quality, high natural productivity of the soil, space availability, economic and social welfare of coastal communities are all factors that makes the long southern coastline of Iran highly suitable particularly for shrimp culture development. Typical production levels reported as, warm water fish farming - 10 MT./ha, cold water fish farming - 3 MT./100 sq2, shrimp farming 3.5-4 MT./ha (McVey et al., 2002).

![Aquaculture contribution to fishery production](image)

In 2014 there were 203m piece of ornamental fish produced. As part of a stock enhancement programme 331m fingerlings were released. The majority of fingerlings consisted of sturgeon with some inland water species and shrimp. Sturgeon from the Caspian Sea is highly regarded for Caviar production. As a result, 80-90% of global sturgeon catch came from the Caspian Sea resulting in overfishing close to extinction levels.

The total area of fish ponds in the Islamic Republic of Iran is estimated at approximately 51,078 ha in 2014. The major warm water species produced are the common carp (Cyprinus carpio) and the three main Chinese carps, namely, grass carp (Ctenopharyngodon idellus), silver carp (Hypophthalmichthys molitrix) and the big-head carp (Hypophthalmichthys nobilis). Of the total Iranian aquaculture production in 2014, carps represented 45.8 percent, rainbow trout 34 percent, aquaculture-based fisheries production 13.9 percent, cultured shrimp 6 percent and 0.2 percent for other aquaculture products such as sturgeon and lobster.
About 80.7 percent of the total aquaculture production is utilized mainly for domestic markets in 2014. Aquaculture production increased rapidly from 3,219 tonnes in 1978 to 371,840 tonnes in 2014, representing approximately 39.2 percent of the total fish production. This proportion is expected to increase during the fifth sixth-year plan which began in 2017 to 45.5 percent. The legal and institutional framework for aquaculture development in the Islamic Republic of Iran is relatively well established, and the law on conservation and harvesting of aquatic resources, approved by the Parliament in 1997, drives fisheries and aquaculture activities in the country.

As part of a stock enhancement programme along the southern Caspian Coast, the government had established nine hatcheries to produce bony fishes and sturgeon fingerlings. All aquaculture activities, including feed and larvae production, fish and shrimp culture, processing, marketing and trade are carried out exclusively by the private sector. The government supports the private sector by providing low rate interest loans and suitable land at competitive prices.

The Islamic Republic of Iran, has given serious attention to aquaculture activity during the last three decades where investment in aquaculture development began in the early 1980s along the Caspian Coast and in some of the southwestern provinces. Initial attempts began with the culture of rainbow trout (*Oncorhynchus mykiss*) near Tehran at Mahisara (Karaj) in 1959, the first warm water farm was established in Gilan Province by the Abzi Company in 1971. Shrimp culture in the country goes back only as far as 1991 when the Food and Agriculture Organization (FAO) assisted the Islamic Republic of Iran with the development of shrimp farming in the Gulf region. The industry has developed so fast in the past years. Production reached 22,475 tonnes in 2014.

The total number of people employed in fisheries has risen from 93,213 in 1993 to 208,472 by 2014 of which the number directly employed in aquaculture and aquaculture-based fisheries was 68,287. Shrimp culture plays an important role in the alleviation of poverty and the creation of job opportunities along the southern coast of the country. It has created about 8,896 direct, full-time jobs in farms and hatcheries and almost an equal number of indirect, full-time jobs in feed production, processing units, trade, distribution and support services. Moreover, the number of part-time jobs created in related sectors such as construction, transport, equipment services, etc., has also been significant.
Warm Water Fish Culture

There are almost 50,835 ha allocated for warmwater fish farming around the country, producing some 170,341 tonnes of fish in year 2014 or 45.81% of total aquaculture production. The provinces of Mazandaran, Khuzestan, Guilan and Golestan are the main geographical areas where warmwater fish farms are located and account for 91.27 percent of the total warmwater production (155,485 tonnes). Mazandaran produced 30.33 percent; Khuzestan 28.08 percent, Guilan produced 25.15 percent and Golestan 7.75 percent of the total warmwater production (Holt et al., 2007).

Fig. 7 Carp production by type

Cold Water Fish Culture (Rainbow Trout)

Trout farms are distributed across the centre, the northwestern and western parts of the country mostly in mountainous areas characterized by cool summers and cold winters. The farming system consists of simple raceway made of concrete through which water flows continuously. An increased number of farms along with improving farming techniques and facilities have boosted annual production of trout from 280 tonnes in 1978 to more than 126,515 tonnes by 2014. The production of rainbow trout takes place in Mazandaran

Fig. 8 Trout production
In 2014, total coldwater production in these five provinces accounted for more than 49.7 percent of the total cold water production; rainbow trout alone accounted for more than 34.02 percent of the total aquaculture production.

**Shrimp Culture**

In 2014, shrimp production reached almost 22,475 tonnes produced from 7,053 hectares of coastal ponds, located mainly in five provinces in southern and northern regions. Compared to the previous year, production levels and land use increased by approximately 47.58 and 76.99 percent, respectively. The shrimp farming operations sharing is as follows: Boushehr 64.51 percent, Hormozgan 26.34, Khuzestan 6.06, Golestan 2.14 and Sistan va Belochehtan 0.93 percent (Rosenberg, 2008).

**Culture-Based Fisheries**

Lakes and reservoirs with an area totalling 1.5 million hectares provide a good capacity for freshwater aquaculture around the country. Among this total, some 351 water bodies with an area of 800 thousand hectares are regarded as having good potential for aquaculture purposes and recreational fishing. At present, some 746,096 hectares of natural and semi-artificial water bodies are under exploitation and in 2014, 51,666 tonnes of fish were produced. The southwestern region of the Islamic Republic of Iran (Khuzestan province) has good potential for receiving water from the Republic of Iraq,
however the water-use policy in Iraq will affect fisheries in these vast areas (Rosenberg, 2008).

A similar situation exists in the eastern part of the country, where rivers from Afghanistan bring water to the Hamon Lake. These water bodies create job opportunities; income and food for the population living in these areas, however, the lack of proper policy or agreement with neighbouring states creates difficulties and an unstable income and lifestyle for people in the catchment areas of these water bodies.

The main responsibilities of the Iranian Fisheries Organization within the aquaculture subsection are as follow:

- Aquaculture development research and implementation.
- Planning and preparation of the national development plans.
- Identification and training in the aquaculture sector.
- Improvement of existing farmers' knowledge.
- Promotion of new culture systems.
- Fish stock enhancement programmes.
- Investment in aquaculture infrastructure.

The construction and operation of any fish farms require licences and consists of three steps: 1. Acceptance of the plan (primarily agreement), 2. Permission for construction of the farm, 3. Farm operation and production licences.

Applied Research, Education And Training

Since 1970, the Ministry of Science, Research and Technology has organized a fisheries science course within Iran's university programmes. At present, 16 state, 10 universities of applied sciences and 36 open universities offer bachelor courses, and 12 state and 10 open universities offer master and post-graduate courses in various fields related to fisheries and aquaculture. The universities of Tehran, Shahid Chamran (Khuzestan Province), Tarbiat Modarres (Mazandaran Province) and Gorgan (Golestan Province) are the oldest universities in the field of fisheries science (National Research Council, 1978).

Aquaculture Methods

A review of the development of aquaculture in Iran by Tarbiat Modares University reports the following methods are currently applicable in Iran. The number of farms remains unclear as there are a few unlicensed farms (Rosenberg, 2008).

- Extensive aquaculture: The number of inland lakes, dams and reservoirs in Iran offer ideal conditions fish farming. The majority of reservoirs by the Caspian Sea produce Chinese and common carps (Rosenberg, 2008; Buck et al., 2008).

- Semi-intensive aquaculture: In Iran this includes production of carp in earthen ponds, rainbow trout in raceways (approximately 20km² in 2008) and shrimp farming. Raceways are made of concrete and water runs through continuously. Trout farms have been developed mainly in mountainous areas along the centre, north western and western parts of the country where winters and cold and summers are cool (Clifford, 1985; Rosenberg, 2008).
- **Intensive and super intensive aquaculture**: 108 licenses have been issued in recent years for the development of recirculation production systems. Out of these, 32 are known to be operational with a capacity of 2,400 tons. In 2002, 430 tons of rainbow trout were produced using this method (3% of total Rainbow trout production). Equipment inadequacy has been the main reason for lower productivity levels and the costs associated with this method are still higher than raceway systems (Wedemeyer, 1996; Browdy and Moss, 2005; Rosenberg, 2008).

**Integrated Farming Systems**

Although not a common method, the Iran Fisheries Organisation has received funding with the purpose of introducing new techniques to increase the productivity of both water and soil resources in the agriculture sector. Fish culture in paddies following the harvesting of rice and irrigation reservoirs have brought considerable benefits to rural families including food security. Around 2,100 tons (13%) of the total rainbow trout production is produced using integrated systems as are 740 Ttons of Chinese carp (1.3%). There are extensive rice paddies in the northern part of Iran which would allow for further development and expansion of this system (Morris and Winter, 1999).

**Inland Saline Aquaculture**

Inland salt affected areas become unsuitable for traditional agriculture. Research by the Inland Brackish water Fish Research Center of the Iranian Fisheries Science Research Institute, suggests that using saline groundwater in aquaculture could offer a solution for productive use of this land. Rainbow trout is potentially a suitable species for such culture systems due its adaptability to fast changes in salinity. Such a system would need to be developed in a manner that offers a sustainable economic base for rural areas and prevents further degradation of land. For the same reasons, future expansion would be limited to the size of the site. However, the abundance of salt-affected land and water resources lead to investigating these as a suitable resource for aquaculture (Allan et al., 2009).

![Fig.10 Number of fish farms and types in Iran](image)
Seafood consumption is expected to increase to 18 kg per capita by 2025. According to IFO, the annual per capita consumption of fish in Iran is 10 kg as against the global average of more than 20 kg. Greater awareness of fish as a healthy option and source of protein, expansion of aquaculture and campaigns by the IFO and Ministry of Health and Medical Education have all encouraged higher fish consumption (Sapkota et al., 2008). Increase of production and consumption, improvement of fishers and farmers welfare, promotion of exports and generally provision of food security are the main aims of Iran’s Fisheries development plans. Demand for trout is particularly exceeding production, and as such, the government is currently supporting a major programme to increase output. The programme has involved both building state-owned hatcheries and on-growing units and by providing licenses, land and juvenile fish to private farmers. Brown trout has also attracted some interest for culture in cages and raceways. Development of the aquaculture sector in Iran will have a focus on marine cage culture. A proportion of this will be in brackish waters with tilapia. Potential investors in cage farming will be granted with financial incentives according to the Management and Planning Organisation of Iran. Studies by the IFO have indicated good potential for cage farming in brackish water and marine species along the coasts of Iran. Cages can be placed in lakes, ponds, rivers or oceans. Some focus is being placed in the northern provinces of Gilan, Mazandaran and Golestan with cage farms expected to yield 20,000 tons of fish annually. Plans include export of fish fry to regional countries as well (Hu et al., 2014).

Research in Aquaculture

The oldest research center within fisheries is the Iranian Fisheries Research Organization (IFRO) which was established in 1917. Its objective is to conduct scientific research on aquatic organisms and their environment and identifying and developing best practices for stock recovery and sustainable harvesting. The commercial importance of sturgeon as a species has led to the establishment of the International Sturgeon Research Institute (ISRI), based in Rasht. Its research focuses on conservation and sustainable use of sturgeon stocks in the Caspian Sea. It also aims to encourage cooperation with scientists worldwide to conduct research in the Caspian Sea. Iran’s universities have been offering fisheries science courses since 1970 and these were arranged by the Ministry of Science, Research and
Technology. Bachelor, master’s and post graduate programmes related to fisheries and aquaculture are on offer in more than 20 universities. The longest running programmes have been by the Universities of Tehran, Gorgan University of Agricultural Sciences and Natural Resources in Golestan, the University of Guilan and Tarbiat Modares University (Chen, 1976; Kalantari et al., 2008). As yet there is little link between universities and industry however.

Other research organisations and university departments are;
- Iranian Fish Processing Research Center, Bandar Anzali,
- National Inland Water Aquaculture Research Center, Bandar Anzali,
- National Fish Processing Research Center, Bandar Anzali,
- Aquaculture Knowledge and Industry Coordination Center,
- Coldwater Fish Research Center – CFRC, Tonekabon,
- Seafood Processing Knowledge and Industry Coordination Center,
- Persian Gulf and Oman Sea Ecological Research Institute,
- Iranian Artemia Research Center,
- South of Iran Aquaculture Research Center, Caspian Sea Ecology Research Center, Sari,
- Mariculture Research Center, Ahwas,
- Langeh Research Station,
- Brackish water Research Station, Bafgh-Yazd, Inland water Aquatic stocks Research Center, Golestan,
- Offshore Fisheries Research Center, Chabahar,
- Iran Fishery Data Collection System (IFDCS),
- Department of Fishery, Faculty of Fisheries and Environment, University of Agricultural Science and Natural Resources, Gorgan, Iran
  • South of Iran Aquaculture Fishery Research Center, Ahvaz
  • Department of Agricultural Economics at Shiraz University
  • Department of Agricultural Management, Rasht Branch, Islamic Azad University
  • Department of Agronomy, Lahijan Branch, Islamic Azad University, Lahijan
  • Faculty of Marine Sciences, Tarbiat Modares University, Noor

Sustainability in Aquaculture

Sustainability as a concept, especially in fisheries and aquaculture is still in a relatively nascent stage. There have been some discussions mostly by educational and research institutions on suggestions or calls for sustainable practices in fish farming in recent years. One example is a paper by researchers from Islamic Azad University, that suggests integrated rice fish farming should be encouraged more due to its being a low cost and relatively simple method for producing high value protein and minerals. Rice fish farming offers the advantage of complementary use of land and water and decreased use of fertilizers, insecticides and pesticides. Economically from the point of view of the farmers this means less costs and increased profits through sales of rice and fish. Another example is the paper by Mohammad Allayari from the same university which aims to grade the sustainability of fisheries in the Guilan province. The paper
calls for action by government authorities as it concludes that fisheries are at a border of unsustainability and middle status rating (Black, 2001).

The desire to implement sustainable practices and pay consideration to the environment and the resources it offers are seen in the sixth Five-Year Plan (2016 - 2020) set by the IFO and local governments around the country for the fisheries and aquaculture sectors. The plan focuses on: Increase of the share of fish in ensuring Domestic Food Security,

- Responsible Conservation and Sustainable harvesting of Aquatic Resources
- Increase of productivity
- Improve balance of export/Import trade in fish market This will occur through: Food security through increasing domestic fish production
- Responsible and sustainable utilization of wild fish resources
- Proper use of infrastructure
- Improved productivity in aquaculture
- Quality improvement and waste reduction in fisheries
- Market improvement
- Fish conservation and enhancement
- Increased fish consumption

Further sustainability assessments will be required if the plan is to be followed and these will need to address environmental, economic and social factors in order to establish policies, programmes and action plans. Sustainability methods to follow depends on species, location, local traditions and local knowledge. Implementation of a sustainability plan will require first and foremost, human resources development and capacity building. Education and provision of knowledge to fisheries to create and nurture environmental awareness and offer training on best practices that will change behaviours and attitudes would form the basis. The procedure envisioned, would be that local governments/public organisations work on these issues with the fishing cooperatives. Funding for cooperatives and providing capital will aid in providing the means to spread awareness and create training programmes.

Illegal fishing and pollution are also problems that add to the issue and will need to be addressed in this effort. Responsible and efficient sourcing of broodstock and juvenile fish taking into consideration the effect of transport for these and ensuring these are either produced locally or sourced from as nearby as possible as well as minimizing biodiversity and wildlife impact are important factors to consider. In addition, resources and waste management are key issues in addressing environmental impact, including effluent management, water quality control, sediment control, sludge management, soil and water conservation and efficient fishmeal and fish oil use. Disease control systems, hygiene, microbial sanitation, use of antibiotics and pharmaceutical are also important aspects that cannot be omitted in an effective sustainability plan (Yussefi and Willer, 2003).
Challenges In Iranian Aquaculture

Although there are fish farms spread across the country and aquaculture has proven to be feasible, the practice does not come without challenges. Lack of knowledge on up to date practices and technologies, hygiene, disease control, water quality, low hatching rates, feed quality and management, especially at the hatchery phase and the absence of a strategy for genetic improvement of stocks are all issues the sector needs to address (Paperna, 1991; Brunner et al., 2008).

**Trout farming freshwater resources:** Iran has a large semi arid region with little rain, so freshwater bodies are limited and decreasing every year. A lot of the resources for rainbow trout have shared ownership which may create conflicts. Costs for feed, labor, fry and drugs for trout farming have increased in recent years. As much as 60% of costs associated with trout farming are for feed only. Disease control is also a major issue especially in hatcheries where polluted waters may come from rivers. There is not enough applied research on the topic. Two research centers have been established to tackle this problem, one in the southwest in Kohgiloye and BoyrAhmad province and the other in the north in Mazanderan province, (Tunikabon city) (Bagheri et al., 2008).

**Shrimp culture:** Lack of financial liquidity in order to acquire the right equipment including aerators, pumps, and necessary inputs to improve the management and the control of the production operation has slowed down the industry. White Spot Syndrome caused major economic problems resulting in changing species entirely. There is low average production per hectare and so far production of SPF (Specific Pathogen Free) and SPR (Specific Pathogen Resistant) broodstocks of shrimp inside the country has not been successful resulting in increased costs due to having to rely on imports. Production levels for shrimp culture have not realized their full potential yet. Poor feeding management and the insufficient use of quality feed seem to have been the main cause (Rahimi et al., 2010; Pazir et al., 2011).

![Fig.12 The global trend of shrimp production (Fisheries and Aquaculture), 1950-2014 (FAO, 2016)](image_url)
Fig. 13 The trend of shrimp capture in Iran (0.2% of global capture), 2001-2015

Table 2 Shrimp production (Fisheries and Aquaculture) in Iran, 2010-2014

<table>
<thead>
<tr>
<th>Shrimp Culture (ton)</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrimp capture (ton)</td>
<td>7,603</td>
<td>6,861</td>
<td>8,948</td>
<td>8,789</td>
<td>8,567</td>
</tr>
<tr>
<td>Total (ton)</td>
<td>13,962</td>
<td>14,887</td>
<td>19,100</td>
<td>21,487</td>
<td>31,042</td>
</tr>
<tr>
<td>Shrimp Export (ton)</td>
<td>2,602</td>
<td>4,141</td>
<td>4,904</td>
<td>11,585</td>
<td>11,610</td>
</tr>
<tr>
<td>Per capita consumption (g)</td>
<td>156</td>
<td>145</td>
<td>189</td>
<td>130</td>
<td>252</td>
</tr>
</tbody>
</table>

Fig 14 Methods to improve shrimp industry

**METHODS**

- Study the current situation, problems and limitations of the Iran shrimp industry and the results of research projects
- Identify the strengths, weaknesses, opportunities and threats (SWOT) of shrimp industry and by combining these results with the method of experts brain storming

The strategic components of Iran shrimp industry have provided
Fig 15. Cultivation of Vannamei shrimp in underground brackish waters, Dashtestan, Busheher, 2010.

**Sturgeon:** Sturgeon culture is relatively new, compared to other species therefore further exploration in the technologies, feeding and genetics are needed to ensure the most efficient farming methods are developed and used. The main purpose of sturgeon aquaculture is the production of caviar. More efficient and reliable methods for separating fish according to gender would enable better management of monosex populations of caviar producing females. Warmwater fish farming in general faces challenges including lack of technical knowledge, low production, fish disease, and in feeding and fertilizing management. The slow maturation rate of sturgeons also poses some challenges, control of reproduction and captive breeding is necessary (Bronzi et al., 2011).

**Rice fish farming:** Fish farmers in rice paddies received little access to support given by the fisheries organisations, facilities and loans (Lu and Li, 2006). There is a general lack of knowledge in transportation methods for fingerlings, whose supply is usually poor, as well as in disease control and prevention. Adequate feed is another issues as well and environmental control – wildlife entering the ponds, water shortage, inappropriate temperatures, pesticide pollution coming from upstream farms and poor oxygen content are all threats to species raised in integrated rice fish farms (Berg, 2002).

**References**


AQUACULTURE IN LEBANON
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Abstract
Lebanon is a mountainous country on the eastern shores of the Mediterranean Sea. It is a country of four distinct seasons with considerable precipitation compared to its geographical neighbors. Lebanon has 217 km of coastline and an abundance of natural springs, small rivers and artesian water (Fig. 1)[1]. Marine aquaculture in Lebanon is almost absent except for one private farm in Akkar area of Northern Lebanon for shrimp production. It is a penaeid shrimp (*Litopenaeus vannamei*) farm in the northern town of Abboudiyeh. More than 90% of aquaculture production in Lebanon is freshwater aquaculture, rainbow trout, *Onchorhyncus mykiss*, presented in Akkar, Hermel and Zahle. Aquaculture of some freshwater species, *Salmo trutta fario*, tilapia and some carps, were also tested. Total fish production contributes less than 27% of local consumption in the country, depending largely on imports to cover the 73% left. This indicates that there is a promising potential for development in aquaculture sector [2]. A National Fishery Plan for Marine Aquaculture in Lebanon was developed by CNRS and Italy but still not achieved.

Introduction
Aquaculture activities are supported by 'The National Council for Scientific Research (CNRS-L)' that is a public institution established in 1962 and assigned with the task of formulating national science and technology policy, initiating, guiding, supporting and conducting scientific research programs and activities in Lebanon. It advises the government on all science and technology issues. The CNRS conducts research through its specialized centers and supports research projects having an impact on the socio-economic development of the country. The specialized centers are Center for Remote Sensing, Lebanese Atomic Energy Commission, Geophysics Center and The National Centre for Marine Sciences.

Research activities at the National Centre for Marine Research focus on monitoring of the coastal zone by creating a national observation network, modeling the cycles of contaminants and using bioindicators, evaluation of specific diversity by characterizing the living communities more particularly the migratory species and their habitats, production and transfer of matter in the coastal and marine ecosystems and fishery stock evaluation. The activities done in the centre are primary and secondary production (phyto- zoo plankton), benthology (meiofauna, macro invertebrates), bacteriology (FC, FS, and total coliforms), hydrobiology (physical and chemical parameters), chemistry (inorganic and organic contaminants), biochemistry, water circulation, and fishery.

CANA-CNRS R/V, 27 meters length with a gross weight of 123 tons, and the CADMOS-CNRS catamaran, 7 m length, together, support all research activities.

Freshwater Aquaculture: Trout production, *Onchorhyncus mykiss* was developed in the early 1960s when the MoA established the Anjar Center for Aquaculture in the Bekaa area and purchases eggs from Denmark. This was the first hatchery producing rainbow trout fingerlings and distributed them free of charge to growers to encourage intensive and semi intensive growing of the species.
Farmers grow the fish to market size in concrete flow through raceways or ponds. Water is aerated by flowing down small terraces [1].

The second most cultured fish in Lebanon today is tilapia (*Oreochromis niloticus*). A small farm (Hadath Fish Farm) grows tilapia commercially in an oval concrete raceway located in a greenhouse structure [1].

**Marine Aquaculture:** There is only one saltwater aquaculture facility in Lebanon, a penaeid shrimp (*Penaeus vannamei*) farm in the northern town of Abdeh developed in 2003. Shrimps are stocked into half acre earthen ponds filled with full strength seawater and equipped with paddlewheel aerators (Fig. 2). Water is exchanged as needed. The farm imported new species from Florida in 2003, but survival was less than 20%. In 2004, species were imported from Malaysia [1]. The annual production is 25 tons. Farmers provide fish aquafeed.

Regulation

Ministry of Agriculture (MoA) has no licensing requirement to establish a farm; however it is regulated by Ministry of Environment which requires an Environment Impact Assessment (EIA) study. The establishment is subject to local authorities (Municipalities). Current related regulations are under revision by MoA. None of the Ministries: Water Resources, Agriculture, Industry and Environment know what to do with aquaculture, so there are no control on water usage, effluent quality and disposal, importation of exotic species, location of farms, usage of chemicals or introduction of diseases [1].

Ministry of Environment (MoE) has a protocol for an Environment Impact Assessment (EIA) but it is not implemented because nobody is sure if aquaculture falls within their authority. However, interest and awareness are rising and various institutions are working to draft policies that will be reviewed by the government agencies concerned [2].
National Action Plan for Aquaculture

For a sustainable aquaculture development and support to the fishery sector a National Action Plan Fishery for Marine Aquaculture in Lebanon was developed but not yet achieved. This project settled on the organization of a mission of Italian expert in the framework of the agreement between CNRS-L and Mediterranean Agricultural Institute of Bari (MAI-Bari) signed on March 7th, 2010. The plan intended to contribute to the identification of appropriate aquaculture sites and technology. Selected suitable sites for cage installation are Tyr bay, Saida bay, Beirut/Jounieh and Chekka bay (Fig.3). These sites seems to be the best sites for aquaculture development since they are protected from the south west wind. The plan provided suitable approaches and methods for marine aquaculture. Sea bass and sea bream were considered potential marine aquaculture species and related to Lebanese markets. Training program for local stakeholders and analysis of the environmental risks are necessary for success of aquaculture.

The local hatchery unit will be in the Ministry of Agriculture premises in Batroun for fry and fingerlings production. The hatchery project include many specifications: laboratory equipment, phytoplankton and zooplankton production sector, tanks for breeders and larva production, breeders stock of both sea bass and sea bream are needed, automatic feeders, generators and water pump stations.

Lebanese institutions involved in cage installation procedures are Ministry of Agriculture, Transport and Environment. The role of CNRS will be of crucial importance in the developing of research programs and integration with fishery management.

Hoping that the information contained within provides a picture of the possibilities towards further developing aquaculture in Lebanon and support towards its active adoption and implementation [3].

Fig.3 Lebanese map showing the planned suitable sites for marine aqua-
**Future Perspective**

Aquaculture production needs the support of ministries to gain achievement on the plan, legislations, regulations, establishing of enterprises. The effects of aquaculture on environment need to be studied more and regulations to protect environment must be enforced by government. More training programs, involving both institutes and technicians, and research programs on aquaculture should be supported. Projects financial needs and human resources are the two factors necessary for development of the sector.

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[1]: The status of aquaculture in Lebanon. Nada Lebbos and I. Patrick Saoud


[3]: Sustainable aquaculture development and support to the fishery sector. Final report, 2011.
Introduction:

Libya covers about 1,750,000km² with a total population of 6.7 million. Most of the people are living in the coastal areas.

Fig.1 Map of Libya

Tripoli is the capital and the largest city and Benghazi is the second. Libya is not just desert. There are forests and green landscapes around the country. Libya also has historical places.

Fig.2 Nature of Libya
Natural Resources: Petroleum and natural gas are the most important natural resources. Oil reserves in Libya are the largest in Africa and among the ten largest global reserves. Oil production was 2 million barrels per day.

Aquaculture Sector

The Marine Wealth Ministry was established in 1988 to administer the aquaculture sector, this evolved into an independent aquaculture authority which, in turn, was replaced in 2001 by the National Marine Investment Institute. Within this institute a new administration was formed in 2005 called the Aquaculture Development Administration.

Marine Biology Research Center: The most important and efficient of all the bodies related to aquaculture is the MBRC, which is now under the ministry of Agriculture, Livestock and Marine Wealth. The MBRC consist of 52 researchers and specialists in the fields of Aquaculture, Fish biology and fisheries, Microbiology, Benthos, Planktons, Chemistry, Pollution and Environment.
History and general overview: Aquaculture does not have a long history in Libya. It started in the early seventies of the last century. Fresh water is limited in Libya, therefore dams and small lakes were used for culturing several species of carp imported from China (common carp, grass carp, bighead carp and silver carp), and cat fish as a semi intensive culture. This experiment was very successful with very good growth rate for most species, but was not accepted by the local consumers, for this reason fresh water culturing did not develop. In the early nineties, Tilapia sp (Nile Tilapia and Red Tilapia) was introduced and accepted, due to its physical appearance, good taste and it spread very quickly. Irrigation ponds in agriculture farms used for rearing it.

Marine culture started at the early nineties at a farm in Ein Elgazala, as a government project. Fingerling of seabass, sebream and Mugil spp. were collected from the wild and reared in small cages in Ein Elgazala lagoon.
Tuna rearing was introduced to Libya at 2003 by the private sector, two companies, Ras Alhilal and Noor Elhaya.

Fish farms, hatcheries for freshwater and marine culture species are distributed along the coast.
Freshwater fish (tilapia) rearing in the irrigation ponds of agriculture farms is widely distributed along the coast, at rural areas and in the south of Libya. Some governmental agriculture projects are also used for freshwater fish rearing.

Earth and concrete ponds and net cages are used for rearing species such as the European seabass, gilthead seabream and the bluefin tuna. While, initially some problems were encountered, especially, with the operation of the earthen ponds as a result of lack of experience. The mariculture sector initially relied on imported fry and fish feed from countries such as France, Italy, Portugal and Austria. They have succeeded in hatching imported fertilized European seabass eggs at National Marine Investment Institute’s fish hatchery complex, which is completed in 2004 and distributed free to the farmers.

In 2005, fertilized eggs of the gilthead seabream were also supplied by the MBRC to Farwa Hatchery Complex and as a result approximately half a million fry were distributed to farmers. In 2008, the Farwa Hatchery Complex produced seabass and gilthead seabream fry and distributed to farmers with low price.

In 2004, the first survey was carried out on aquaculture farming, which showed that the production of market size fish reached (391 ton) consisted mainly of European seabass and sea bream (231 tons), Blue fin Tuna (150 tons) and Tilapia (10 tons), while in 2005 and 2006 production was 300 tons, in 2007 it was 240 tons, but in 2008, 2009 and 2010 it was only 110 tons.
Four different types of fishing activities are normally carried out in Libya: Artisanal coastal fishing, lampara fishing, coastal trawling and Tuna fishing.
Conclusion

From 2011 until now the fish farms in Libya stopped working completely, except one new private fish farm (Shat El-Aman) which have worked between 2014-2016 and produced 25 tons European seabass. The bluefin tuna catch continued and they are farmed outside Libya according to Libyan quota (1300 ton).

References


AQUACULTURE STATUS IN MOROCCO

Widad Natify

Morocco has an important continental freshwater. However, despite this wealth of water, this country has a relatively poor fish fauna. At the beginning of the last century, new species started to be introduced and acclimatized and series of tests applied in natural waters. European, American and Asian species were imported to ensure the development of sport fishing, commercial production and ecotourism in the country. The High Commission for Water, Forests and Desertification Control (HCEFLCD) proceeded from the twenties for the introduction of 35 species belonging to 9 families, but only a dozen of species are now naturalized. As a result of more than three quarters of a century of action on the development of fish farming in Morocco is negative in relation to the quantities produced. Factors that may contribute to the development of inland aquaculture in Morocco are to improve the livestock and to optimize fish feed, as producing more efficient and environment friendly fish feed. Fish farming can be a locomotive and development tool in helping to diversify production and increase incomes, generate employment and ensure food security.

The nine species currently cultured in Morocco, belong to six major families of cold water and hot water, Cyprinidae, Salmonidae-Esocidae, the Centrarchidae, cichlids and Anguilidés, that are either endemic or non-native fresh or brackish water species.

Three types of methods are used for breeding these species, the intensive system is used mainly by private farms, linked to production for direct consumption in semi-intensive system for tilapia production, and the extensive system in the production of salmonids Cyprinidae, the Esocidae the centrarchids and cichlids (restocking).

Production of freshwater fish in 2006 was estimated as 6,000 tons, in 2013 the production was estimated as 13000 tons. The increase in the production of fish has positive effects as supplying high quality animal protein to rural populations, contributing to the improvement of income of fishermen and generating a valuable market. The plan referred by the High Commission for Water, Forests and Desertification Control (HCEFLCD) is to reach a production of 50,000 tonnes in the next ten years, knowing that the HCEFLCD is the largest producer of freshwater fish while the private sector remains at a limited production around 1000 tonnes per year.

Based on these data, we can say that fish farming has not yet reached a sustainable economic dimension in Morocco, either in terms of volume and in terms of place of this activity in the production systems, despite infrastructure public key, and also despite the mastery of fish farming, compared to agricultural products, which Morocco has an important place in the world. Among the reasons which may explain this situation is the absence of national and regional policies to promote fish farming, this can have a direct relationship with the fishery products, where Morocco is recognized by the marine fish production. In addition, there is a predominance of the public sector and modest private sector involvement, knowing that the state investments made to date in this area are oriented towards the renovations of fish farms to develop the technical bases that make up the foundations of this business. Also, since the distribution of fishery products are less developed within the country and eating habits, based on meat products, are more pronounced in rural areas. Similarly, Morocco is not a major consumer of fish products.
In 2014, inland aquaculture in Morocco received again a well deserved attention, the strategy initiated by the High Commission for Water, Forests and Desertification Control (HCEFLCD) as a sector which can bring important contribution to the fight against poverty, food security, prosperity of producers and well-being of consumers.

Consumption and increasing demand for aquatic products, acclimatization of introduced aquaculture species that enriches the fish fauna and water wealth, climatic and geographical variations are real assets to support the ongoing development of inland aquaculture sector. The chances of developing this sector in Morocco are important.

Mastering the technique of reproduction is the key parameter for improving the profitability of farming and our country has farmed structure renowned for the production of fish from cold and warm waters. Moreover, the availability of food suitable for food requirements of the species is a factor to develop this sector respecting the aquatic environment. Any time, to take advantage of this untapped potential harm, the development of aquaculture is currently part of the overall national and regional policy of Morocco, which will undoubtedly contribute to food security, the fight against poverty, and job creation.
MARI-CULTURE STATUS OF PAKISTAN

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Introduction

Aquaculture is the rearing of aquatic organisms under controlled or semi-controlled conditions. The reasons for having freshwater and marine aquaculture activities are the decline of fisheries resources and the rising demand for seafood. Aquaculture rooted in China 2000 BC and the first written record is also from China by Fan Li, 460 BC. Oyster culture started in Japan 3000 and in Romans 2000 years ago. Many techniques were developed since 1970.

Aquaculture in Pakistan

Aquaculture does not have a long history in Pakistan. Freshwater farming developed in the country, but marine farming is still in its infancy. Sindh Fisheries Department, Marine Fisheries Department, National Institute of Oceanography and Fisheries Development Board are institutions working on aquaculture. Experimental shrimp farming started in 1980s by Government of Sindh, Garho and private companies. NIO obtained extensive production in 1990s, established experimental shrimp hatchery in 2003 and pilot in 2006 at Sonmiani. Marine Fisheries Department started hatchery project in 2002. Fisheries Development Board was established in 2007. Hatcheries and grow-out areas are shown in Figure 1.

Fig.1 Coastal areas of Pakistan

Capture Production

Dominantly reared aquaculture species are *Fenneropaneus merguiensis* (banana shrimp), *Lates calcarifer* (Barramundi), *Perna viridis* (green mussel), *Ulva lactuca* (green alga, sea lettuce) and *Scylla serrate* (mud crab). Other aquaculture species are *Findicus* and *P. monodon*, freshwater prawn, oyster, sargassam, tilapia. There is no regular marine aquaculture production.
Shrimp Farming

In 2015, total shrimp production was 70 tons by imported feeds and in 2016, the production was 55 tons by local feeds. NIO Experimental Hatchery's total production was 1 ton in 2010 by farm made feed type.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Production</th>
<th>Feed type</th>
<th>Seed Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>70 ton</td>
<td>Imported</td>
<td>Imported</td>
</tr>
<tr>
<td>2016</td>
<td>55 ton</td>
<td>Local</td>
<td>Imported</td>
</tr>
</tbody>
</table>

Issues for the Development of Mariculture in Pakistan

Pakistan has a coastline of 1000km long but the mariculture is still infancy. One of the important problems is the lack of technical persons. More research is essential for the improvement of aquaculture. There is need for hatchery and formulated feed. There has to be more experimental work on IMTA, feed and water quality.
Recommendations

- Native species should be cultured to avoid the environmental risk of exotic species.
- Government and private sector should promote the research and commercial production of shrimp by providing the facilities to relevant field.
- Good quality feed should be prepared locally which can help the native species to grow fast in local environmental condition.
- Provide opportunity to the skilled people of relevant field. Also, train the farmers and local fisherman for growing the shrimps in grow-out pond.
- Such system should be developed which can produce regular production of seed in the hatchery.
- Local boats should be equipped with all the facilities which could be helpful in capturing the broodstock from the wild.

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OVERVIEW OF AQUACULTURE IN SAUDI ARABIA

Assad Al-Thukair

Introduction

Riyadh is the capital city of Saudi Arabia. Population of the country is 32 million. Saudi Arabia is located in the middle east and covers 80% of Arabian Peninsula, an area of 2.15 million km$^2$. The coastline is 2.4 km long along the Red Sea and Arabian Gulf. Economy is based on oil and petrochemicals. Food supplies of the country are aquaculture, dairy, cattle, fishery and imported food. The responsible authority for fisheries and aquaculture is the Ministry of Environment and Water and Agriculture. Fisheries sector can be divided as traditional and industrial. Traditional sector is focused on fish traps, gillnets and hand lines. Industrial sector is focused on trawl nets to catch shrimp and fish. There are 10,000 boats in the Red Sea and 600 boats in the Arabian Gulf. Fish catch is more than 100,000 tonnes per year.

Main overfished native species are shrimp, emperors, scads, jacks, groupers, sea breams and snappers and the migratory species are Spanish mackerel, Indian mackerel, longtail Tuna and kawakawa.

Current Status of Aquaculture

There is an increase in seafood demand and the consumption exceeds fish catch. Food security should be provided to meet the country vision of 2030. Long coastline and adjacent lands and government funds are available to support aquaculture industry. Aquaculture industry is regulated and supervised by the Ministry through established guidelines, licensing procedures and funding mechanisms. Ministry of Environment and Water and Agriculture has planned to invest around US $10 billion in aquaculture projects by 2030. Aquaculture production, including shrimp (54%), freshwater fish (20%) and marine fish (26%), is less than 30,000 tonnes.

Aquaculture methods: Open cage systems for sea-based farms are located 5 km of the shore. Closed system are used for land-based farms. Farming in ponds and land-based opened farms are being discontinued.

Challenges and opportunities: Long term investment commitments, encountered endemic diseases for some farmed species, limited local expertise in aquaculture, strong competition with exported seafood and harsh environment conditions are the challenges in aquaculture sector. Governmental funding support and long term plan to invest aquaculture, continuous increase in local seafood demand, research and development are the opportunities for aquaculture.
L’AQUACULTURE AU SENEGAL

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I. INTRODUCTION

L’exploitation des ressources halieutiques de la Zone Economique Exclusive (ZEE) sénégalaise (Figure 1) offre des retombées importantes sur les plans économique (revenus des pêcheurs, renflouement des finances publiques, apport de devises, etc.) et social (emplois directs et indirects, sécurité alimentaire, etc.), tant en aval qu’en amont du système pêche (Dème et Kébé, 2000 ; Diadhiou et al., 1998 ; MPEM, 2013).

Cette exploitation, outre les marchés intérieurs, permet l’approvisionnement d’industries spécialisées dans la transformation et la commercialisation des différents types de ressources: démersales, pélagiques côtières ou hauturières (CRODT, 2016).

II. HISTORIQUE DE L’AQUACULTURE AU SÉNÉGAL

La pisciculture traditionnelle pratiquée en Casamance est pratiquée en Basse Casamance dans des bassins piscicoles aménagés en amont de la mangrove dans le cadre du dessalement des rizières salées (Figures 2 et 3). Ces bassins sont des aménagements hydrauliques gagnés sur la mangrove et situés en aval des rizières inondées. Aujourd’hui, ces types d’aménagements ont tendance à reculer au niveau des villages où les structures de la société sont remises en cause par l’exode rural, la volonté d’indépendance des jeunes, l’individualisme et le développement d’activités plus lucratives (Diaw et al., 1987).

Fig. 2. Configuration d’un type de bassin

Figure 3. Récolte de poissons dans un bassin Piscicole traditionnel en Basse Casamance (Cormier-Salem, 1992)

L’ostréiculture traditionnelle est également pratiquée dans cette région du côté de Diogué, Kabrousse et à Boudiédiète où les femmes Diolas avaient l’habitude de planter près de la berre des piquets de de Kad (Acacia albida) pour capter et faire grossir sur place du naissain d’huîtres. Chaque bâton est la propriété de la femme qui l’a plantée, appropriation matérialisée par un bout de tissu. Les huîtres sur les bâtons sont récoltées à partir de l’année suivante, la récolte pouvant s’étendre sur 3 ans. Ces parcs, réalisés par les populations, sont de nouveau actifs à Diogué et à Kabrousse (Bousso et al., 1992). Concernant l’ostréiculture traditionnelle, elle est moins importante que la pisciculture.

A côté de la pisciculture et ostréiculture traditionnelle en Basse Casamance, des élevages (poissons, huîtres, crevettes) ont été expérimentés dans la vallée du Fleuve Sénégal (pisciculture), sur la Petite Côte (ostréiculture à Joal), au Sine Saloum et en Casamance (pisciculture, ostréiculture et creveticulture).

III. LE DÉVELOPPEMENT DE L’AQUACULTURE MODERNE AU SÉNÉGAL

Des essais d’élevage moderne de poisson, d’huître, de moule, de crevette et de production d’algues macrophytes et microphytes (spiruline) ont expérimenté dans le nord, l’ouest, le centre et le sud du pays. Certains l’ont été avant les indépendances en 1960 et se sont poursuivis après. D’autres ont débuté que récemment. C’est le cas de l’élevage des moules, de l’ormeau et la culture des algues macrophytes et de la spiruline.
Dans le bassin du fleuve Sénégal, des expériences de pisciculture moderne ont été menées dans le cadre de projets de développement, de démonstration ou de recherche développement (Diouf, 1991). Différents systèmes d'élevage furent testés lors de ces expériences :

- pisciculture intensive en étang;
- pisciculture en cage;
- pisciculture extensive;
- rizipisciculture.

Des essais d'élevage moderne de l'huitre ont également été initiées en Casamance, au Saloum et sur la Petite Côte du Sénégal (Bousso et al., 1992). L'exemple le plus réussi de ces essais est celui de Scordel en 1911 motivé par le désir de satisfaction du marché constitué par les colons de la capitale fédérale de l'ex-Afrique Occidentale Française. Aucune réalisation ne suivit ces essais qui pourtant ont donné au bout de 22 mois d'élevage, ont permis d'avoir des huîtres de 75,7 mm de taille commerciale pour 54 g de poids dans la région de Joal (Petite Côte). Ces essais prometteurs furent repris en 1935 par A. Crémoux. Il fit construire des casiers, aménagea des parcs et les excellents résultats techniques qu'il obtint ainsi que la réglementation de 1961 en matière de conditionnement et de commerce l'incitent à établir un programme de vulgarisation qui concernait :

- une prospection des zones de production
- la création et l'aménagement des parcs contrôlés par la station.

Cependant l'expansion de l'ostréiculture au Sénégal s'est faite à partir de 1946 avec A. Blanc. La station ostréicole qu'il dirige concentrera ses efforts sur :

- l'étude de la biologie de C. gasar et du captage du naissain ;
- l'amélioration des techniques de grossissement et de vulgarisation auprès de nouveaux ostréiculteurs autochtones dans plusieurs localités de la Petite Côte et du Saloum. grossissement de l'huitre dans la baie de la Somone.

Photo 1: Collecte et choix de collecteurs de naissains (coquilles d'huitres)
Photos 2: Préparation des collecteurs: Percer les coquilles à l’aide de pointe ou de perceuse

Photo 3: Enfiler coquilles autour d’une corde en nylon de 0,3mm de diamètre

Photo 4: Attacher guirlandes sur perche en Eucalyptus de 8m de long et transporter dans zones de collecte de Naissains. Chaque guirlande porte 5 collecteurs (coquille) et chaque perche 120 à 140 guirlandes.
Photo 5: Poser de guirlandes dans la zone de balancement des marées, suivi et du captage nais-sain de l’huître

Photo 6: Récolter les huîtres de plus de 6 cm de long après 18 mois d’élevage


En 1968, la coopérative de Sokone est affiliée à celle de Joal plus expérimenté et mieux équipée. A partir de 1971, des difficultés apparaissent dans les relations de ces deux coopératives. La production de Sokone qui atteignait 7 200 douzaines pour une valeur commerciale de 620 119 F CFA en 1967, a commencé à baisser pour atteindre 300 douzaines en 1980.

En 1983, un volontaire japonais est affecté auprès de la coopérative pour aider à aplanir les pro-bèmes de la production de l’huître. Le Centre de Pêche de Missirah, créé autour de la même période, viendra également en appui aux ostréiculteurs dans le sens d’un encadrement et d’une assistance aux Groupements d’Intérêt Economiques (GIE) ostréicoles.

Au moins 4 tentatives furent initiées dans cette région entre 1940 et 1991 :

Kassel : 1955;
Djivent, Kabrousse et Karabane : 1963;

Kassel : 1955

Dans cette expérience, les méthodes de culture étaient basées sur le détroquage d’huîtres de dimension propre à une commercialisation immédiate, soit 7 cm de diamètre, connut un grand succès auprès des riverains. Il permit la commercialisation de près de 3 000 douzaines d’huîtres en 1955. Le contrôle de salubrité était assuré par le Service de l’Elevage. Après l’Indépendance, le Service des Pêches n’a pas continué l’expérience.

Djivent, Kabrousse et Karabane : 1963

L’initiative de cette expérience revient à la DOPM. Les méthodes de culture utilisées sont identiques à celles qui existaient à Kassel en 1955. La production d’huître était écoulée par l’usine PROPECSEN à Ziguinchor. Après quelques années de fonctionnement, la clientèle fera défaut après que la société soit MAUREL et PROM a commencé à importer des huîtres de France.

Un entrepreneur privé, reprendra les parcs ostréicoles de Kabrousse mais il échouera du fait de la concurrence des huîtres de Joal qui bénéficient de la garantie du Service des Pêches.


Ce programme franco-canadien de production de l’huître de palétuvier avait comme objectif de permettre aux femmes cueilleuses d’huîtres d’augmenter leurs revenus et de préserver la mangrove des effets néfastes de la cueillette. Les villages de Djivent et Karabane ont pris part au projet.

Les méthodes de culture étaient basées sur le détroquage des huîtres d’une certaine taille (huîtres de plus de 2 cm de diamètre) et leur mise en pochons sur des tables ostréicoles en fer à béton. En outre, des recherches étaient menées sur le captage du naissain (Gilles, 1991 ; Diadhiou, 1995).


Depuis quelques années, une expérience pour développer l’élevage de l’huître est tentée dans cette région par la Coopération Japonaise. Elle consiste à réaliser le captage du naissain sur des collecteurs, de réaliser le prégrossissement, le détroquage avant de procéder à l’élevage des huîtres.

Concernant la crevetticulture, il faut noter l’expérimentation de l’élevage de la crevette à la station de Katakaloous (Casamance) de 1983 à 1990. Ce projet dont France Aquaculture avait la responsabilité, du moins dans sa première phase (1983-1987), s’est déroulée avec l’appui de la DOPM. Il avait alors comme objectif à démontrer qu’un élevage rentable de la crevette était possible sur des post larves
importées de France en deux ans. Des tests devaient permettre de sélectionner les espèces les mieux adaptées aux conditions locales de température et de salinité. Quatre espèces furent testées à partir de post larves importées : *Penaeus vanamei*, *P. indicus*, *P. monodon*, *P. japonicus*. Les espèces locales *P. notialis* et *P. kerathurus* furent également testées à partir de post larves et de juvéniles prélevés dans l’estuaire.

Les résultats ne furent pas aussi bons que prévus et la durée du projet fut prolongée avec une seconde phase (1988-1990). De nouvelles infrastructures sont réalisées :

- une écloserie pour produire 1 à 2 millions de post larves par mois avec salle de maturation, salle d’élevage larvaire, salle d’algues et d’artémias ;
- quatre stations de grossissement d’un hectare ;
- un forage d’eau douce permettant de contrôler la salinité durant les premières phases du développement.

Le Programme Spécial de Sécurité Alimentaire de la FAO a eu à empoisonner des bassins de rétention. Les résultats obtenus sont modestes avec des rendements de l’ordre de 500 kilogrammes par hectare à Fadiga dans le Sénégal Oriental, de 500 à 1000 kilogrammes à l’Anambé en Haute Casamance, autour de 119 kilos à Loul Sessène, Ndiosmone, Shanghai, Ndiemou et N’Diaye N’Diaye dans la région de Fatich (PSSA, 1999). Ces résultats médiocres étaient dus en grande partie à la qualité des alevins de poissons, de l’aliment fourni et à l’environnement des bassins de rétention. Dans certaines localités l’ensemencement est réalisé à partir d’alevins sauvages, provenant des cours d’eau environnants ou quelque fois de la station d’alevinage de Richard Toll.

Après quelques mois d’élevage, les poissons sont récoltés à l’aide d’engins de pêche. Les produits de la pêche sont auto consommés ou vendus sur place. Au vu des faibles rendements obtenus, on peut noter que cette forme de pisciculture revêt un caractère purement artisanal et se rapproche beaucoup plus de la cueillette.

Le tableau 1 ci-dessous résume l’ensemble des systèmes piscicoles pratiqués au Sénégal et les rendements des élevages.

### Tableau 1: Quelques résultats d’expériences piscicoles réalisées par le CRODT (Ndiaye, 2007)

<table>
<thead>
<tr>
<th>Zone éco géographiques</th>
<th>Site</th>
<th>Type d’aménagement</th>
<th>Rendements en tonnes</th>
<th>Indice de conversion alimentaire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vallée du fleuve Sénégal</strong></td>
<td>Richard Toll</td>
<td>Etangs artificiels de 1000 m²</td>
<td>10</td>
<td>Réel : 16 Potentiel : 16&lt;br&gt;Granulé Sente-nac&lt;br&gt;IC = 2.48&lt;br&gt;Granulé Sente-nac&lt;br&gt;IC = 2.9</td>
</tr>
<tr>
<td></td>
<td>Mbane</td>
<td>Cages fixes de 16m²</td>
<td>0,357</td>
<td>1</td>
</tr>
<tr>
<td><strong>Basse Casamance</strong></td>
<td>Tobor</td>
<td>Etangs artificiels de 1000 m²</td>
<td>4,5</td>
<td>Réel : 9 Potentiel : 9&lt;br&gt;Granulé Sente-nac&lt;br&gt;IC = 4,5&lt;br&gt;Aliment local&lt;br&gt;IC = 2,5</td>
</tr>
<tr>
<td></td>
<td>Kartiack</td>
<td>Bassins piscicoles traditionnels (modèle 1)</td>
<td>0,339</td>
<td>2,5</td>
</tr>
<tr>
<td><strong>Autres régions du Sénégal</strong></td>
<td>Sine Saloum&lt;br&gt;Loul Sessene&lt;br&gt;Ndiosmone&lt;br&gt;Shanghai&lt;br&gt;NDiaye Ndiaye</td>
<td>Bassins de rétention naturels (modèle 3)</td>
<td>0,119</td>
<td>0,500&lt;br&gt;Alimentation naturelle + ap-port de sous produits agricoles</td>
</tr>
<tr>
<td></td>
<td>Sénégal Oriental&lt;br&gt;Fadiga&lt;br&gt;Anambé</td>
<td>Plaine d’inondation (modèle1)</td>
<td>0,500</td>
<td>3&lt;br&gt;Alimentation naturelle + ap-port de sous produits agricoles</td>
</tr>
</tbody>
</table>

La production de spiruline au Sénégal

![Spiruline séchée](image)
Elle est plus riche en protéines que la viande de bœuf et le soja. Au moment où on retrouve 70% de protéines végétales dans la spiruline, on en trouve que la moitié dans ces deux aliments, pourtant plébiscités dans ce domaine.

On rencontre aussi dans cette algue la vitamine B carotène (dont la teneur est 30 fois plus élevée que dans la carotte) et les vitamines B1 et B2. On y retrouve aussi du fer, du calcium, du magnésium, du phosphore, etc.

Dans la zone des Niayes, de nombreux maraîchers ont diversifié leurs activités de production en intégrant la pisciculture au maraîchage. C’est le cas de la ferme aquacole de Mbèye, dans le Bambilor.

Dans la zone de Ndangalma (Baol), l’ANA a aidé des promoteurs privés à installer des bassins aquacoles. Outre le poisson, les pisciculteurs cultivent du gombo, de la tomate, l’oignon et le haricot cultivés à côté des bassins de pisciculture (Diatta, 2016).

La production de spiruline est réalisée principalement dans deux localités, à Ndiaffate et à Khombole.

A Ndiaffate, dans le département de Kaolack, sur la route Passy-Sokone, c’est le religieux suisse, le père Marcel Pichonaz, qui est l’initiateur de la plus grande station de production de spiruline actuellement fonctionnelle au Sénégal. Coût de l’infrastructure : 75 millions de FCFA.

L’Algoculture au Sénégal

Les algues entrent dans la composition de divers produits industriels (produits de beauté, produits pharmaceutiques, produits alimentaires, etc.). Leur exploitation constitue une activité alternative très prometteuse pour les populations des régions côtières. Elles sont riches en minéraux (iode, fer, calcium, magnésium, azote, potassium), oligo-éléments et vitamines (B12, C, E), contiennent des immunostimulants et sont des antioxydants puissants. En outre, les algues rouges produisent des polysaccharides (gélose, alginate et carraghénane). L’intérêt industriel de ces polysaccharides réside dans leur propriété à augmenter la viscosité à faible concentration. Ce sont essentiellement des agents gélifiant, épaississants et stabilisants. La demande mondiale en dérivés d’algues ne cesse de croître (Figure 3).

Au Sénégal, la culture d’algue est une activité récente et très marginale. L’algoculture est une activité à faible coût d’investissement et fondée sur une technologie très accessible. Malgré un faible niveau d’exploitation au plan national « les algues suscitent un intérêt croissant auprès d’un bon nombre d’opérateurs en particulier pour l’exploitation, la fabrication de produits alimentaires et de compost ».

Un projet-test de culture d’algues macrophytes a été expérimenté au niveau de Pointe Sarène sur la Petite Côte entre juillet 2009 et février 2010 par l’Agence japonaise de coopération internationale (Jica), l’Ong Sos-environnement et les habitants de cette localité.

Dans le courant de l’année 2016, l’ANA a eu à financer le Gie Aqua-Production, composé de 6 étudiants diplômés de l’Université Gaston Berger de Saint-Louis, de jeunes plongeurs du village de Ngor et d’un enseignant-chercheur spécialiste des algues pour la culture des algues rouges à Ngor village. Les algues rouges assez abondante à certains endroits du littoral sénégal constitué une opportunité intéressante en termes d’emplois et de génération de revenus monétaires pour les populations des régions côtières.
Au Sénégal, la culture d’algue est une activité récente et très marginale. L’algoculture est une activité à faible coût d’investissement et fondée sur une technologie très accessible.

**Algues rouges**

Les espèces d’algues présentant un intérêt commercial se retrouvent sur les côtes sénégalaises appartiennent à trois grands groupes :

**Algues rouges ou rhodophycées**

- Hypnea musciformis est utilisée à la fois pour ses propriétés nutritionnelles et pour sa teneur élevée en carraghénane ;
- Hypnea cervicornis pour sa teneur élevée en carraghénane ;
- Gracilaria dentata verrucosa est utilisée à la fois pour l’iodation des produits alimentaires médicaux et pour la production d’agar ;
- Meristotheca senegalensis, très riche en carraghénane (32%) et en anhydro-galactose (13.4%) est exporté vers les pays asiatiques dont le japon.

**Algues brunes ou phéophycées**

Les genres Sargassum, Padina et Dyctiota, contenant de fortes teneurs en iode, sont utilisés comme additif alimentaire ou pour la production d’engrais biologique en mélange avec d’autres algues rouges et vertes.

**Algues vertes ou chlorophycées**

- Ulva lactuca, riche en magnésium, et Enteromorpha intestinalis.

**IV. LE DÉVELOPPEMENT DE L’AQUACULTURE AU SÉNÉGAL**

Au Sénégal, on maîtrise déjà l’élevage des espèces comme le tilapia (Wass) et le Clarias. Sur la figure 2 est représentée la carte des différentes expériences aquacoles en cours actuellement dans le pays.
L’ANA prévoit par ailleurs de développer l’élevage des espèces marines. La construction d’un centre de recherches appliquées en mariculture est envisagée dans ce cadre sur la Petite Côte du côté de Djifère avec l’appui de la coopération sud coréenne. Elle œuvre également à l’intégration de l’aquaculture dans les systèmes de production locaux. Outre l’élevage du poisson, nous encourageons celui des huîtres et de la spiruline, une micro-algue qui contient des vertus extraordinaires dont des protéines végétales sans commune mesure avec la teneur d’aliments comme la viande ou le soja en protéines. Il contribue au renforcement de la sécurité alimentaire. La zone des Niayes, zone à vocation maraîchère vit à l’heure de la diversification avec la pisciculture qui s’y développe. Ce même phénomène est entrain d’être observé dans le Gorom, le Bambilor et le Diender. Le Baol n’est pas en reste. Une ferme piscicole avec des bassins en béton a été érigée à Ndangalma. A Touba, les chefs religieux, se sont mis à la pisciculture. A Dakar et dans ces environs, on note le même engouement pour l’aquaculture avec la création de fermes aquacoles qui pour produire du poisson (dans la zone des Niayes) qui pour élever des moules ou des ormeaux (sur la côte au niveau de Dakar et de sa banlieue). Dans le domaine de l’Ostréiculture, l’ANA ait du benchmarking pour voir les meilleures pratiques au Brésil, en Asie du Sud-est et ailleurs. Les technologies les plus adaptées à notre écosystème ont été adoptées pour renforcer le dispositif d’élevage des huîtres au Sénégal.

LES ACQUIS DANS LA PROMOTION DE L’AQUACULTURE

Parmi les acquis, on peut citer:

- La volonté de l’État à soutenir le développement de l’Aquaculture;
- Le vaste réseau hydrographique du pays (fleuve Sénégal, estuaire du Sine Saloum, estuaire de la Casamance, fleuve Gambie, lacs et rivières, bassins de rétention, aménagements autour des barrages hydroélectriques);
- La création d’institutions en charge de la promotion des activités aquacoles (ANA, ANIDA, PRODAC, ANPEJ, etc.);
- Construction de bassins piscicoles, d’écloseries de poissons, de fabriques d’aliments pour poisson;
- Développement de la coopération avec les grands pays aquacoles pour la formation, le renforcement et l’assistance technique;
- Le développement de filières aquacoles au niveau techniciens et des cadres à l’école nationale des techniciens des pêches et de l’aquaculture et des universités (UCAD, UAMb, USSA, UGB);
- L’amélioration de la production aquacole, du nombre d’emplois dans le secteur (Figure 2) même si cela reste fragile du fait que l’essentiel des intrants utilisés sont attendus pour l’essentiel de l’ANA (l’aliment pour poisson entre autres);
- Les acquis de la recherche en termes de connaissances scientifiques et d’adaptations de technologies de production (Ndiaye et al. 2007; Diadhiou et al., 2015; Diadhiou et al, 2017; Diadhiou et al., 2018).
LES FAIBLES DANS LA PROMOTION DE L’AQUACULTURE

Pour les faiblesses, il y a:

• La dispersion des efforts de développement entre plusieurs institutions (ANA, ANIDA, PRODAC, ANPEJ…);

• L’absence de recherches d’accompagnement dans la mise en œuvre des projets et programmes;

• Le sous équipement des écloseries de poissons et des fabriques d’aliment gérées par les agences de l’État (ANA, ANIDA);

• La distribution gratuite de l’aliment aux producteurs. Les quantités fournies sont souvent insuffisantes et ne sont pas toujours disponibles à temps ce qui finit par découragés de nombreux acteurs;

• Les alevins de poissons fournies aux pisciculteurs ne sont pas de qualité dans la plupart des cas;

• Les services d’encadrement des aquaculteurs sont souvent dépourvu de personnel qualifié en nombre et ne disposent assez de crédit pour fonctionner correctement;

• Les objectifs poursuivis par l’ANA sont souvent assez vastes et difficiles à atteindre avec les moyens mis à disposition par l’État;

• Le code de l’aquaculture n’est pas encore adopté par l’assemblée nationale ce qui limite l’arrivée d’investisseurs privés disposant de moyens financiers pour se lancer dans la production de masse;

• Le prix de l’aliment de qualité importé est cher et reste inaccessible à la grande majorité des pisciculteurs

• Le prix du courant électrique est également cher;

• Sur le plan environnemental, il y a l’irrégularité très forte du régime hydrologique du bassin du fleuve Sénégal. Cette donnée disparaîtra sans doute avec l’entrée en service des barrages de Diama et de Manantali;

• Du point de vue de la socio-économie, l’absence de recueil de données sur les populations cibles et les éléments économiques et financiers de l’élevage des poissons ont constitué un handicap majeur pour le développement de la pisciculture dans cette région (Bousso et al., 1992);

• Sur le plan administratif, la pisciculture a souffert de son mode de gestion. Les chefs de projets doivent pouvoir gérer eux-mêmes les fonds destinés à soutenir les activités des programmes de pisciculture dont ils ont la charge.
V. CONCLUSION ET PERSPECTIVES

Après un peu plus de dix ans d’expérimentation, les cas de réussite sont extrêmement rares voire inexistantes alors que le potentiel en eau et en terre pour le développement de l’aquaculture existe. Le total de la production aquacole ne dépasse pas les 1000 tonnes en 2012, alors que les prévisions de production envisagées par l’ANA à l’horizon 2015 est de 159 000 tonnes.

Cette situation a amené la SCA à envisager la révision du plan d’investissement aquacole. Ce nouveau plan, en dehors de la révision des prévisions de production pour les années à venir, a identifié des projets pertinents pour le développement du secteur dont les financements sont prévus dans le PSE.


RÉFÉRENCES BIBLIOGRAPHIQUES


AQUACULTURE IN TURKEY

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Institute of Marine Sciences and Technology

The world population is growing so as the search for new sources of secure food. In this sense aquaculture is identified as a high potential area for new source of protein. Aquaculture can also achieve this without many burdens on the ecosystem.

**Table 1** Volume of main product groups in the various culture environments in 2015 (brackish water production is included in the marine environment.)

<table>
<thead>
<tr>
<th>Product (in Thousands of Tons)</th>
<th>Freshwater Aquaculture</th>
<th>Mariculture/Marine Aquaculture</th>
<th>Aquaculture Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finfish</td>
<td>44,108</td>
<td>7,800</td>
<td>51,907</td>
</tr>
<tr>
<td>Crustacean</td>
<td>2,857</td>
<td>4,495</td>
<td>7,351</td>
</tr>
<tr>
<td>Molluscs</td>
<td>284</td>
<td>16,148</td>
<td>16,432</td>
</tr>
<tr>
<td>Aquatic plants,</td>
<td>90</td>
<td>29,273</td>
<td>29,363</td>
</tr>
<tr>
<td>Other aquatic animals</td>
<td>523</td>
<td>427</td>
<td>950</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>47,861</strong></td>
<td><strong>58,143</strong></td>
<td><strong>106,004</strong></td>
</tr>
</tbody>
</table>

FAO – FishStatJ 2017 March.

The product groups listed in Table 1 are cultured by using various technologies, influenced by the environment and determining the social, economic and environmental sustainability of the production. The majority of freshwater fish are carp produced in Asia (37.5 million tons) in pond based systems, thus ensuring the local protein supply for underdeveloped regions. Asian countries produce the majority of mariculture farmed species which are mainly extractive species such as molluscs (e.g. mussels and oysters) and aquatic plants (e.g. seaweeds). Products from marine aquaculture also have an important role in the food supply and application of aquaculture technologies to different (new) species in marine areas have a potential to supplement the global shortage in captured fisheries (Bardocz. et al. 2018).

Inland aquaculture started in Turkey in the 1970s. But, aquaculture expanded rapidly with the contribution of marine fish farms in the 1980s. It was dominated by cage farming of sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*), and trout (*Oncorhyncus mykiss*). In the Turkish marine finfish sector sea bass and sea bream are dominant. Turkish aquaculture production has increased from 61,000 tons in 2000 to around 253,395 tons in 2016 (TUIK, 2018). It has been going through a period of unprecedented growth over the past 10 years (Figure 1).

![Aquaculture Production of Turkey](image)

**Figure 1:** Overall aquaculture production in Turkey. (TSI, 2018)
This figure illustrates that aquaculture production (fresh and marine water) increase progressively. In 2007, marine production is %57 of total production and in 2016 it is %59. It is the rapid growth of the aquaculture sector which makes it remarkable. Development opportunities for aquaculture in the coastal zone of Turkey are limited because of the difficulties in obtaining access to suitable sites. Its expansion in coastal waters has not only added more pressure to marine and coastal ecosystems, but has also created conflicts among existing users of coastal resources. Consequently there was a need for expansion space and this growth has led to the drafting and implementation of new planning and management policies by the Turkish government. Priority and legitimacy over the Maritime Space was supported by the legal framework and given to the aquaculture industry through the establishment of a mariculture zone. This was a basic move to avoid conflicts and to assure the sustainable development of the sector. The Ministry of the Environment amended existing environmental legislation. It was then obligatory for the farms to be moved from the shallow shoreline waters to the deeper areas, particularly in gulfs and bays (FAO, 2017).

### Table 2 Fisheries and Aquaculture Potential

<table>
<thead>
<tr>
<th>Resources</th>
<th>Numbers</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Lakes</td>
<td>200</td>
<td>906.118</td>
</tr>
<tr>
<td>Dam Lakes</td>
<td>206</td>
<td>342.377</td>
</tr>
<tr>
<td>Man-made Lakes</td>
<td>952</td>
<td>27.032</td>
</tr>
<tr>
<td>Seas (total surface)</td>
<td>4</td>
<td>24.607.200</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1.362</strong></td>
<td><strong>26.000.000</strong></td>
</tr>
</tbody>
</table>


Table 2 shows potential area for fisheries and aquaculture. There are 33 rivers with 177.000 km in length and coastal line 8.333 km. Turkey has second longest coast line in the Mediterranean.

### Table 3 Species and type of aquaculture activities in Turkey

<table>
<thead>
<tr>
<th>Environment</th>
<th>SPECIES</th>
<th>Type of Aquaculture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish</strong></td>
<td><strong>Marine</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seabass (<em>Dicentrarchus labrax</em>)</td>
<td>Seacages/pond&amp;tank culture</td>
</tr>
<tr>
<td></td>
<td>Seabream (<em>Sparus aurata</em>)</td>
<td>Seacages/pond&amp;tank culture</td>
</tr>
<tr>
<td></td>
<td>Meagre (<em>Argyroso musregius</em>)</td>
<td>Seacages</td>
</tr>
<tr>
<td></td>
<td>Corb (<em>Umbrina cirrosa</em>), Commondentex</td>
<td>Seacages</td>
</tr>
<tr>
<td></td>
<td>(<em>Dentex dentex</em>)</td>
<td>Seacages</td>
</tr>
<tr>
<td></td>
<td>Redporogy (<em>PAGRUS pagrus</em>)</td>
<td>Seacages</td>
</tr>
<tr>
<td></td>
<td>Sharpsnoutseabream (<em>Diplodus puntazzo</em>)</td>
<td>Seacages</td>
</tr>
<tr>
<td></td>
<td>Bluefin tuna (<em>Thunnus thynnus</em>)</td>
<td>Seacages</td>
</tr>
<tr>
<td></td>
<td>Blue spaltedbream (<em>Dentex gibbosus</em>)</td>
<td>Seacages</td>
</tr>
<tr>
<td><strong>Fish</strong></td>
<td><strong>Freshwater and Marine</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trout (<em>Rainbowtrout</em>) (<em>Oncorhynchus mykiss</em>)</td>
<td>Pond&amp;tank culture</td>
</tr>
<tr>
<td></td>
<td><strong>Carp</strong> (<em>Cyprinus carpio</em>)</td>
<td>Pond culture</td>
</tr>
<tr>
<td></td>
<td><strong>Trout</strong> (<em>Salmotruta labrax</em>)</td>
<td>Seacages/pond&amp;tank culture</td>
</tr>
<tr>
<td></td>
<td><strong>Seabass</strong> (<em>Dicentrarchus labrax</em>)</td>
<td>Seacages/pond&amp;tank culture</td>
</tr>
<tr>
<td></td>
<td><strong>Sturgeon</strong> (<em>Acipencer sp.</em>)</td>
<td>Tank culture</td>
</tr>
<tr>
<td><strong>Mollusc</strong></td>
<td><strong>Marine</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mussels (<em>Mytilusgalloprovincialis</em>)</td>
<td>Long –lines and rafts in thesea.</td>
</tr>
</tbody>
</table>
Table 3 shows species and type of aquaculture activities in Turkey. During the last decade number of marine and freshwater species increased.

**KAYNAKÇA**


FAO-Word Bank 2017, Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture;Mariculture Parks in Turkey


AQUACULTURE PRODUCTION
AND
TECHNOLOGIES
Worldwide aquaculture has continued to grow in the past decades. It has been the fastest growing animal-food-production with an average annual growth rate of 6.6 percent from 1970 to 2008 (FAO, 2010). This huge development also occurred all along Mediterranean countries. Production of about 1.9 million tonnes in 2010 and annual average growth rate of 7% in the past 10 years. This has played an important role in enhancing the regional fish production, and meeting rising demand for fishery products. This trend will continue in future, in response to an increasing demand for seafood supported also by improving farm-

![Figure 1. The places of fish cages in the Mediterranean (Trujillo et al., 2017)](image)

Worldwide aquaculture has continued to grow and reached about 74 million tonnes in 2014. It involves around 50 million tonnes of finfish, 16 million tonnes of molluscs, 7 million tonnes of crustaceans and 7 million tonnes of other aquatic animals. This increase also occurred in Mediterranean and Black Sea countries. Aquaculture today is crucial for regional fish production in these areas. In fact, considering all the environment and farming technologies applied, the regional aquaculture production increased from around 1 million tonnes in 1995 to around 2 440 000 tonnes in 2015 (FAO, 2017).

In the aquaculture sector, marine cage farming is growing due to the increasing operations established along the Mediterranean coast. If we can minimize the cage farming effects on the environment then we can increase aquaculture production.

**Allocated zones for aquaculture (AzA) Definition**

In accordance with the rapid development of aquaculture, an integrated coastal zone management (ICZM) approach becomes crucial to secure the sustainability of the sector. In fact, when we concentrate on coastal zones, the availability of suitable areas for marine aquaculture is becoming critical for the further development of the sector in the Mediterranean. Then the improvement of site selection and the establishment of a specific marine spatial planning for aquaculture becomes obvious. Establishing AZAs is a priority for the sustainable development of aquaculture in the Mediterranean as it could make the integration of aquaculture easier into coastal areas and contribute to ameliorating coordination among the different authorities and actors involved in aquaculture development.
Management plan

After being established to guarantee its sustainability, an AZA needs to be conducted by a management plan. The main objectives of AZA management plans include:

- Assuring the preservation and protection of the AZA;
- Assuring social and/or economic advantages for the local communities;
- Assuring the maintenance of a good environment and of the ecological services accommodate the environment;
- Obtain protection for critical or representative habitats, ecosystems and ecological steps;
- With the help of participatory approach abstain conflicts among different human activities;
- Guaranteeing benefits for the farmers.

The authority should be expert on the aquaculture activities and these experts in the area should manage the AZA. They should be working in cooperation with the related users and stakeholders.

Case Study in Turkey

Aquaculture production versus fisheries can be seen in figure 3. The dramatic fall of fisheries is presented. Wild fish stocks are already under pressure from over-fishing, environmental degradation and pollution. The reason can be over fishing, pollution etc. Starting from 1999 the production has decreased fifty percent. Aquaculture production has filled this gap. In 2016, its share of the marine aquaculture and fresh water aquaculture production were around %57.8 and %42.2 by volume respectively. The sector can be characterized by limited species (primarily three species: rainbow trout, sea bass and sea bream) in floating cage systems.

Figure 2. Different zonation related to AZA for management proposals (Macias FAO, 2017)
Mariculture zoning was carried out in terms of a 2006 Environmental Law. In this mariculture zone aquaculture has precedence over other uses. It is recognized by physical and spatial planning authorities, a system aimed at integrating aquaculture activities into coastal zone areas that should avoid conflicts with other users. According to this law, marine aquaculture facilities should not be constructed in sensitive areas such as enclosed bays and gulfs or in natural and archeologically protected areas. In connection with this law, a notification which describes criteria for aquaculture site selection, in enclosed bays and gulfs was published in 2007, (MEF, 2007). Regarding this notification two mariculture zones were defined in Gulluk Bay, Mugla. There was Milas Zone and Bodrum Zone as defined by Turkish Inter-Ministerial Consortium,
Conclusion

When thinking of the wider ecosystem, the concept of AZA is rather limited to zoning process, thus form the fundamentals of sustainability. To be successful effective implementation of AZAs should be encouraged. The right usage of AZA would enable more knowledge on the natural environment and its interrelationship with coastal aquaculture production processes. It would also enable reducing impacts on the environment, accelerating local economic development, promoting food security and social acceptability, and stimulating institutional capacities for the sustainable development of aquaculture.

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MEF, 2007: Notification to identify the closed bays and gulfs qualified as sensitive areas where fish farms are not allowed. Turkish Official Gazette 26413 In Turkish


TUIK, 2017. Turkish Statistical Institute http://www.turkstat.gov.tr
The ecosystem approach to aquaculture (EAA) and its relevance to achieve sustainability objectives of the sector. An Ecosystem Approach for Aquaculture is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems.

The EAA is guided by three main principles:

1. Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation of these beyond their resilience,

2. Aquaculture should improve human-well being and equity for all relevant stakeholders,

3. Aquaculture should be developed in the context of other sectors, policies and goals.

The strategy has these three objectives at the core;
When can an EAA start

Ecosystem Approach to Aquaculture (EAA)

1. Initiation and Planning
   Scoping and Baseline Data
   Broad Objectives

2. Identify and prioritize Issues
   Component Trees
   Risk Assessment

3. Develop Management System
   Set Operational Objectives
   Select Indicators
   Evaluation/Selection of Mgmt Options

4. Implement and Monitor
   Finalizing Management Plan
   Formalize Management Plan
   Review Performance
   Report and Communicate

• Defining the management area/unit
  • Basic information about the aquaculture system in that unit
    • Stakeholder analysis
    • Institutional analysis
    • Agreement on general objectives by all stakeholders

• Issues and problems identified, prioritized and agreed upon by the stakeholders

• For each priority problem, operational objectives and indicators identified
  • Management options identified (cost-benefit analysis), discussed and agreed upon by stakeholders

Management Plan
The EAA can be used at any geographical scale

Scale

EAA management measures; e.g. facilitating nutrient re-cycling and improved social benefits

Aquaculture spatial planning in the EAA

- The spatial planning of aquaculture (zoning or the location of sites) can use the EAA framework considering the social, economic/productive, environmental and governance elements
- These are the “elements” of the carrying capacity to sustain aquaculture in a specific area or water body
- FAO has been developing tools and guidelines for aquaculture zoning and site selection, we talked about this in my first presentation
  
  Addressing social carrying capacity (example, FAO project Izmir Turkey)
**Step 1. Defining the scope**
Defining the -aquaculture activity, -boundaries, -societal values and -high level objectives.

Over development of cage farms in an enclosed bay

Conflict with tourism and homes

Identify areas of conflict between environmental, social and economic interests in the aquaculture zone
Key stakeholders are:

- Ministry of Agriculture (central and local offices)
- Maritime Affairs and Marine traffic
- Ministry of Environment
- Ministry of Tourism
- Ministry of Public Works
- Coastguard
- Universities specialising in Aquaculture and the Environment
- Research Institutes specialising in Aquaculture and the Environment
- Cage farmers (Small-scale, medium-scale and large-scale)
- Aquaculture Producer Organisations, Aquaculture associations
- Hotel Operators
- Diving clubs
- Fishery Cooperatives
- Summer Holiday Home owners
- Environmental NGOs

Agreeing on community values and high level objectives

<table>
<thead>
<tr>
<th>VALUE</th>
<th>OBJECTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Outcomes</td>
<td>Optimising economic benefits to the farmers; with potential for social development</td>
</tr>
<tr>
<td>Seascape and pollution</td>
<td>Maintain good visual aspect from coast and maintain good water quality and clean beaches</td>
</tr>
<tr>
<td>Ecosystem services</td>
<td>Maintaining relevant ecosystem functions and services (including productivity, biodiversity)</td>
</tr>
</tbody>
</table>

Suggested high level objectives

- To reduce the environmental impact and impact to the seascape, whilst allowing the continued sustainable growth of cage aquaculture using the Ecosystem Approach to Aquaculture strategy to draft a road map that can be implemented by the Government in an equitable manner.
Information required for the baseline study
To include
- Present and historical aquaculture development
- Overview of the aquaculture area (geographical location, boundaries, water resources, carrying capacity considerations for used water bodies, local administration aspects)
- Present Management Plan
- Present legal, institutional and administrative frameworks
- Main stakeholders (upstream, producers, downstream).

Planning vs management
• Planning
  • Cross-sectoral (many Agencies)
  • Multi-disciplinary
  • Holistic perspective (EAA/ICZM)/MSP
• Management
  • Line agencies/Ministries/Departments
    • Fisheries/Aquaculture
    • Environment
    • Tourism
  • Not holistic ecosystem management (sectorial)

Step1-Identifying the issues
• Identifying assets and issues
  • Ecological assets
  • Socioeconomic assets/outcomes
  • Ability to achieve or governance
• Develop issue trees
  • Ecological
  • Social
  • Governance
Issues are often related to different parts of the process and to the assets in each component of this process.

A risk analysis typically seeks answers to four questions:
1. What can go wrong?
2. How likely is it to go wrong?
3. What would be the consequences of its going wrong?
4. What can be done to reduce either the likelihood or the consequences of its going wrong?

Undertake risk analysis to prioritise key issues

- Likelihood
  - How often is an impact likely to occur

- Impact
  - If an impact occurs what is the ..............

- Issues to be formulated as possible negative outcomes of present management in relation to stated broad objectives

- Risk to be measured in relation to stated broad objectives and against a better management.
### Likelihood of occurring

<table>
<thead>
<tr>
<th>Rating</th>
<th>Recurrent Risks</th>
<th>Single Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost Certain</td>
<td>Could occur several times per year</td>
<td>More likely than not - Probability greater than 50%</td>
</tr>
<tr>
<td>Likely</td>
<td>May arise about once per year</td>
<td>As likely as not - 50/50 chance</td>
</tr>
<tr>
<td>Possible</td>
<td>May arise once in ten years</td>
<td>Less likely than not but still appreciable - Probability less than 50% but still quite high</td>
</tr>
<tr>
<td>Unlikely</td>
<td>May arise once in 10 years to 25 years</td>
<td>Unlikely but not negligible - Probability low but noticeably greater than zero</td>
</tr>
<tr>
<td>Rare</td>
<td>Unlikely to occur during the next 25 years</td>
<td>Negligible - Probability very small, close to zero</td>
</tr>
</tbody>
</table>

### Level of impact

<table>
<thead>
<tr>
<th>Rating</th>
<th>Economic</th>
<th>Social and Community</th>
<th>Environment &amp; Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catastrophic</td>
<td>Business failure</td>
<td>Loss of employment, livelihood and hardship</td>
<td>Major widespread environmental impact and irreversible environmental damage</td>
</tr>
<tr>
<td>Major</td>
<td>Business are unable to thrive</td>
<td>Reduced quality of life</td>
<td>Severe environmental impact and danger of continuing environmental damage</td>
</tr>
<tr>
<td>Moderate</td>
<td>Significant general reduction in economic performance relative to others</td>
<td>General appreciable decline in services</td>
<td>Isolated but significant instances of environmental damage that might be reversed with intensive efforts</td>
</tr>
<tr>
<td>Minor</td>
<td>Individually significant but isolated areas of reduction in economic performance relative to others</td>
<td>Isolated noticeable examples of decline in Quality of life</td>
<td>Minor instances of environmental impact that could be reversed</td>
</tr>
<tr>
<td>Insignificant or positive</td>
<td>Minor shortfall in profitability relative to others or positive</td>
<td>There would be minor areas in which the region was unable to maintain its current services</td>
<td>No environmental impact or benefits to the environment</td>
</tr>
</tbody>
</table>

### Assessment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Almost Certain</td>
<td>5 = Low</td>
<td>8 = Medium</td>
<td>12 = High</td>
<td>16 = High</td>
<td>20 = Extreme</td>
</tr>
<tr>
<td>4. Likely</td>
<td>4 = Low</td>
<td>6 = Medium</td>
<td>9 = Medium</td>
<td>12 = High</td>
<td>15 = High</td>
</tr>
<tr>
<td>3. Possible</td>
<td>3 = Low</td>
<td>4 = Low</td>
<td>6 = Medium</td>
<td>8 = Medium</td>
<td>10 = Medium</td>
</tr>
<tr>
<td>2. Unlikely</td>
<td>2 = Low</td>
<td>1 = Low</td>
<td>3 = Low</td>
<td>4 = Low</td>
<td>5 = Medium</td>
</tr>
<tr>
<td>1. Rare</td>
<td>1 = Low</td>
<td>2 = Low</td>
<td>3 = Low</td>
<td>4 = Low</td>
<td>5 = Medium</td>
</tr>
</tbody>
</table>

### Risk levels

<table>
<thead>
<tr>
<th>Risk Level Descriptors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>Risks demand urgent attention and adaptation solutions need to be found as soon as possible at all levels.</td>
</tr>
<tr>
<td>High</td>
<td>Risks are the most severe that can be accepted as part of routine operations but adaptation solutions need to be addressed quickly.</td>
</tr>
<tr>
<td>Medium</td>
<td>Risks can be expected to form part of routine operations but adaptation solutions need to be developed in the medium term and the risk monitored regularly.</td>
</tr>
<tr>
<td>Low</td>
<td>Risks will be maintained under review but it is expected that existing farm management will be sufficient and no further action will be required to find adaptation solutions unless they become more severe.</td>
</tr>
</tbody>
</table>
I. Generalities on fish reproduction in captivity

1. Introduction

The most difficult problem is the absence of sexual maturation, or abnormal or incomplete maturation. These situations are often observed in various economic species maintained to be reproduced in captivity. The possible causes are numerous and can be combined: inadequate feeding, inadequate factors of the breeding environment, stress of confinement, etc. In this case it is generally recommended to base the definition of breeding parameters on strong research on the ecology of the species and the role of external factors in controlling the various stages of gametogenesis in order to determine the essential factors to be controlled. Moreover, knowledge of the mechanism of action of these external factors through the neuro-endocrine system is also important to overcome the defect of some of these breeding parameters.

Another type of problem encountered in most species, particularly in the species of our northern and temperate regions, is the breeding seasonality, which occurs at a time of year which generally prevails during the favourable period. Feeding fingerlings in the natural environment. The development of the gonads follows a seasonal cycle linked to the evolution of certain external factors including temperature and photoperiod.
2. Neuroendocrine mechanisms in fish reproduction

**Reproductive Axis in fish**

*Environmental factors*
(photoperiod, lunar cycle, temperature, rainfall, social factors, ...)

- Gametogenesis
- Final maturation

- Brain

- Pituitary

- Full grown gametes
- Fertile gametes

**Gonadal steroids**

Pituitary innervation (Neurohormones) and synthesis and routing of Gonadotropins

**Reproductive cycle in fish (female)**

Environment

- Hypothalamus
  - GnRH (+)
  - Dopamine (-)

- Brain

- Pituitary
  - GHT I
  - GHT II

- Liver
  - Follicle Stimulating Hormone (FSH) (+)
  - Testosterone (T)
  - Estradiol (E2) (+)

- Ovary
  - Sex steroids
    - 17,20 Beta Dihydroxy Progesterone

- Vitellogenesis
- Final Oocyte Maturation (FOM)
The ovary contains the mechanism necessary for the synthesis of Sexual steroids, steroidogenesis. All steroids are derived from cholesterol, estrogens (C18 steroids: estradiol (E2), estrone (E)), androgens (C19 steroids: testosterone (T), 11-Ket testosterone (11-KT), androstenedione) and progestogens (C21 steroids: progesterone, 17α-hydroxyprogesterone (17α-HP), 17α,20β-dihydroxy-4-pregen-3-one (17α,20βDHP)).

There are synthesized in the follicular calls (Theca and granulose), under the control of GTHs. At initial stages, E2, T and 11-KT are secreted and their circulating levels increase in parallel with gonadal development. At later stages, levels of these steroids decrease and there is a release of the steroids implicated in oocyte maturation (Maturation Inducing Steroids MI) and others (17α,20βDHP: in salmonids or 17α, 20β21-THP: in other marine fish).

3. Gametogenesis and reproductive cycle

Schematically, ovarian development can be divided in three major stages, previtellogenesis, vitellogenesis and maturation:

The Previtellogenesis composites the period in which the oogonias proliferate by mitotical divisions, becoming primary oocytes when they pass to the first meiotic division, where they are arrested until further development during the maturation stage.

The Vitellogenosis period is characterized by the progressive incorporation of Vitellogenin VTG into the growing oocytes, via receptor mediated encocytosis and intracellular cleavage of VTG to give rise to the York reserves of egg.
The Maturation stats with the migration of the nucleus towards the periphery and its subsequent breakdown. The oocytes continues the progress of meiotic division that will be completed after fertilisation. During maturation York and lipid droplets coalesce and, in marine teleosts, the oocyte largely increase its volume by hydration. Once maturation is completed, oocyte is ovulated by expulsion from the follicle to the oviduct or peritoneal cavity. Some oocytes that not progress in their development become atresic, they degenerate and their content is reabsorbed by the surround follicular cells.

Once maturation is completed, oocyte is ovulated by expulsion from the follicle to the oviduct or peritoneal cavity. Some oocytes that not progress in their development become atresic, they degenerate and their content is reabsorbed by the surround follicular cells.
Hatchery design and management

The most common method of rearing in the hatchery is the “intensive method”, which is based on the separation of all phases of rearing in order to control all the stages:

Management of brood stock (storage and handling)
Egg production and maturing (programming and induction)
Incubation and hatching of eggs
Larval farms and fry production
The cultivation of live prey (larval feeding)
The larval observation laboratory and water quality analyzes;
The technical room where the filters, pumps and aerators are grouped together.

1. Fluids

The hatchery uses fresh water, sea water and air. These must always be in perfect working order. The dysfunction of one or the other may lead to the temporary halting of the hatchery and the loss of the breeding stock in progress. The various networks are generally grouped together in the technical room to simplify installation, maintenance and use.

2. Fresh water

It is mainly used for cleaning equipment and rinsing a small utensil.

In each compartment of the hatchery will be placed a container of 200 liters which contains 40 g / m³ of chlorine (disinfection). At the end of the day the container will be emptied onto the floor to serve as a general cleaning of the room.

Freshwater can also be used to reduce the salinity of sea water (eg: live prey). In this case, it must be dechlorinated by one of the following means:

Using a industrial dechloriser
Aging of water in tanks or tanks at least 24 hours before use
Use of sodium thiosulfate (Na₃ SO₃)

3. Sea water

Seawater arrives in the hatchery by pumping. Generally two pumps that have a constant flow assure the supply. They can be used either individually or simultaneously as required. An emergency auxiliary pump supplied by an electrical circuit different from the previous one and installed in another location, is to be provided in the event of a breakdown.

The degree of filtration of seawater varies according to the hatchery unit. After the first pumping, the water usually passes through a 50 micron sand filter and arrives directly either at the nursery or in a tank in case of storage. After the tank it can pass:

directly to the brood stock maturation unit
undergo further filtration at 5 microns (larval rearing, rotifers, Artemia) and then at 1 micron for algae and hatching.

Sea water can also undergo heat treatment (heating or cooling) as required. This treatment requires a boiler or a cold or mixed pool.

4. Air

The air supply is supplied by a battery of boosters (2 or 3), the start-up of which depends on the demand. Each device has a flow rate that allows it to feed all the units hatchery.
The air intake must be clear and clean. The fragility of these devices requires careful maintenance. Any suspicious operating noise must be reported to the logistics manager who will diagnose the problem and if its necessary disassembly.

(e.g.: Suppresseurs « SIEMENS Type ELMO.G de 110 m³/h à 2,25 m. Moteur 3 KW).

II. Organisation of broodstock compartment

1. Objective

The storage of broodstock in maturation tanks is to provide them with the necessary conditions for the development of the gonads, to obtain better reproduction and fertilized eggs. This step provides simultaneous maturation of females and males and requires good coordination with the other units.

2. The broodstock

Generally, brood stock are derived from the natural environment, but are sometimes supplemented by individuals from rearing farms. They are selected among the healthiest animals (healthy, without malformation), exceeding 5 years of age (about 1.5 to 2 kg). The stocks are annually renewed at rates ranging from 15 to 20%. The choice of brood stock is decisive for the success of maturation and consequently the spawning.

3. Broodstock tanks

They are generally rectangular or circular ponds of reinforced concrete, each having a capacity of 12 to 20 m³. They are supplied with seawater filtered at 50 microns and equipped with an aeration system to allow a good oxygenation and mixing of the water. They are equipped with a central bottom discharge (for emptying and cleaning) and a tangential from the top, allowing the collection of eggs and the elimination of the suspended matter (fat).

Water filtration: 30-50 microns
Renewal of water: 2 m³/h for tank to 10-12 m³
Oxygenation: 1-3 m³/h for tank of 10-12 m³

Lighting by neon tubes of 2X60 watts. The photoperiod is natural in the case of natural laying and artificially staggered by a timer system, for staggered laying.

III. Rearing management

1. Routine operations

Biotechnical factors are to be monitored and measured during the maturation period, and are then displayed on a control panel on a daily basis:

- measure temperature, salinity and pH and monitor dissolved oxygen levels
- check that ventilation and water supply are at normal flow
- If the turbidity is too high, remove 1/3 to 2/3 of the volume of water.
- Check the health status of the livestock. Report sick animals and extract the dead (in case), record their numbers as well as their sex and weight
- Clean the bottom of the tank before distributing the next ration. If the remains are too important, estimate them and subtract their weight from the next ration.
- Make a biometric every month: Record the total number of brood stock (male and female), individual weights and sizes and determine by IC Condition Index (K) in each bin.

All this information must be recorded in a tracking register.
2. Monitoring and control of maturation

The captive breeding of marine fish is a relatively complicated process in all species, because under conditions close, maturation are often take place, but there is always a blockage in the later stages and the most impossibility of egg release without hormonal induction.

- **Photoperiod and temperature**

  Spawning can be "natural" made during the natural reproduction period. It can be shifted out of this period (delayed or advanced), which allows a better occupation of the hatchery (profitability, occupation) and sometimes a significant economic gain (energy, growth, ...).

  Teleost fish as poikilotherm animals are seasonal breeders which reproduce at specific periods of the year showing a close adaptation with the seasonal changing environmental factors such as photoperiod and temperature. The time of reproduction, at least of most commercial species, is restricted to few months and can be held at any season of the year according to the species considered but always keeping similar times of appearance from one year to another which in general are most suitable for the survival of the progeny produced. The figure present the spawning season of a marine teleost, the sea bass which will be used a model to develop this presentation, which occurs from January to March coinciding with the lowest temperature of the year and the first increase of the shortest photoperiod.

![Restricted spawning periods in relation with the cyclic changes of photoperiod and temperature](image1)

Manipulation of natural environmental factors including photoperiod and temperature are very effective to alter the timing of the main reproductive process (oogenesis/spermatogenesis, oocyte maturation, ovulation /spermiation and spawning). To get spawns from given species of teleost fish all year round, it necessary to organize several groups of male and female broodfish and adapt them to different phase shifted cycles of both photoperiod and temperature with respect to natural environment cycles. Generally, there is a close correlation between the magnitude of the photoperiod phase shift of the rhythm with respect to the control group (natural photoperiod rhythm) and the magnitude of the time shift with respect to natural spawns.

![All year round spawns by modification of the seasonal cycles of photoperiod and temperature](image2)
Compressed photoperiods refer to seasonal light cycles compressed into periods of time shorter than 1 year (4, 6, 8 months per cycle). These modified seasonal photoperiods generally induce earlier spawns than control fish under natural ambient condition. On sea bass 6 months compress annual cycle induce spawning 2-4 months earlier than the control fish.

Extend photoperiod, refer to seasonal light cycles extend into periods of time longer than 1 year (18 months per cycle) were effective to delay spawns by 3 months in Atlantic Salmon and rainbow trout.

The increases or progressive disminutions of seasonal light and temperatures can be replaced by the use of photoperiod of constant length and constant temperatures (or combination of both). Fish exposed to different photoperiods altered their spawning time according the phase-shift levels applied to them. However this manipulation requires a precise and complex adjustment of the photoperiod regimes, particularly if the teleost species have longer cycle of maturation. Replacement of these progressive changes of seasonal day length by constant lengths of photoperiod or a combination of photoperiod of constant lengths have been very effective. Constant long photoperiods applied throughout the year induced a delay of maturation spawning time of sea bass whereas an exposure to constant short days provoked an advance in spawning time. A series of experiments done with trout (Bromage et al., 1984) demonstrated that exposure to long day until September and the short days in the following months advanced spawning time one month in comparison with a control group.

- **Food**

The broodstock is fed with commercial dry foods (specially rich in proteins and phospholipids). The granules favor the maturation of the females but their effects can have a negative impact on the quality of the gonads, specifically on the gametes. For this purpose, high-quality fresh foods are also used in addition, such as mussels, shrimps or squid. Brood fish are usually fed all week with a day of fasting.

Locally produced semi-wet foods are often used to complement some fish species that are not very food-intensive, such as mullets.
• **Biometry**

This is the periodic determination of the principal metric characters of each fish. The fish are anesthetized with phenoxy-ethanol (0.3 ml / l) and weighed and measured individually to determine respectively the individual total weight (Wt) the total length (LT) and fork length (LF). The Condition Index (IC), are then calculated, the evolution of which gives an idea of the general state of the fish (overweight). 

\[ IC = \frac{Wt}{LT^3} \]

• **Biopsy**

The biopsy consists of taking oocytes using a sterile polypropylene cannula (Cornier pipette), introduced into the female's genital orifice under anesthesia.

The microscopic observation of the oocytes taken after "deopacification" by a solution called EFA makes it possible to determine the stage of evolution of the oocytes and their follicular structure.

The examination of the structure of these oocytes which have a size between 650 and 800 μm allows us to distinguish the presence of a central nucleus, yolk globules and lipid globules. In conclusion, it can be said that these oocytes belong to stages II of vitellogenesis. Oocyte development often stalls for most breeding species at this stage. The hormonal injection is therefore necessary for the resumption of the meiosis and the continuation of the maturation until ovulation.

• **Hormonal injection**

In fish hatcheries, the administration of extracts of pituitary glands of carp (hypophysation) is a most common technique. Human chorionic gonadotrophin (HCG), extracted from the urine of pregnant women, is also frequently used. It is also possible to intervene at an advanced stage of maturation by a synthetic compound, the Luteinizing hormone releasing hormone (LH-RH) and more recently some analogues, like (LHRH-a). All these products are used successfully to achieve final maturation and ovulation. The solvent used to prepare the hormone extract solution is a 0.9 percent (physiol) ordinary salt (NaCl) solution. The hormones used remain HCG (Human Chorionic Gonadotrophin) and LHRH-a (Luteinizing Releasing Hormone analogue). The most appropriate injection method is intramuscular injection into the dorsal muscle between the base of the dorsal fin and the lateral line.
Direct administration into the abdominal cavity (intraperitoneal injection) is sometimes applied by the lateral insertion of the needle under the base of the pectoral fin into the abdominal cavity. However, this method can damage the internal organs and also lead to loss of extract by accidental injection into the esophagus or the digestive tract. It usually requires a fine needle (insulin), but it is not recommended.

**Spawning**

Process of final maturation and ovulation takes time. It varies from one species to another and depends largely on the temperature of the environment. On function of the temperature it is possible to establish a spawning time.

The physical parameters of the final maturation are: the increase in size by hydration and the translucency of the oocytes.

For female which are at the end of vitellogenesis, spawning is usually done 72 hours after the last hormonal injection. The fertilized eggs are mostly pelagic species and their collection is facilitated through the overflow of the pond tank. Unfertilized or dead eggs flow under their weight.
Grey mullet Chelon labrosus

The relative rarity of males and the problem of timing their maturation with females are a reality in breeding. Artificial fertilization by in vitro mixing of sperm recovered in a mature male and mature oocyte extracted by streeping in a hydrate could be an alternative, if it is well controlled. Thus we have thought to test the effectiveness of this technique C. labrosus in the first place. Encouraging but still perfectible in the coming years, streeping is currently leading to average fertilization rates of 32%.

Streeping?

Different stages: oocyte collection, sperm collection, contact between male and female gametes, feather blending, filtration and recovery of fertilized eggs (supernatant)

Incubation and hatching

After collection and counting by the dilution or weighing method (100 g approximately 100,000 eggs) the eggs are incubated either in the same larval rearing tanks (density around 1000 eggs per liter) or in cylindroconic incubators of 40 to 60 liters with a double inlet of filtered water and sterilized with UV, from the bottom and tangentially to allow the suspension of the eggs and the non-clogging of the mesh of the incubator (500 microns).
V. Summary of zootechnical results obtained at INSTM Center of Monastir hatchery

- Grey mullet (*Chelon labrosus*)

<table>
<thead>
<tr>
<th>Minimum acclimation time</th>
<th>3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spawning period</td>
<td>February-March</td>
</tr>
<tr>
<td>Spawning temperature</td>
<td>15°C</td>
</tr>
</tbody>
</table>
| Hormonal induction       | 1<sup>st</sup> injection: 10 000 UI HCG/kg  
                          | 2<sup>nd</sup> injection: 10 000 UI de HCG + 100 μg de LHRH-a |
| Latency                  | 72H     |
| Fecundity                | 890 000 eggs/kg of fish |
| Fertilisation rate       | 83%     |
| Eggs diameter            | 1 150 μm |
| Incubation               | -15°C  
                          | - 88 H  
                          | - Hatching rate: 95% |
| Larvae Length Jo         | 3,40 mm |

- Flathead grey mullet (*Mugil cephalus*)

<table>
<thead>
<tr>
<th>Minimum acclimation time</th>
<th>3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spawning period</td>
<td>August - September</td>
</tr>
<tr>
<td>Spawning temperature</td>
<td>25°C</td>
</tr>
</tbody>
</table>
| Hormonal induction       | 1<sup>st</sup> injection: 10 000 UI HCG/kg  
                          | 2<sup>nd</sup> injection: 10 000 UI de HCG + 200 μg de LHRH-a |
| Latency                  | 12H     |
| Fecundity                | 675 000 œufs/kg de poisson |
| Fertilisation rate       | 33%     |
| Eggs diameter            | 950 μm  |
| Incubation               | - 25°C  
                          | - 22 H  
                          | - Hatching Rate: 85% |
| Larvae Length Jo         | 2,50 mm |
**HATCHERY: LARVAE DEVELOPMENT AND REARING**

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1. Introduction

Most fish species spawn large number of eggs which are very small compared to adult fish size. There are also differences between egg types which are mainly related to size and composition. For illustrating this (Fig. 1) we may refer to eggs of sparids _versus_ those of salmonids. The first are small eggs which usually measure about 1 mm and have a water content of 90% while the second are larger eggs which measure more than 4 mm and have a water content of only 60%. The newly hatched larvae issued from these types of eggs measure about 3 mm and 18 mm respectively.

The fish larvae are tiny and also much less developed than the juveniles in terms of morpho-functional features. They are highly vulnerable and must undergo major changes (Fig. 2) to reach the juvenile stage which corresponds to the acquisition of the adult shape and the adult mode of organ operating, excluding puberty.

In crustaceans, shellfish or echinoids, these changes occur through different successive steps (nauplius, zoe and mysis in crustaceans or trocophore, D-larvae and veligere larvae in shellfish ...) until the final metamorphosis. In fish the changes occur throughout embryonic and larval development, which ends with metamorphosis, in a dynamic continuous process (Osse and van den Boogaart, 1995). These changes are crucial for the further survival and growth of the fish and concern all the functional systems (digestive, respiratory, locomotory, nervous and sensory, immune, hormonal...). The differences in egg types and thus potential embryo size and available reserves affect embryonic duration as well as the potential level of development of the larvae at hatching and at first feeding (Table 1). Surviving till the juvenile stage is a challenge and as smaller is the larva as difficult is the challenge. Global survival rates are highly variable depending mainly and first on eggs types and thus on species, either in the wild or in rearing conditions. For a same species, the survival rates are related to quality of broodstock (strain, nutritional status, age) and environmental conditions (water quality, feed availability, predation, specific behavior such as cannibalism _etc._).
In hatcheries, survival rates are generally much higher than in the wild as most factors are set to the optimal conditions. Nevertheless, the survival rates may also be variable according to the used technology and the experience and the know-how of the staff. In the wild, medium survivorship is about 5% in a cohort of large fish larvae while it is only about 0.1% in a cohort of small fish larvae (Houde, 1992). Enormous fecundities of fishes are balanced by high egg and larval mortalities resulting from natural interacting environmental factors and the vulnerability, the gsize and the growth of the early stages (Dahlberg 1979; Houde, 1987; 1989; Meekan et al. 2006). In intensive hatcheries with highly experienced staff, these rates may rise up to about 60% for species such as salmonids or tilapia, 20-30% for species such as bream and bass and about 10-20% for species showing high cannibalistic behavior such as perch and pikeperch. In mesocosms, these rates may reach higher values but global productivity per unit of water is smaller as rearing densities are much lower. In the hatchery, the main role of aquaculturist or “larvi-culturist” is to provide the best conditions (temperature, O₂, water quality, light, feed, etc.) to the tiny and fragile organisms that are the larvae, with the objective of getting the best possible survival rates of good quality juveniles (absence of malformation, growth performances, etc.).

Table 1: Characteristics of fish eggs types and corresponding larvae at hatching and first feeding.

<table>
<thead>
<tr>
<th>Species</th>
<th>Egg size mm</th>
<th>Temp. °C</th>
<th>Incubation days</th>
<th>Hatching size mm</th>
<th>FF. Age days</th>
<th>FF. size mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epinephelus coeruleus</td>
<td>0.72 - 0.76</td>
<td>24</td>
<td>1 - 2</td>
<td>1.6 - 1.8</td>
<td>2</td>
<td>2.4 - 2.6</td>
</tr>
<tr>
<td>Pseudoplatystoma americana</td>
<td>0.74 - 0.80</td>
<td>8</td>
<td>8 - 10</td>
<td>3.0 - 3.4</td>
<td>6</td>
<td>3.6 - 4.1</td>
</tr>
<tr>
<td>Sparus aurata</td>
<td>0.90 - 1.10</td>
<td>17</td>
<td>3 - 4</td>
<td>2.6 - 3.2</td>
<td>3</td>
<td>3.4 - 3.6</td>
</tr>
<tr>
<td>Pagrus pagrus</td>
<td>0.90 - 1.10</td>
<td>17</td>
<td>3 - 4</td>
<td>2.6 - 3.0</td>
<td>3</td>
<td>3.3 - 3.6</td>
</tr>
<tr>
<td>Chelon labrosus</td>
<td>1.10 - 1.20</td>
<td>16</td>
<td>3 - 4</td>
<td>3.5 - 3.7</td>
<td>4</td>
<td>3.8 - 4.0</td>
</tr>
<tr>
<td>Dicentrarchus labrax</td>
<td>1.10 - 1.50</td>
<td>14</td>
<td>3 - 4</td>
<td>3.2 - 3.7</td>
<td>4</td>
<td>4.0 - 4.6</td>
</tr>
<tr>
<td>Sander lucioperca</td>
<td>1.10 - 1.30</td>
<td>14</td>
<td>4 - 5</td>
<td>3.8 - 4.3</td>
<td>5</td>
<td>4.8 - 5.5</td>
</tr>
<tr>
<td>Micropterus salmoides</td>
<td>1.40 - 1.80</td>
<td>16</td>
<td>2 - 3</td>
<td>4.5 - 5.5</td>
<td>6</td>
<td>5.8 - 6.3</td>
</tr>
<tr>
<td>Oreochromis niloticus</td>
<td>1.30 - 2.50</td>
<td>26</td>
<td>2</td>
<td>8 - 10</td>
<td>2</td>
<td>14-15</td>
</tr>
<tr>
<td>Salvelinus fontinalis</td>
<td>4.40 - 5.00</td>
<td>4</td>
<td>80 - 100</td>
<td>18.0 - 24.0</td>
<td>60 - 70</td>
<td>24.0 - 28.0</td>
</tr>
</tbody>
</table>

FF.: first feeding

1. Fish hatchery technologies

There is a large variety of fish hatchery technologies (Fig. 3). The most basic and oldest technologies being the extensive methods practiced outdoor in ponds where natural conditions are offered to the eggs/larvae seeded at a very low density (<1 larva/liter) often after the elimination of potential predators and a boost of preys development. The most sophisticated and more recent technologies being the intensive and hyper-intensive methods practiced indoor with infrastructures providing strictly controlled conditions (photoperiod, light intensity and spectrum, temperature, water quality, hydrodynamism, oxygenation, feed, disinfection etc.), using high rearing densities (reaching up to 200 larvae/liter). Between these contrasting technologies, there are multiple intermediate technologies, including the mesocosms, which are generally designated as semi-extensive or semi-intensive methods (Ben Khemis et al., 2006; Zouiten et al., 2008; 2011).
Fig. 3: Illustration of few hatcheries technologies: ponds (1 and 2); structures for intensive larviculture (3 and 4) and mesocosms (5 and 6).

All these technologies are generally classified (Fig. 4) according the size of enclosures, stocking and harvesting densities and the density of food supplied (Divanach and Kentouri, 2000). Hatchery technology and, notably, intensiveness markedly affect fish larvae development (Favaloro and Mazzola, 2003; Izquierdo et al. 2010; Roo et al. 2010; Zouiten et al., 2011).

Fig. 4: Classification of hatchery technologies according to larval density, enclosure size and feed supply (Adapted from Divanach and Kentouri, 2000)

The types of hatchery technology to be selected depends first and mainly on the investment capacity and the production objectives. Secondarily it depends also on a large number of parameters such as selected species, local geo-climatic context, space availability, market specificity. Most of aquaculture production relies on intensive hatcheries but only few species are actually so well known as to be reared successfully in such industrial system for which the economical break point of such hatcheries is high (Divanach and Kentouri, 2000) due to cost of both infrastructures and operations (energy, engineering and biological know-how, experienced staff). The economical break point was estimated to be around a production of 2 Millions of fry/year at the end of the nineties but it is nowadays estimated to be higher than 15 Millions of fry/year.
2. Fish hatchery steps

From the egg stage to the weaned pre-grown juvenile stage, the zoo-technical process may be divided into four distinct steps consisting in: incubation of eggs; rearing of early larval stage; weaning of post larval/young juvenile stage; pre-growing, grading and sorting of juvenile/fry. These steps concern different developmental stages for which particular zootechnical conditions must be provided to fulfill the specific biological needs of the reared stage of the species and in adequacy with its abilities (Fig. 5).

Fig. 5: Hatchery steps.

2.1. Incubation of embryonic and pre-larval development stages

2.1.1. Biological specificities

Development and growth of embryos and larvae need relatively huge amounts of energy and building materials. At hatching, the digestive tract of fish larvae is often lacking or un-functional, organogenesis is far from being achieved and mouth is still closed. Thus, the fish eggs must contain all the nutrients required by the developing embryo from the time of fertilization until the time at which it becomes able to meet its needs by consuming exogenous food (Jobling, 1995). These nutrients inherited from the mother (Fig 6), constitute the body and the reserves of the embryo. Reserves consist in the yolk sac (vitellus) which contains lipoproteins, proteins, peptides and free amino acids (Thorsen and Fyhn 1996) as well as micronutrients – vitamins and minerals – required for proper development. The yolk reserves are used both as building materials for tissue synthesis (growth and organogenesis) and as metabolic fuels. In addition to the yolk sac, various species also possess one or more oil droplets, containing mainly neutral lipids used only as energetic source (Gatesoupe et al., 1999). According to Rønnestad et al. (1998; 1999), free amino acids appear to be a significant energy substrate during the egg stage and the early yolk-sac stage while fatty acids from neutral lipids derived from the oil globule seems to be the main metabolic fuel after hatching.

Females can exert a range of non-genetic effects on their offspring, in particular, they may modify the size and the weight of the eggs depending on the amount of energy they have accessible for reproduction, which implicitly suggest modification of the available amounts of energy and building materials per egg and larva both at hatching and at mouth opening (Donelson et al. 2008; Ben Khemis et al., 2014). Quantitatively, the deposited materials within the larvae and their reserves depend on species egg size, spawns quality, age and feeding status of the female, the time (early or late) within reproduction period and genetic of broodstocks strains (in seabass Atlantic strain has eggs of 1.5 mm Ø while those of the Mediterranean strain has eggs of 1.2 mm Ø).
The rate of consumption of reserves is influenced by external factors, in particular incubation temperature and light which increase metabolic and swimming activities respectively (Gatesoupe et al., 1999). Thus the development stage and the size attained at the end of the exclusively endotrophic period (i.e. at first feeding stage) may fluctuate considerably. Up to 40% difference in larvae mass has been reported. In sea bass, the protocol, frequently referred to as the “French technique”, is characterized by a dark environment during the 10 first days after hatching (thus until 5-6 days after mouth opening), which allow then the use of small newly hatched brine shrimp *Nauplii* as first food. Major difficulties of larviculture being related to smallness of the larvae, it is advantageous to select the biggest eggs and to apply low temperature and dark conditions during incubation for optimizing yolk deposition into tissues and obtain the largest possible larvae at the onset of feeding.

**Table 2:** Size and proximal composition of eggs and morphometry of early larvae from wild

<table>
<thead>
<tr>
<th>Eggs</th>
<th>Wild</th>
<th>Captive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg diameter (mm)</td>
<td>1.11 ± 0.05</td>
<td>1.25 ± 0.01</td>
</tr>
<tr>
<td>Egg weight (mg)</td>
<td>0.92 ± 0.04</td>
<td>1.13 ± 0.05</td>
</tr>
<tr>
<td>Water content (%)</td>
<td>87.69 ± 0.74</td>
<td>87.15 ± 0.40</td>
</tr>
<tr>
<td>Dry matter (%)</td>
<td>12.31 ± 0.74</td>
<td>12.85 ± 0.40</td>
</tr>
<tr>
<td>Protein (% of dry matter)</td>
<td>64.52 ± 5.40</td>
<td>64.55 ± 5.19</td>
</tr>
<tr>
<td>Protein absolute content (mg/egg)</td>
<td>0.073 ± 0.003</td>
<td>0.094 ± 0.003</td>
</tr>
<tr>
<td>Lipids (% of dry matter)</td>
<td>26.78 ± 1.94</td>
<td>23.12 ± 1.75</td>
</tr>
<tr>
<td>Lipids absolute content (mg/egg)</td>
<td>0.030 ± 0.001</td>
<td>0.034 ± 0.001</td>
</tr>
</tbody>
</table>

| Larvae at hatching          |              |              |
| Total length (mm)           | 3.8 ± 0.3    | 4.2 ± 0.2    |
| Volume of vitellus (µl)     | 0.141 ± 0.019| 0.169 ± 0.035|
| Volume of oil droplet (µl)  | 0.049 ± 0.017| 0.041 ± 0.008|

| Larvae at first feeding      |              |              |
| Total length (mm)            | 4.8 ± 0.2    | 5.3 ± 0.2    |
| Specific growth rate (% per day) | 4.7 ± 1.5    | 5.3 ± 1.1    |

Means ± SE. Values with different letters in the same line are significantly different (P<0.05).

**2.1.2. Zootechnical practices for eggs and embryos incubation**

Incubation is generally performed under environmental conditions similar to those of spawning. Avoiding thermal fluctuations, salinity shocks, O₂ restrictions, any stress to eggs during handling (disinfection, transfer, shipping, etc.) is essential as lesions may lead to abortive embryos or abnormal larva. Egg quality is an essential factor affecting larviculture success and quality of fry, a reliable control must be systematically performed on each spawn or batch of spawns in the case of collective broodstock. As a general rule, good batches have usually less than 10% abnormal eggs but abnormality rate between 10 and 20% may be accepted if there is a severe shortage, or when eggs are imported from other hatcheries (Moretti et al., 1999). In addition to the buoyancy, adhesiveness and other global specific characteristics, a sample consisting in at least 30 to 100 eggs must be observed under a stereomicroscope looking for the conformity of:

- Transparency and color
- Ratio of dead (opaque) or unfertilized eggs (transparent but no signs of development)
- Shape, size, and number of oil droplet
Incubation process depends on the types of eggs in the sense of benthic or pelagic and may be performed either in specific structures (Fig. 6) or sometimes in larval rearing tanks in specific:

Benthic eggs such as those of as salmonids, perch, carps or plaice, are kept on nests, trays or in incubation jars. These types of eggs are generally highly susceptible to infections and thus according to the duration of the incubation, the eggs need daily or weekly disinfection (peroxide, formalin, iodine) Ben Khemis et al., 2000; 2016) or the elimination (picking) of each dead egg for large eggs (Mc Daniel et al., 1994).

Pelagic eggs, such as those of most marine species (bass or bream) are kept in specific hatching units or directly in the rearing enclosures. They are usually disinfected only once at the moment of transfer from spawning tank as a prophylactic barrier between broodstock zone and hatchery. These eggs are generally less susceptible to infections as dead eggs sink and thus do not remain in contact with viable eggs.

![Fig. 6: Incubation structures for benthic egg types - artificial nest (1 and 2); trays (3 and 4) and jars (5 and 6); and pelagic egg types (7 and 8).](image)

2.2 Larval and early juvenile development and rearing

2.2.1 Biological specificities

At first feeding, the larvae have more or less deposited material within the body, including reserves, depending upon the type of eggs. The length of time the larvae can survive without taking external nourishment depends upon the amount of reserves remaining at hatching, and upon the rate at which it is used up (Jobling, 1995). In small larvae, the reserves are limited and do not allow to reach metamorphosis. In nature, most first feeding fish larvae consume zooplankton, regardless the later stages are carnivorous, omnivorous or herbivorous and whether they consume pelagic or benthic organisms. The shift in diet occurs generally after metamorphosis or even later.

Fish larvae issued from large eggs or having large amount of reserve may reach an advanced developmental stage at first feeding, including a well developed and functional digestive system. In the hatchery, they can be fed formulated inert diets since first feeding. It is notably the case for salmonids or tilapias, which do not need further weaning procedure at the end of larval rearing.
Fish larvae issued from small eggs are generally small and poorly developed, with a primordial digestive system poorly performing. The larvae have just few days of energetic autonomy and thus they need to feed rapidly for their further development (Barnabé, 1991). All the fish species reared by Mediterranean aquaculture correspond to this type of larvae (i.e. small pelagic larvae). Their survival depends on first feeding success and thus on the supply of adequate preys and feed during this key moment (Fernández-Díaz et al.; 1994). If their reserves get exhausted and they become too weak to search for and capture preys, they reach the “point of no return” (Jobling, 1995; Yúfera and Darias, 2007). Even should they find preys after this time, they will continue to starve to death (Jobling, 1995). With small fish larvae, the appropriateness of food supply (quantitatively and qualitatively) from the onset of feeding is the key to successful juvenile production in hatcheries (Ben Khemis et al., 2000).

Efficient feeding and delivery of nutrients to organs rely on:

- Detection of preys: Development of sensory system - vision in particular
- Ingestion of preys: Development of predation capacity - swimming performance and mouth size
- Digestion of preys: Development of exocrine pancreas, intestine, stomach and gastric glands, digestive enzymes and hormonal regulation
- Absorption of nutrients: Development of intestine – length size and cell maturation
- Delivery of nutrients: Development of circulatory system
- Delivery of oxygenation: Development of respiratory system - branchial apparatus

The larval period can vary substantially in duration within and among species (Pepin 1995); nonetheless, it takes place in a rather short period of time (i.e. few weeks to few months) compared to life cycle (Fuiman 1983) and it is generally characterized by growth rates much faster than any other developmental stage (Pedersen 1997). Between early larval stage and young juvenile stage, the relative increase in biomass corresponds to multiplication by several hundreds of folds as it may be illustrated with the example of thick lipped grey mullets (Chelon labrosus) larvae (fig. 7).

![Fig. 7: Growth of Chelon labrosus early stages between hatching and 70 days old. From Ben Khemis et al. 2013](image)

The pattern of development is regulated by gene expression and appears to be similar among species even though the timeframe may be more or less extended (Osse and van den Boogaart 1995, 1999; Zambonino Infante and Cahu, 2001; Kvåle et al., 2007; Lazo et al., 2007). However, in newly hatched larvae, not all organs and systems can grow simultaneously (Osse et al. 1997); consequently, development as well as growth intensities are often not distributed uniformly among the organs and across the body segments (Fuiman 1983).

It is admitted that differences in relative growth during the transition from the newly hatched fish larval stage to the post-metamorphic juvenile stage are due to the necessity of setting priorities during early development to create at least primary conditions for survival (Osse and van den Boogaart 1995, 1999). As a result, differential growth and development of body parts (Fig 8) are observed in allometric analysis of growth in a same species (Fuiman, 1983; Gisbert, 1999; Ben Khemis et al., 2006; 2013); as well as differential timing of organs functional development (Fig 9) between species (Rønnestad et al., 2013).
Fig. 8: Allometric pattern of *Chelon labrosus* larvae development. From Ben Khemis et al., (2013).

Fig. 9: Age of detection of first gastric glands in various species of interest in aquaculture. Inserts show two examples of first developing gastric glands (arrows). From Rønnestad et al.
Development is genetically programmed but some features may be influenced or modulated by a large variety of factors such as the diet or the zootechnical practices. The inadequacy of diet delays the normal intestinal maturation process consisting among others in a progressive shift (Fig 10) from the cytosolic digestion of the peptides with leucine-alanine peptidase enzyme to their extra-cellular digestion after the development of the border membranes rich in alkaline phosphatase enzyme (Cahu and Zambonino Infante, 1995). The increase in dietary phospholipids leads to higher activities of brush border membrane enzymes (Fig 11), suggesting a better development and intestinal maturation (Hamza et al., 2008). Osteological development appears more advanced (Fig. 12) while incidence of malformation is lower in young *Dicentrarchus labrax* reared in mesocosm comparatively to intensive technology (Zouiten et al., 2011). At first feeding most fish larvae are stomachless and some fish species remain it all along their life. When this organ develops, the acidic protease activity starts due to pepsin, which is secreted by the gastric glands (Walford and Lam, 1993; Douglas et al., 1999). This occurs late in larval development and might be delayed (Fig 13) if weaning from live preys is performed too early during development (Hamza et al., 2007).

**Fig. 10:** Changes in the activity of the cytosolic leucine-alanine peptidase and the brush border membrane alkaline phosphatase during the development of *D. labrax* fed adequate (unbroken lines) or inadequate (broken lines) diet. From Cahu and Zambonino Infante, (1995).

**Fig. 11:** Modulation of levels of alkaline phosphatase (A) and aminopeptidase N (B) during development of pikeperch (*Sander luciopeca*) larvae fed different dietary phospholipid levels (PL1, PL5, PL9 =1, 5 or 9% respectively). From Hamza et al. (2008).
2.2.2 Zootechnical practices

2.2.2.1. Environmental conditions

Rearing of larvae is generally performed under environmental conditions allowing best growth performances and avoiding any stress or development of malformations. Species has different specific needs (table 3) in terms of temperature, light intensity, water quality, hydraulic currents, etc. In intensive hatcheries, the used tanks are generally cylindro-conical, to allow an easier daily cleaning, and provided with sur-pressed air with, gentle water currents, dark walls (to avoid wall syndrome behavior) and controlled light. Skimming water surface from oily film is essential to allow proper inflation of larvae swimbladder. In some species, modulation of temperature during particular periods (low or high) might be used to obtain monosex populations. Low temperatures during early development of seabass produce population with females dominating rates (Koumoundouros et al., 2002).

Table 3: Specific abiotic conditions for the rearing of seabream, seabass or pikeperch larvae.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Seabream</th>
<th>Seabass</th>
<th>Pikeperch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>18-20</td>
<td>18-20</td>
<td>18-20</td>
</tr>
<tr>
<td>Light intensity</td>
<td>lux</td>
<td>3000</td>
<td>3000</td>
<td>300</td>
</tr>
<tr>
<td>Turbidity</td>
<td>clear/turbid</td>
<td>Highly turbid (green water)</td>
<td>Clear</td>
<td>Clear</td>
</tr>
<tr>
<td>Photoperiod</td>
<td>hours</td>
<td>06h/18h</td>
<td>06h/18h</td>
<td>06h/18h</td>
</tr>
<tr>
<td>Salinity</td>
<td>PSU</td>
<td>34-37</td>
<td>34-37</td>
<td>0 to 3</td>
</tr>
<tr>
<td>Oxygen content</td>
<td>%</td>
<td>80-100</td>
<td>80-100</td>
<td>80-100</td>
</tr>
<tr>
<td>TAN-Ammonia N</td>
<td>ppm</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>
2.2.2.2. First feeding and live preys

In the wild, fish larvae consume a variety of organisms (ciliates, rotifers, copepods, larvae of annelids …) and they modify their prey selection according to their ingestion ability for optimizing their energetic budget (Kentouri, 1985; Polo et al., 1992; Fernandez-Diaz et al., 1994); to prey abundance, morphology or motion (Kentouri, 1985; Buskey et al., 1993; Munk, 1995); to change in their visual acuity (Pankhurst, 1994); to enhancement of their swimming performance (Gisbert 1999).

In all rearing methods, the larvae are the top predator of food chains (i.e. the last beneficiaries of matter fluxes). However, both the species and the various rearing methods let to tackle differently the question of initial feed supply. For the large larvae well developed at first feeding, the fish are fed onto artificial diets since first feeding (tilapia, salmonids, blackbass, etc.). For the small larvae producing live feed has no relevance for extensive techniques in which feeding is exclusively provided by natural zooplankton. On the contrary, it becomes a post of growing importance with intensification of rearing methods. Few prey species have been selected (Fig. 14), the most commonly used being Brachionus rotifers and Artemia brine shrimps, with respect to the easiness of obtaining regular and massive productions rather than to the adequacy of prey for the larvae. Cultivated marine copepods have also been considered as an alternative diet source for larvae feeding (McEvoy et al., 1998; Payne and Rippingal, 2001 Hamre et al., 2013). Better growth and development performances are reported for larvae fed copepods, even as partial ration within the diet, however larviculture based on these live preys account for only a small part in fry production, owing to the difficulty of producing sufficient quantities (Shields, 2001).

![Fig. 14: Live preys used in hatcheries for feeding small pelagic fish larvae and production unit.](image)

The quality of produced life preys is highly variable according to environmental and trophic conditions during production and stocking until their consumption by the larvae (Frolov et al., 1991; Carié et al., 1993; Robin and Gatesoupe, 1999; Shields, 2001). Both rotifers and brine shrimps are known to present nutritional deficiencies for a variety of nutrients, essential for fish larvae. Indeed, they are generally poor in Highly Unsaturated Fatty Acids (HUFA) as they have limited elongation and desaturation capacities (Robin and Gatesoupe, 1999). Furthermore, their Free Amino Acids (FAA) contents also differ from those found in natural plankton (Rønnestad et al., 1999) and do not have a profile that entirely meets the requirements for the early stages of fish species (Aragão et al., 2004).
To overcome these nutritional deficiencies, microalgae and/or specially formulated enrichment diets have been developed for live preys (Rainuzzo et al., 1989; Navarro and Amat, 1992; Han et al., 2000). The artificial enrichment diets are either emulsions or freeze-dried powders containing high levels of HUFA as well as protein, FAA and vitamins. The importance of high dietary HUFA is unequivocal; however, the appropriate dietary ratios of the three essential fatty acids docosahexaenoic acid (DHA, 22:6n-3), eicosapentaenoic acid (EPA, 20:5n-3) and arachidonic acid (ARA, 20:4n-6) appear to vary between fish species and development stage (Estévez et al., 1999; Sargent et al., 1999) and must take into account the prey metabolism (Navarro et al., 1999).

Live feed have also been identified as a critical source of microbial loading in the marine fish hatchery (Shields, 2001). They are potential vectors for disease transmission to larvae (Ringø and Gatesoupe, 1998) at a stage characterized by incomplete immune protection and limited therapeutic possibilities. Rigorous hygienic procedures must be applied in life feed production (Moretti et al., 1999). Protocols have recently been elaborated for the disinfection of cultured live preys but these can only be used with Artemia (Sahul Hameed and Balasubramanian, 2000; Gatesoupe, 2002). The use of probiotic bacteria as additives has also been suggested (Gatesoupe, 1999; Douillet, 2000; Tovar-Ramírez et al. 2010). Selection of candidate probiotic bacteria are based on three main criteria: in vitro antagonism to pathogens, ability to colonize the digestive tract of the target species and disease resistance of treated larvae when challenged with pathogens (Gatesoupe, 1999). Stimulation of the non-specific immune response offers a further means of protection for fish larvae prior to their acquisition of specific immune defense and this has led to uptake of commercial immuno-stimulant products by European marine fish hatcheries, although there is little published evidence regarding their effectiveness (Shields, 2001), notably when included in enrichment diets.

Production cost of live preys is relatively high. Indeed, it is consuming space (indoor facilities), energy (light, thermoregulation, and sterilization), equipment (tanks, UV, filters, freezer), high-priced entrants (cysts, enrichment diets, micro-algae production or paste purchase) and intensive-labor of experienced staff. In hatcheries, life feed represents an important charge which has a substantial impact on the cost of the fingerlings; hence considerable attention should be given to the optimization of their use (Moretti et al., 2005). In addition to the sanitary and quality risks related to their use, a failure in their production might jeopardize the success of seed production. Moreover, for Artemia, cyst provision is not guaranteed from year to year as sudden shortages due to environmental changes and poor yields may occur (Lavens and Sorgeloos, 2000). Despite all these major zoo-technical and economic constraint, life feed remain a key post in seed production as their use is mandatory for larval rearing, especially at first feeding, of a large number of species producing small pelagic larvae.

### 2.2.2.3. Early co-feeding with compound diets

Considerable progress has been made in microdiet formulation: attractants are added to ensure larval consumption; buoyancy and palatability have been improved; proximal composition takes into account specific nutritional needs of the larvae and the use of matrix-bound or microencapsulation techniques limit leaching of nutrients and allow longer hydro-stability of particles. In addition to knowledge concerning feeding behavior and digestive physiology in larval fish (Tovar-Ramírez et al., 2010; Hamza et al., 2012; Rønnestad et al., 2013), these technical progresses microdiet formulation and processing allow
reduction of the pre-weaning period of fish larvae (Person-le-Ruyet and Bergot, 1999; Ben Khemis et al., 2003; Gisbert et al., 2016). Even though some successes have been reported with larvae of sea bass (Cahu et al., 1998), sea bream (Yúfera et al., 1999), red drum (Lazo et al., 2000) or pike perch (Ostaszewska et al., 2005) fed exclusively compound diets from first feeding, weaning larvae since first feeding or at early feeding stage generally leads to lower growth or even to death (Cañavate and Fernández-Díaz, 1999; Ben Khemis et al., 2000; Hamza et al., 2007). In winter flounder larvae, this occurred despite effective consumption of a microencapsulated diet by the larvae and was associated to RNA/DNA ratios (indicators of nutritional condition) similar to those of starved larvae, suggesting that the larvae were unable to assimilate nutrients from the diet to sustain their metabolism (Ben Khemis et al., 2000).

Dabrowski and Glogowski (1977) were among the first authors suggesting that live prey may contribute to digestive enzymatic activity in larvae gut. This hypothesis was sustained by Lauff and Hofer (1984) as well as Munilla-Moran (1990). The addition of digestive enzymes to a microdiet improved growth in sea bream (Sparus aurata) larvae while in contrast, it did not result in any significant change in sea bass (Dicentrarchus labrax) larvae growth (Kolkovski, 2001). Contrastingly, Cahu and Zambonino Infante (1997) showed that weaned sea bass larvae have similar amylase and trypsin level in pancreatic segment but lower secretion compared to Artemia fed larvae. They concluded that poor growth of weaned sea bass larvae is not due to endogenous enzyme deficiency but may be due rather to inadequacy of conventional compound diet in meeting larval digestive specificities. Similar hypothesis was also supported for sea bream (Yúfera et al., 1999). Considering that larvae exhibit high hydrolytic capacity related to their weight and that enzyme activity pattern is age-dependent, but can be modulated by diet composition, Cahu and Zambonino Infante (2001) consider that larvae have the ability to digest and thrive on compound diet, if this diet is well adapted. Furthermore, maturation process of digestive enzyme can be enhanced, stopped or delayed depending on composition of diet (Zambonino-Infante and Cahu, 2001).

Maximum expression of trypsin is generally obtained with diets containing 50–60% proteins while secretion of pancreatic enzymes is controlled by the level of cholecystokinin which in turn is indirectly and positively regulated by the dietary protein level and chain length (Cahu et al., 2004). Bearing in mind this physiological aspect of hormonal trypsin regulation during early larval stage, these authors suggest that continuous feeding rather than a fractioned one would be more appropriate for feeding. Moreover, maturational changes of digestive tract occur earlier when the protein fraction of the diet is constituted by a moderate level (around 20% of the dry matter) of protein hydrolysate (Zambonino Infante et al., 1997; Cahu et al., 1999). Earlier digestive maturation is observed when the lipid level is high (20% of the dry matter) and includes a significant fraction of phospholipids instead of triglycerides. This was observed in sea bass (Zambonino Infante and Cahu, 1999); cod (Wold et al., 2007) as well as pike perch (Hamza et al., 2012). Dietary addition of spermine, also enhance digestive enzymes activities (Péres et al., 1997; Zambonino Infante et al., 1998). This polyamine, found in high level in live preys that induce good larval development, had been reported to act on cell metabolism and proliferation by stimulating DNA, RNA and protein synthesis (Péres et al., 1997).
This dietary modulation of pancreatic and intestinal enzymes involved in protein digestion provides useful information concerning the nature and molecular form of dietary protein and lipid supply that would be adequate for larval stages (Zambonino Infante and Cahu 2007). Yet, it has also been shown that an addition of live food is sufficient to significantly improve growth and physiological condition of larvae fed compound diet (Cañavate and Fernández-Díaz, 1999; Ben Khemis et al., 2000, 2003). This has also been reported with microalgae (Reitan et al., 1997; Lazo et al., 2000) which stimulate digestive enzyme production, at both the pancreatic and intestinal level (Cahu et al., 1998). Kolkovski et al. (1997a) who still supported the hypothesis of live prey digestive enzymes involvement in digestion also suggested a possible triggering of larval digestive process due to contribution of gastric hormones or non specific factors like visual or olfactory stimuli associated with increased peristalsis. In gilthead seabream larvae fed Artemia nauplii compared to larvae fed dry diets, Kolkovski et al. (1997b) found a bombesin (a neuropeptide closely related to mammalian gastrin releasing peptide) increase of 300%, indicating that the nauplii stimulate bombesin activity, allow increased peristalsis and assist in the digestion process.

Overall, co-feeding fish larvae with inert and live diets improve growth and might pre-condition larvae to accept inert diet at weaning (Roselund et al. 1997). Recent knowledge concerning modulation of digestive maturation is the key of the lastly developed starter microdiets and actual feeding strategies:

- maximum expression of trypsin with 50–60% proteins
- protein with a moderate level (around 20%) protein hydrolysate
- high lipid level (12-20% of the dry matter)
- includes a significant fraction of phospholipids
- specific HUFA requirements
- dietary additives (spermine a polyamine found in live prey) for triggering peristalsis
- continuous feeding (rather than fractioned) bearing in mind hormonal trypsin regulation.

2.2.2.4. Weaning

Replacement of live feed with exclusive use of microdiets is called weaning. It is considered an important progress considering the easier use, the reduced cost relatively to live preys and the lower risk in management. Larvi-culturists are interested in performing weaning as soon as possible but only if it doesn’t impair larvae development and later juveniles performances. Evolution of feed manufacturing and knowledge allow performing earlier the weaning of most fish larvae (Table 4).

<table>
<thead>
<tr>
<th>Decades</th>
<th>Seabass age (dph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eighties</td>
<td>40-50</td>
</tr>
<tr>
<td>Nineties</td>
<td>30-35</td>
</tr>
<tr>
<td>Last decade</td>
<td>20-25</td>
</tr>
<tr>
<td>Nowadays</td>
<td>10* onwards with 1 mg larvae</td>
</tr>
</tbody>
</table>

* French protocol (Atlantic strain with 10 days in the dark at low temperature)
Weaning diets are generally first distributed in excess comparatively to the reared biomass and its real consumption. Up to 10-15% or even 20-25% of the biomass in the daily rations is commonly suggested. This first distribution in excess is necessary to optimize fish consumption but it is also highly polluting. Particular attention must be given to water quality during this period (renewal, recirculation flow rate, biofiltration performance, etc.). Contrastingly with co-feeding, at weaning the formulated diets are used concomitantly with progressively diminishing rations of live preys in periods lasting 1 to 2 weeks. The fish are generally maintained within the larval rearing until metamorphosis.

2.2.2.5. Pre-growing, sorting and grading of weaned juveniles

Weaned metamorphosed juvenile fish are generally transferred at (around 45 days old for seabass) to the nursery (Fig 15) for pre-growing until 2-3 g mean weight. This dedicated section of the hatchery is a sector with of enlarged tanks in which water circulation is a key parameter for keeping good rearing conditions as final biomass density might reach up to up to 20 kg/m$^3$. Optimal water circulation is related to the shape of the tank and to its water depth; it eliminates dead zones and water stratification, helps in accumulating faeces and debris close to the outlet, provides current for a healthy swimming activity, distributes oxygen evenly in the water and attracts fish under the automatic feeders (Moretti et al., 1999). The tank capacity is typically between ten and twenty-five m$^3$ since a larger size become more difficult to handle due to the many operations of sorting (elimination of malformed fish), grading and thinning out of the fish population. Grading is generally performed each 2-3 weeks and consists in separating the population into homogenous groups by passing fish through a series of sorters (Fig. 15) of different calibers. Ideally, size variability in each group is maintained between 10 and 15 %. This allow better conversion rate of distributed feed by adapting pellets size and fish size and it also allow limiting mortality related to cannibalism for the species showing this type of behavior (seabass, seabream, pikeperch, …). Sorting is performed as soon as possible, ideally concomitantly with first grading operation, and has the objective of eliminating fish showing malformations of skeleton (lordosis, scoliosis, jaw, etc.) or absence of functional swimbladder. It is performed under anaesthesia.

**Fig. 15:** Nursery units (1 and 2); graders (3) and operating a manual grader (4); automatic grader Helios 10 for 0.8-10g fish (5); manual sorting of malformed fish (6)
3. Conclusion

Hatchery design and engineering as well as production management including automation and integration of R and D results greatly improved survival and quality of produced fish fry (Fig 16 and 17).

Fig. 16: Automatic belt feeder (1); skimmer (2); demand feeder (3)

The recent studies concerning ontogenesis of larvae digestive function in fish, permitted inert diet formulations better meeting larvae digestive capacities and nutritional requirements. These advances allowed applying earlier co-feeding or weaning strategies in the hatcheries, depending on the species or according to the used rearing technology, the production objectives or the socio-economic context. Within the coming years, live feed will undoubtedly be further replaced by microdiets and total replacement will certainly be achieved for a growing number of species. The cost-effectiveness of the different possible feeding strategies and the zootechnical constraints will ultimately determine the preferential utilization of compound diets or live feed. Nevertheless, it is likely that the decision may differ much from region to region, and between industrial and backyard hatcheries (Lavens and Sorgeloos, 2000). Further improvement is expected from actual research programs on genetically selected strains (resistance, performance, fillet yields, etc.), vaccination, and sharing knowledge and experience.

Fig. 17: Main factors influencing seabream fry rearing performances (1980-96). From Moretti et al. (1999).
References


The development of aquaculture relies primarily on the supply of specimens to be raised, but for the majority of species, the natural recruitment is insufficient to constitute a basis for large scale farming. The rearing of fish larvae is an essential step in the production of fingerlings for fish farming and restocking efforts. Currently, only a limited number of marine fish species are being produced and with variable success. The major obstacle to commercial production of currently cultivated species and success for candidate species is the use of an appropriate live feed during the first feeding stage of the larval cycle.

Appropriate Live Feed for Larviculture of Marine Fish

Fish larvae must be fed live foods, which have the nutrition, and enzymes (exogenous) they need, before their own digestive system is formed (Conceicao et al., 2010). A diet with an appropriate nutritional composition, an appropriate size and that stimulates a food response is needed to increase the number of marine fish species produced in aquaculture (Cortney et al., 2012). Nutritional quality of live prey used in larvae culture are primordial. For development, marine fish larvae need an essential fatty acid specially "Docosahexaenoic acid (DHA, 22:6n-3)" and "Eicosapentaenoic acid (EPA, 20:5n-3)", in fact the ratio of DHA to EPA significantly affects the survival of marine fish larvae (Oliva-Teles, 2012). The physical characteristics of live prey is also important for larval rearing. The size of living organisms and their ability to initiate a food response of fish larvae are necessary characteristics in marine larviculture. The stimuli produced by the movement of live feeding organisms are necessary for many marine fish larvae to create a food response (Cortney et al, 2012).

The live feeds are indispensable for the successful rearing of larvae of most marine fish species. They can not be replaced by fish meal or other forms of manufactured/ dry feeds in a near future because of their prime role in triggering hunting behavior of fish larvae. Currently, the most commonly used live-feed organisms in commercial fish farming are rotifers (Brachionus spp.) and nauplii of the brine shrimp Artemia (Bengtson 2003; Cortney et al., 2012).

Live Feeds

Most commercial hatcheries rely on rotifers and Artemia as larval feed, for their ease of production, cost and reliability.

1. Rotifer

Rotifers are small metazoans with over 2000 species described; most inhabit freshwater lakes and ponds. The phylum Rotifera consists of a relatively small group of minute, unsegmented, pseudocoelomate, aquatic invertebrates with bilateral symmetry (Das et al., 2012). In commercial hatcheries, two marine species, Brachionus plicatilis and B. rotundiformis have been used due to their small size. Generally, rotifers propagate quickly under suitable conditions, with populations doubling over a few days. This is an advantage for fish hatcheries with a large demand for live feeds during the larval phase.
The rotifers feed by filtering the particles (microalgae, organic detritus, etc.) suspended in the medium and having a size of 2 to 20 μm. They move continuously and filter water using their ciliary crown (organ also called vortex) (fig 1). The absorbed food particles are first crushed by microscopic forceps (organ called mastax) and digested in the stomach (Lavens and Sorgeloos, 1996).

Rotifers are small, with a body width (BW) of 90–350 microns but are nevertheless larger than the mouth gape size range of many first feeding marine fish species. Originally, only one species of rotifer, *Brachionus plicatilis*, was recognized in marine aquaculture. People recognized that there were differences among strains and began to denote rotifers as: L-Type (large), S-Type (small) and SS –Type (super small). In the 1990’s it became apparent that there are in fact at least two distinct species, *B. plicatilis* (L-Type) and *B. rotundiformis* (S-Type and SS-Type)(table 1) ((Lavens and Sorgeloos, 1996; Das et al., 2012).

*Fig. 1* General morphology of rotifer, Photo of *Brachionus plicatilis*(credit INSTM)

<table>
<thead>
<tr>
<th>Rotifer strain</th>
<th>L-Type “<em>Brachionus plicatilis</em>”</th>
<th>S-Type, SS-Type “<em>Brachionus rotundiformis</em>”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tolerates (7-10 °C).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tolerates full seawater salinity</td>
<td>Tolerates full seawater salinity</td>
</tr>
<tr>
<td>Mean lorica length</td>
<td>150 to 280+ µm</td>
<td>120 to 180+ µm</td>
</tr>
<tr>
<td>commercially available</td>
<td>Reed Mariculture.</td>
<td>Aquatic Eco-Systems Inc. (Apopka, Florida, USA).</td>
</tr>
</tbody>
</table>

**Culture of rotifer**

Intensive production of rotifers is usually performed in batch culture within indoor facilities; the latter being more reliable than outdoor extensive production in countries where climatological constraints do not allow the outdoor production of microalgae. Basically, the production strategy is the same for indoor or outdoor facilities, but higher starting and harvesting densities enable the use of smaller production tanks (generally 1 to 2 m³) within intensive indoor facilities.
Stock culture of rotifers

Culturing large volumes of rotifers on algae, baker’s yeast or artificial diets, always involves some risks for sudden mortality of the culture. Technical or human failures, but also contamination with pathogens or competitive filter feeders are the main causes for lower reproduction, which can eventually result in a complete crash of the population. Relying only on mass cultures of rotifers for re-inoculating new tanks is too risky an approach. In order to minimize this risk, small stock cultures are generally kept in closed vials in an isolated room to prevent contamination with bacteria and/or ciliates. The rotifers for stock cultures can be obtained from the wild, or from research institutes or commercial hatcheries (Lavens and Sorgeloos, 1996). At the Laboratory of Aquaculture in INSTM, the stock cultures for rotifers are kept in a thermo-climatised room (26°C ± 1°C) and exposed to the light of two fluorescent light tubes at a distance of 20 cm (light intensity of 3000 lux on the tubes). The culture water (seawater diluted with tap water to a salinity of 25 ppt) is aerated, prefiltered over a 1µm filter bag and autoclaved. Inoculation of the tubes is carried out with an initial density of two rotifers.ml⁻¹. The food consists of marine Chlorella cultured, after one week the rotifer density should have increased from 2 to 200 individuals.ml⁻¹.

For starter cultures, the upscaling of rotifers is carried out in static systems consisting of erlenmeyers of 500 ml placed 2 cm from fluorescent light tubes (5000 lux). The temperature in the erlenmeyers should not be more than 30°C. The rotifers are stocked at a density of 50 individuals.ml⁻¹ and fed 400 ml freshly harvested algae (Chlorella 1.6.10⁶ cells.ml⁻¹). During this short rearing period, no aeration is applied. Once the rotifers have reached a density of 200-300 individuals.ml⁻¹ they are rinsed and concentrate with 60µm filter. The concentrated rotifers are then distributed in several 50 l bottles at a density of 50 individuals.ml⁻¹ and a mild tube aeration provided.

Mass production

There are two general methods for culturing rotifers, the batch method, and the continuous. The batch method where a given volume of water is added or exchanged each day and the culture is restarted at regular intervals. The continuous method, which often employs recirculation-based technology to increase the density of rotifers cultured while minimizing the need to restart cultures. Batch cultivation is probably the most common method of rotifer production in marine fish hatcheries. The cultural strategy consists of either the maintenance of a constant culture volume with an increasing rotifer density or the maintenance of a constant rotifer density by increasing the culture volume (table 2).
Food and nutritional quality of rotifers

Rotifers can like the most zooplankton feed mainly on suspended feed. In commercial hatchery, rotifer can be fed with different of food such as phytoplankton (Chlorella, Isochrysis, ...), yeast (Saccharomyces cerevisiae) and special commercial foods such as Culture Selco (INVE).

Microalgae produce a good quality rotifers but this is tedious and costly. The cheapest food is yeast, but the rotifers produced are not very nutritious and require further enrichment. In fact, commercial foods produce high-quality rotifers because they are specially formulated to achieve high levels of protein, fat (especially polyunsaturated fatty acids - EPA and DHA) and vitamins. The enrichment products contain all these nutrients and must be administered in culture for 12 to 24 hours to the rotifers to improve their quality (Koustopoulou et al., 2012).

Table 2. Rotifer Production: optimal culture and enrichment conditions (Lavens and Sorgeloos, 2001).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Optimal conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank</td>
<td>Any Size/Shape (2-6 m³)</td>
</tr>
<tr>
<td>Temperature</td>
<td>25-27 °C (Preheated Water/Heat Exchange)</td>
</tr>
<tr>
<td>Salinity</td>
<td>18-25 ppt</td>
</tr>
<tr>
<td>Oxygen</td>
<td>5-7 ppm (Pure Oxygen)</td>
</tr>
<tr>
<td>pH</td>
<td>7.5-8.5</td>
</tr>
<tr>
<td>NH₃/NH₄⁺</td>
<td>&lt; 10 mg/l</td>
</tr>
<tr>
<td>NH₃</td>
<td>&lt; 1 mg/l</td>
</tr>
<tr>
<td>water</td>
<td>Filtered (1 mm), UV, Chlorinated/Neutralized</td>
</tr>
<tr>
<td>Aeration</td>
<td>Reasonably Strong</td>
</tr>
<tr>
<td>Illumination</td>
<td>Low Light Conditions (2000 lux)</td>
</tr>
<tr>
<td>Batch Culture</td>
<td>3-5 days</td>
</tr>
</tbody>
</table>

2. Brine Shrimp, Artemia

Artemia is a genus of aquatic crustaceans also known as brine shrimp (fig 3). The genus Artemia (Leach, 1819) (Branchiopoda, Anostraca) is a cosmopolitan taxon typically adapted to live in stressful environmental conditions of hypersaline habitats such as salt lakes, coastal lagoons and solar salt works found almost all over the world (Triantaphylidis et al., 1998). It proliferates in brackish waters (chott, saline, etc.). Initially, Artemia was developed as a first feed for especially penaeidae shrimp production in the 1960s where after fish hatcheries took up the concept (Sorgeloos et al., 2001). Currently, the most important source of Artemia cysts for aquaculture production is wild-caught in the Great Salt Lake, in Utah, United States (Nielsen et al., 2017).

The use of Artemia salina is mainly motivated by the existence of cysts which can be easily preserved and which are commonly marketed. In addition, the ease of storage simplifies the supply and programming problems of the quantities used. Finally, its use and the necessary equipment are relatively simple (Cortney et al., 2016; Nielsen et al., 2017).
Newly hatched brine shrimp nauplii are about 450 microns in body width (fig 3A), which is usually too large for most first feeding marine fish larvae to consume (fig 4), why first feeding often relies on rotifers. The nauplii (termed A0) should be distributed as soon as they hatch to benefit from their high energy content. The metanauplii (fig 3B) are obtained from nauplii held at 25°C in the hatching tank or in a new tank for one day (A1) or two days (A2). These are used as large prey items for older larvae. They are given a specific diet, such as Culture Selco (INVE).

Since the nutritional content of Artemia fails to meet nutritional requirements in marine fish larvae, enrichment is necessary before use in first feeding. Moreover, the amino acid profile of Artemia is often unbalanced for several fish larval species. Artemia lose their nutritional value after 10 - 12 hours. Brine shrimp have the disadvantage of catabolizing DHA back to EPA. Therefore, the ability to increase the DHA:EPA ratio by enriching brine shrimp may be limited (Das et al., 2012; Abate et al., 2016; Nielsen et al., 2017).

**Life cycle of Artemia**

Fertilized eggs normally develop into free-swimming nauplii (ovoviviparous reproduction) which are released by the mother. In extreme conditions (e.g. high salinity, low oxygen levels) the embryos only develop up to the gastrula stage. At this moment they get surrounded by a thick shell (secreted by the brown shell glands located in the uterus), enter a state of metabolic dormancy (diapause) and are then released by the female (= oviparous reproduction). Under optimal conditions, brine shrimp can live for several months, grow from nauplius to adult in only 8 days’ time and reproduce at a rate of up to 300 nauplii or cysts every 4 days (Godelieve and Thomas., 2002).

**Hatching and growth characteristics of brine shrimp**

Using *Artemia* cysts in commercial hatcheries appears to be simple, but several factors are critical for hatching the large quantities needed in larval fish production. These include cyst disinfection or decapsulation prior to incubation, and hatching under the following optimal conditions: constant temperature of 25-28 °C, 15-35 ppt salinity, minimum pH of 8.0, near saturated oxygen levels, maximum cyst densities of 2 g/1, and strong illumination of 2000 lx (Lavens and Sorgeloos, 1996). All these factors will affect the hatching rate and maximum output, and hence, the production cost of the harvested *Artemia* nauplii. Especially now, that the availability of Great Salt Lake *Artemia* is not stable, *Artemia* harvested from other locations will be subjected to variable quality (Lavens and Sorgeloos, 1996). Recent advancements in artificial larval diets and the variable harvest and supply of brine shrimp from hypersaline lakes may decrease the aquaculture industry's use of brine shrimp in the future (Cortney et al., 2016). However, brine shrimp are still the most commonly used food for marine larvae and serve as the primary food organism between early larval stages and weaning to dry diets (Cortney et al., 2016).
Conclusion
The production of rotifers is relatively simple, the production of this particular live feed can not stand alone and other live feeds are required when the fish larvae increase in size. Brine shrimp are still the most commonly used food for marine larvae and serve as the primary food organism between early larval stages and weaning to dry diets. The present-day use of the live-feed organism’s rotifers and Artemia nauplii for rearing marine finfish larvae depends on the enrichment of feed organisms with fish oil. Fish oil is dependent on a limited resource. Furthermore, Artemia production is dependent on harvest from a single natural production site, subject to environmental events that can have a huge impact on the availability of this resource.

References
Courtney L. Ohs, Eric J. Cassiano, and Adelaide Rhodes (2016) Choosing an Appropriate Live Feed for Larviculture of Marine Fish. The Institute of Food and Agricultural Sciences (IFAS) FA176
SHELLFISH TAPES DECUSCATUS HATCHERY, BROODSTOCK MANAGEMENT, LARVAE AND POST-LARVAE

Medhioub Mohamed Néjib, Medhioub Amel

Institut National des Sciences et Technologies de la Mer Aquaculture Laboratory

Introduction

Shellfish farming has been practiced since 1960s in the lagoon of Bizerte. Mussel culture is based on the natural catchment of the spat and then its growth. Oyster culture on hatchery spat culture. Other species are also harvested in Tunisia, the clam commonly called clovisse Tapes decussatus. Conchyliculture activity was around 1000 tons exported in 2014. with a large market and require. The studies carried out (master plan for aquaculture, national and international expertise) show the great natural potential of the breeding of this species. Besides that these studies showed that control of artificial production and environmental (climate, biological contaminants, chemicals, predators, parasites ...) factors are important for aquaculture of shellfish.

When is a bivalve hatchery necessary?

If there is a demand for seed, there are no reliable source of wild seed, possibility of genetic manipulation and need for selected broodstock makes the bivalve hatchery necessary.

Fig.1 Bizerte lagoon (north of Tunisia) of Tunisia

Fig.2 Harvested and cultured bivalve
A1 Larving rearing  A2 Broodstock conditioning  A3 Juvenile culture (Post-larvae)  
A4 service areas  B2, B3 Algal culture

**Fig. 3** Floor plan experimental bivalve hatchery INSTM, Monastir

**Broodstock Conditioning**

**Conditioning Methods**

- **Temperature**: 21.5 ± 1°C
- **Salinity**: 37 ± 1.5‰
- **pH**: 7.84 ± 0.1
- **Light**: 24h/24

- **Renewal of sea water**: 1,7/24h in Open circuit (flow through system)
- **Feed**: Chaetoceros calcitrans and Isochrysis sp.

- **Feed rate**: 1.109 ç/ clam/24h
Parameter for broodstock conditioning: conditioning index, rate feed and degrees days (DDs in °C)

<table>
<thead>
<tr>
<th>Days</th>
<th>Rate feed</th>
<th>J0</th>
<th>J15</th>
<th>J32</th>
<th>J47</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0,75</td>
<td>1,26</td>
<td></td>
<td>0,95</td>
</tr>
</tbody>
</table>

**IC**

<table>
<thead>
<tr>
<th>Salinity 30 ‰</th>
</tr>
</thead>
<tbody>
<tr>
<td>♂ 13,89 ± 1,95</td>
</tr>
<tr>
<td>♀ 11,07 ± 1,63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Salinity 37 ‰</th>
</tr>
</thead>
<tbody>
<tr>
<td>♂ 13,89 ± 1,95</td>
</tr>
<tr>
<td>♀ 11,07 ± 1,63</td>
</tr>
</tbody>
</table>

**DDs (°C)**

<table>
<thead>
<tr>
<th></th>
<th>495</th>
<th>498</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity 30 ‰</td>
<td></td>
<td></td>
</tr>
<tr>
<td>♂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>♀</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity 37 ‰</td>
<td></td>
<td></td>
</tr>
<tr>
<td>♂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>♀</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DDs = Degree-days according to the following formula: \( \sum n (T2 - T1) \) with T2, conditioning temperature; T1

**Fig.4 IC de bac 2**

During conditioning, the monitoring of the gonad development state is carried out: the condition index according to formula \( IC = (PCS / P.Ccq) \ast 100 \) with

- **IC**: Condition index, **PCS**: dry weight of flesh. **P.Ccq**: weight of the shells.

**Fig.5** Distribution of the oocyte diameter frequencies in *Tapes decussatus* in a natural environment (Hamida et al 2004)
Results
- Offset of laying
- Three months
- Conditioning period
- 12 weeks in winter
- 8 weeks in the spring
- 2 weeks in summer

Brood stock Spawning

Spawning Methods

Egg laying is an important step in the management of the hatchery. It allows to plan the different phases that follow it once the maturation is well conducted, when the spermatozoa are mobile and when the condition index reaches the value greater than 13, the egg is caused according to the following steps:

- Check the mobility of the sperm on a smear of gonads in a hollow blade.
- Isolate the breeders disposed to lay, placing them, dry, for one hour in the bottom of the refrigerator at 4°C.
- Place the clams in a basin of 10 liters filled with sea water filtered at 1 μm, salinity 37‰ and temperature 20°C.
- Wait for the opening of the valves. Increase the temperature by water bath by adding hot water to raise the temperature up to 24°C then 27°C.
- Add milt to the breeders who have started pumping water actively.
- Change the water from the basin if necessary.
- Isolate the clams that have begun to emit their gametes by placing them individually in crystallizers.
- The eggs carried out always show a response of the males before the females. The first male emits its gametes after 70mn of excitation while the emission of the gametes of the first female is realized after 108mn. It is noted that there is no synchronism between the emission of males and females and that spawning does not include all spawners. Indeed, only 70% of the clams can lay eggs.
The fertility (F) which represents the number of oocytes emitted after spawning by thermal shocks. The rate of fertilization (TF) according to the following formula TF = number of fertilized oocytes / total number of oocytes. Hatching rate (TE) number of D-larvae / Total number of fertilized oocytes.

**Culture of Larvae Methodology, Feeding, Growth, Survival, and Metamorphosis**

-Example: the rearing larvae of *Tapes decussatus* clam in the hatchery of INSTM Monastir

The rearing is carried out in 2 steps:

- First step in cylidroconical tank in larval room
- Second step in the sieve in the nursery

**Larval rearing techniques**

-First step in cylidroconical tank

Generally in hatcheries, bivalve larvae are grown in cylindro-conical tanks. These culture tanks can be from 50 to 1000 liters for small productive or experimental volumes up to larger volumes for large commercial hatcheries. Three water circulation systems are used in hatcheries:

- Static System or Closed Aquaculture Systems (CAS)
- Flow-Through System (FTS) or Flow-through Aquaculture Systems (FAS)

**1. The static system**

This system is the oldest is known as Closed Aquaculture Systems (CAS). It is commonly practiced in bivalve hatcheries all over the world. Water was 100% renewed every 2 days (where larvae received full food ration). Food ration will be at the half when the water is not renewed the next day. The preferred ratio is 5-15 larvae/mL. Feed ration of 15 to 100000¢/mL according to age, size and density of larvae. CAS are generally associated with pathologies of bacterial origin characterized by brutal and massive mortalities of the larvae.
2. Flow-Through System (FTS)

The second method of water circulation is the continuous flow system or open flow system known also as Flow-Through System (FTS). In this system, the circulation of the water may be partial or continuous. In the partial flow-through system, the water circulation is interrupted during the day, allowing larvae to feed and is resumed overnight. In the continuous, water and microalgae feed regularly the rearing tank.

Total daily throughput is the same or greater than the total volume tank. Generally, the total throughput is about 4 times the tank volume, for example, 5000 per L in a 500 L CAS tank then 20000 larvae per L in a FTS of the same volume will require a minimum throughput of 2000 L per day.

3. Recirculation Aquacultural Systems (RAS)

The continuous system can be improved by introducing another water recirculation technology, which is the subject of the 3rd system: recirculation aquacultural systems (RAS).

RAS is not common in bivalves culture however, it has been tested on an experimental scale in nurseries for some bivalves.

Methodologie: in larval rearing at INSTM, Bivalves Hatchery CAS and FTS are used.

Parameters:
- Temperature: 20 – 24°C
- Tank volume: CAS: 60, 210 and 500 liters; FTS, 60 and 210 liters
- Density: 25 and 30 ind/mL
- Renewal: CAS every two days, FTS 3 to 7 times/day
- Food: Larvae receive a mixed feeding composed of diatoms and flagellates at the ration of 40 to 80 cells /µL in equivalent Iso sp

Feeding in CAS and FTS

Food: Chaetoceros sp, Isochrysis sp, Tetraselmis sp and Chaetoceros calcitrans. The first three strains were isolated from Tunisian coast, at INSTM Monastir Center

Ration: This ration was equivalent to 40–80 cells of Isochrysis sp and calculated on a cell volume equivalency basis where: 1.0 cell of Iso sp = 2.08 cells Chae sp,

1.0 cell of Isochrysis sp = 0.87 Chaetoceros calcitrans,
1.0 cell of Isochrysis sp = 0.23 Tetraselmis sp.
Second step of larvae rearing

This phase of rearing is carried out in the nursery where the pediveligers perform their metamorphosis. Upon the appearance, under the microscope, of the preliminary pediveligers, the "Early pediveligers" are transferred to sieves (80-90μm) with a useful volume of 6 liters, with a renewal seawater of 0.14 m³/hour. The seawater is thermally regulated to maintain the temperature between (20 to 23°C). Density used of 100,000 to 200,000 Larvae/sieve.
Table 1 Rearing larvae in cylidroconical tank

<table>
<thead>
<tr>
<th>Larvae (D Larvae to early Pediveliger)</th>
<th>Survival rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS (Antibiotic treatment)</td>
<td>80%</td>
</tr>
<tr>
<td>FTS</td>
<td>30-70</td>
</tr>
</tbody>
</table>

Table 2 Rearing early pediveliger to metamorphosis in the sieve

<table>
<thead>
<tr>
<th>Early pediveliger to metamorphosed larvae</th>
<th>Survival rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mortality observed</td>
<td>about 100%</td>
</tr>
</tbody>
</table>

Juvenile Growth

Two phases characterize this stage of pregrossing 1 (PG1) and pregrossing 2 (PG2). While PG1 is carried out in a controlled medium in sieves, PG2 is produced in lagoonal rich media in lanterns or made-up traps. At the end of the PG1, which lasts 35 to 41 days, the post-larvae, raised at a temperature of 23-26°C and in a continuous circuit, reach 0.8 to 4 mm in length with a survival rate of 20 to 54%. At the end of the PG2, which lasts 113 days, the spat, pregrown at a temperature of 27-30°C in an open environment, reaches 7.5 to 12 mm in length with a survival rate of 14%.

Pre-growing (PG2) is carried out in the Monastir lagoon when the spat reaches a size between 0.8 and 4 mm in wooden racks, made of 0.22m² of surface (70x50x5cm), screened by a canvas of 700/400 μm; 1, 2, 4 and 5 mm. These wooden racks are held on the surface of the water thanks to a wooden structure to which they are attached. The traps are transported to sea using a boat and are cleaned every day for the first meshes to avoid clogging and then every week for 4 and 5 mm canvas racks. The structures are lightened, sometimes duplicated after each sorting to allow a good growth. The final weight at the end of the pre-growing cycle is about 1 kg/wooden racks.
Juvenile growth. The total weight increased from 0.9 to 11 Kg after 113 days of pre-growth in the lagoon (fig.13). That is an increase of 11.5 times. The average spat length increased from 1.4 ± 0.3 mm to 11 ± 1 mm for 113 days of pre-growth (fig.14). An increase in size of 9.6 mm.

Table 3 Summary of the Tapes decussatus culture cycle (growth, breeding duration, survival rate)

<table>
<thead>
<tr>
<th>Phase, Age</th>
<th>Size mm</th>
<th>Time</th>
<th>Survival rate %</th>
<th>Cumulative Survival rate %</th>
<th>Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-Larvae</td>
<td>0.94 ± 0.04</td>
<td>J0</td>
<td></td>
<td>100</td>
<td>20-22°C</td>
</tr>
<tr>
<td>Larvae culture</td>
<td>0.201±12.58</td>
<td>J0-J12</td>
<td>45-80</td>
<td>80</td>
<td>23-24°C</td>
</tr>
<tr>
<td>pédiveligère 15</td>
<td>0.208±10.72</td>
<td>J12-J16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>jours</td>
<td>15 jours</td>
<td>J16-J25</td>
<td>50-100</td>
<td>80</td>
<td>23±1°C</td>
</tr>
<tr>
<td>Metamorphosis</td>
<td>0.23±0.014</td>
<td>9 jours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metamorphosed larvae</td>
<td>25 jours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early juvenile</td>
<td>0.8-4</td>
<td>J25-J59</td>
<td>20-54</td>
<td>43</td>
<td>23-26°C</td>
</tr>
<tr>
<td>59 à 66jours</td>
<td>J25-J66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile</td>
<td>7.5-12</td>
<td>113 jours</td>
<td>14</td>
<td>6</td>
<td>27-30°C</td>
</tr>
<tr>
<td>J179</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Growout</td>
<td>32-40</td>
<td>24 à 36 mois</td>
<td>12-50</td>
<td>3</td>
<td>12-35°C</td>
</tr>
</tbody>
</table>

Table 3 shows the VRR project valorization of research results for clam development Tapes decussatus.


SHELLFISH PRODUCTION: TURKISH EXPERIENCES

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Abstract

Turkey is surrounded by the Mediterranean Sea (south part), the Black Sea (north part) and the Aegean Sea (west part) which is a large peninsular country bridging Europe and Asia. The Sea of Marmara, the Bosphorus and the Dardanelles which are the Turkish Straits demarcate the boundary between Thrace and Anatolia.

Turkey has a great potential natural sources for both inland and marine fisheries activity but aquacultural investments and efforts had been slowly rising up since 1990’s. During the past two decade, aquaculture production has been increasing rapidly however fisheries production has remained stable and/or gradually decreased. Moreover, bivalve production generally has been based on from natural stocks but recently it has been started mussel production via aquaculture. The most produced shellfish species are striped venus (Venus gallina), Mediterranean mussel (Mytilus galloprovincialis) and carpet shell clam (Ruditapes decussatus) in Turkey.

Key words: Turkey, shellfish, aquaculture, fishery

Introduction

Turkey has 8 333 km coastline with different ecological properties, so it is one of the best countries having suitable conditions for aquaculture and fisheries. In Turkey the total fisheries production has remained comparatively stable over the last decade, however aquaculture production has been increasing day by day (Fig. 1). Total fishery production amount was approximately 608 000 t in 2013, 537 000 t in 2014 and 672 000 t in 2015, respectively. Fishing amount was 374 000 t, 302 000 t and 432 000 t in 2013, 2014 and 2015, respectively. Moreover, aquaculture production was 234 000 t in 2013, 235 000 in 2014 and 240 000 t in 2015 (TURKSTAT 2013, 2015).
Fig. 1. Fishery production amount of Turkey
The main fishing species are anchovy (*Engraulis encrasicolus*), sprat (*Sprattus sprattus*), European pilchard (*Sardina pilchardus*), horse mackerel (*Trachurus trachurus*), whiting (*Merlangius merlangius euxinus*) and Atlantic bonito (*Sarda sarda*). The most aquaculture species are rainbow trout (*Oncorhynchus mykiss*) and carp (*Cyprinus carpio*) in freshwater and seabass (*Dicentrarchus labrax*) and gilthead seabream (*Sparus aurata*) in marine waters (Fig. 2).

![Fig 2](image1.png)  
**Fig 2.** The most production species via fisheries and aquaculture in Turkey

The marine other product amount via catching was 7 % ratio in total fishery production in Turkey. This production amount is separated as Bivalvia 72 %, Gastropoda17 % and Crustacea 8 % (Fig. 3) (TURKSTAT 2015).
Because of filter feeding organisms, shellfish production areas are very important. This species removes from water column microscopic particulates, including detritus, bacteria and microalgae. Therefore, production areas both fishery and aquaculture are classified into three categories (similar in European Union) A, B and C according to amount of *Escherichia coli* in 100 g shellfish flesh and intravalvular liquid.

**Shellfish Production by Fishing**

Shellfish production is mainly from fisheries except mussel production in a few amounts. Total production of shellfish is approximately 29 000 t, 22 080 t and 37 650 t in 2013, 2014 and 2015, respectively. The most economical species is *Venus gallina*, *Ruditapes decussatus*, *Mytilus galloprovincialis*, *Ostrea edulis*, *Venus verrucosa*, *Donax trunculus*, and *Flexopecten glaber*.

*Venus gallina* is distributed in Black Sea, Marmara Sea and Aegean Sea. Production is mainly from west side of Black Sea and Marmara Sea. Fishing of this species is forbidden between 01 May and 31 August. Hydraulic dredge, dredge and hand dredge are used for collecting. Striped venus was produced 21 827 t in 2014 and 37 404 t in 2015 (TURKSTAT 2015).

*Ruditapes decussatus* is distributed along the coastline of Aegean, Mediterranean and Marmara Sea and especially in Izmir Bay where the main fishery area. Fishermen usually dive with air supply from surface (operating with from boat) and/or they collect clam using with shovel and sieve (Fig. 4) (Serdar 2016). Collecting of this species is prohibited from May 15 to September 15. Production amount of *R. decussatus* was 14.9 t, 83.4 t, 8.8 t and 5.3 t in 2012, 2013, 2014 and 2015, respectively (TURKSTAT 2015). *Ruditapes philippinarum* is exotic species along the Turkish coast, it may be introduced through the ballast waters of ship. It was firstly to be seen Dardanells (Çanakkale Strait) in 2004 and Marmara Sea in 2005 (Tuncer et al., 2004; Albayrak, 2005).
Black mussel, *Mytilus galloprovincialis* is distributed in Black Sea, Marmara Sea and Aegean Sea. Nowadays, this species has been cultured commercial size in Turkey. Black mussel fishery production amount is not stable; it is fluctuated according to year. This species was produced 2,093 t, 887 t, 48.7 t and 192.4 t in 2012, 2013, 2014 and 2015, respectively (TURKSTAT 2013, 2015).

Bearded horse mussel (*Modiolus barbatus*) is mainly distributed Ayvalık, Edremit Bay and around. This species is produced 155.1 t in 2014 and 47.6 t in 2015.

*Ostera edulis* is distributed Marmara and Aegean Sea in Turkey but this species amount is decreasing day by day. Production amount of this species was 11.2 t in 2013, 0.1 t in 2014 and 0.2 t in 2015. On the other hand, some scientific studies reported that *Crassostrea gigas* were determined Aegean and Mediterranean Sea (Doğan et al., 2007). But it has not been obtained any information about population structure in distribution area of this species until now.

Warty venus, *Venus verrucosa* is distributed in Aegean Sea mainly İzmir Bay and Ayvalık seashore. This species is used some restaurant and is sell local market. Production amount is fluctuated and too low, so there is not reported in statistical issues in some year. This species was produced 73 t in 2007, 1 t in 2008, 11 t in 2009 and 8 t in 2010 (TURKSTAT 2011).

Razor clam (*Solen marginatus*) is collected generally for fish bait from Turkish coast. Unfortunately, there is not any information production amount of this species in the statistical report. Moreover, collecting of this species is forbidden between 1 April and 1 August.

Acturally *Donax trunculus* and *Flexopecten glaber* collected regularly, *Pinctada radiata* and *Callista chione* collected occasionally and generally this production amount is not entered in statistical report.

**Aquaculture Attempts for Shellfish Species**

Many scientific studies have been carried out about shellfish species especially mussel, oyster and clam growth, survival, reproduction and culture possibility in Turkish coastline (Serdar 2003; Yıldız 2004; Yıldırım 2004; Serdar et al., 2009; Karayücel et al., 2010). These studies are generally conducted by universities or research centres in a pilot system and it is not commercial size. However, commercial size production via aquaculture by private company is limited.

Before 2004, some attempts for black mussel culture were carried out in İzmir and a private company decided to culture of mussel near fish cages. They hung out rope to sea from fish cage units after mussel attaching and growth, company sold them. The other company collected mussel adult size or nearly harvestable size from natural stocks, then mussels were rest in the seashore where chlorophyll amount was higher, after mass feeding and conditioning, company sold them. These applications were the first step for mussel culture activities in Turkey. After then Republic of Turkey Ministry of Food Agriculture and Livestock put a law into force regulation for shellfish production.

Site selection is very important for commercial size shellfish culture because of growth and survival, after determining suitable culture area, it has to be take preliminary permission from government (Ministry of Food Agriculture and Livestock, municipality, Ministry of Tourism etc) after that this culture area has to be monitored 2 years especially toxic phytoplankton species or toxic algal bloom in the sea water and PSP, DSP and ASP toxins in flesh once a week. In addition to levels of *E. coli*, *Vibrio cholera*, *V. parahaemolyticus*, *Salmonella*, heavy metals, Dioxins and PAH have to be monitored in the flesh.

Only mussel culture has been started in Turkey, production amount is approximately 1,500 t in 2004, 2005 and 2006 (TURKSTAT 2006). This value gradually decreased following years and there was not any mussel production via aquaculture between 2012 and 2014 (Fig. 5). Recently, several enterprises decided to start mussel culture again and production amount was 3 t in 2015 and 329 t in 2016 (TURKSTAT 2016).
Fig 5. Black mussel production via aquaculture.

Some commercial mussel farm from Izmir Bay and Marmara Sea have been presented in Figure 6. In general, they prefer long-line culture system for producing mussel and they use rope for attaching mussel spat. Farmers have some problems during culture facilities according to/depends on region such as fouling organisms or over amount spat. They try to solve these problems. Moreover, in the recent years, some private companies have been completed official permission for the production of mussel especially along the coast of the Marmara Sea and Izmir Bay. At the same time, it is expected that clam and oyster cultures will be accelerated in Turkey.

Current status of commercial shellfish production

Aegean Sea
2 musselfarm 600 ton/year (Active)
9 musselfarm 4 330 ton/year (Official permission)
2 clamfarm 400 ton/year (Official permission)

Marmara Sea
4 musselfarm 7 500 t/year (Active)
3 musselfarm 6 500 t/year (Project)
5 musselfarm 5 100 t/year (Official permission)
2 musselfarm 1 850 t/year (Application)

Conclusion

Shellfish culture is very important activity for Turkish people, because shellfish production via aquaculture is healthy and safety food without any toxins or microbiological contaminants. Furthermore, these culture activities are beneficial Turkish economy due to exportation. However, it has to be drawn a route map for future, for example;

* Determining of new culture areas in Turkish coastline for improving and extending of shellfish culture
* It should be carried out more scientific researches in order to solve biofouling problems
* It should be conducted new examinations for higher meat yield/condition

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* Initiation and development of clam and oyster larvae culture technology in commercial size
* New attempts should be carried out for increasing national and international trade
* Not only fresh but also processed products of shellfish should be delivered

Fig. 6 Some photos from culture area in Aegean Sea and Marmara Sea
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TURKSTAT. 2013. FisheryStatistics. Turkish Statistical Institute, Ankara, Turkey.


Yıldırım, Ş. 2004. A preliminary study on the attachment rates of the Mediterranean mussel to various materials in Mersin Bay (Urla-Izmir) where net cagefish farming is practiced. Journal of Fisheries and Aquatic Science Vol 21; No 3-4, 249-251 (In Turkish).
INTRODUCTION

Some microalgae have the ability to produce potential toxins that can cause poisoning to humans.
Technics of isolation

Plankton sample

1- Filtration / screening to remove predators on 200 /45 /30μm / selective screening
2- General enrichment culture / selective enrichment culture

Where the species of microalgae can be acquired?
- Reputed Collections, institutions or research Laboratories.
- Culture Collection of Algae and Protozoa in the United Kingdom.
- Algobank Caen.
- Institut Pasteur, Paris; Culture Collection of Marine Phytoplankton.
- Australian National Algae Culture Collection-CSIRO.
- Modest living collection of marine microalgae at INSTM center of Monastir (18 species from which 10 are isolated from Tunisian coast.

How to select microalgaespecies?

Selection criteria

Interesting species were selected according to several criteria:
1- Their ease for mass cultivation,
2- Their adequate size,
3- Their ease digestibility,
4- Their good nutritional value for bivalves (from larvae to the genitor) and must not be toxic.
Fig. 3 Feeding selection patterns of *Crassostrea virginica* larvae

Fig. 4 Rates of ingestion and digestion by 2 day old *C. gigas* larvae (Robert, 1998)

Fig. 5 Rates of ingestion and digestion by 6 day old *C. gigas* larvae (Robert, 1998)
Fig.6 Growth of *Crassostrea gigas* larvae fed with *Isochrysis galbana* (control), *Nannochloris atomus* and *Stichococcus bacillaris* (Robert, 1998)

**Size profiles (volume and equivalent diameter)**

In the experimental hatchery of molluscs bivalve at the Monastir Center, the profile of the sizes of the microalgae species used in larval feeding was determined in order to produce a homogeneous multispecific mixture ie in *Iso* sp. equivalent, as is done in the literature and in the hatchery of the bivalves in equivalent *Tiso*.

**Table.1** Tunusian strains, INSTM Monastir (Medhioub A., *et al.*, 2016)

<table>
<thead>
<tr>
<th>Species</th>
<th>Origin // Year of isolation</th>
<th>Diameter (μm)</th>
<th>Volume (μm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Isochrysis sp</em></td>
<td>Gabes Golf, Boughrara, 2008</td>
<td>4.49±0.031</td>
<td>62.7±1.06</td>
</tr>
<tr>
<td><em>Tetraselmis sp</em></td>
<td>Monastir Lagoon, 1998</td>
<td>7.98±0.04</td>
<td>198±27.3</td>
</tr>
<tr>
<td><em>Chaetoceros sp</em></td>
<td>Gabes Golf, Oued Maltine, 2002</td>
<td>2.64±0.023</td>
<td>16.5±1.45</td>
</tr>
<tr>
<td><em>Pleurochrysis sp</em></td>
<td>Monastir Lagoon, 2001</td>
<td>2.35±0.002</td>
<td>17±0.18</td>
</tr>
<tr>
<td><em>Nannochloris maritima</em></td>
<td>Monastir Lagoon, 2015</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Nutrient properties of microalgae**

Biochemical composition:

- Proteins 20 à 40%
- Carbohydrates 5 à 40%
- Lipids 5 à 30% (Low content but rich in Fatty acids)
- Ashes 5 à 25%

This composition may vary with the species and with the culture conditions (light, temperature, pH, nutrient medium....etc), and the culture phases (Brown *et al.*, 1989).
**Nutritional value of microalgae**

- Biochemical quality / culture performance (Larval, post-larval)
- Proteins 30 à 60 % Good growth
- Carbohydrate / Relationship is not clear
- Polyunsaturated fatty acids (PUFAs)
- PUFAs are essential for most mollusc larvae: for membrane structure / prostaglandine
- PUFAs are generally variable between species and culture conditions and contribute to the difference in nutritional value.

**PUFAs in microalgae**

Most microalgae are rich in one or the other of these fatty acids.

![Fig.7 Algal classes (Brown et al., 1997)](image)

**Fig.8 Growth of Tapes decussatus larvae at 20°C fed with mixed diet(control and monospecific diet (Picochlorum sp, Chaetoceros sp) (Medhioub A. et al., 2015)
PUFAs in algae and nutritional value

- Algae lacking PUFA - poor nutritional value (unless in mixed diet),
- Algae with 5 to 30% PUFA (1 to 5% of DW),
- Sufficient PUFA as direct feeds (bivalves, shrimp larvae),
- May be insufficient for enriching rotifers, *artemia* (some marine fish larvae).

**In summary,**

- Most algae are good source of protein, carbohydrates and vitamins.
- Most algae are good source of PUFAs; sufficient as direct feeds (mixed diet) for most of molluscs
- Mixed algal diets - excellent nutritional value
- As the biochemical composition varies with the conditions of culture it is necessary to keep stable these conditions.
- Care should be taken not to feed relatively indigestible species (e.g. *Chlorella* sp.) or, species known to be deficient in the more highly unsaturated fatty acids (e.g. *Dunaliella tertiolecta*).

**The main marine microalgae species used in aquaculture**

**Fish / Crustaceans:** *Chlorella, Nannochloropsis* (INSTM, Center of Monastir, Tunisia),

*Picochlorum* sp (Tunisian coast, Lagoon of Monastir), Nanno spp *Nannochloropsis maritima* (Tunisian coast, Lagoon of Monastir).

**Bivalve molluscs:** *Chaetoceros calcitans*, *C. gracilis*, *Chaetoceros minus*, *Skeletonema costatum*, *Thalassiosira pseudonana* clone 3H, *Isochrysis galbana*, *Isochrysis aff galbana* (*T.iso*), *Pavlova lutheri*, *Tetraselmis suecica*, *striata*, *chui* or *tetrathel* (INSTM, Center of Monastir, Tunisia), *Chaetoceros calcitans*, *Chaetoceros* sp (Gulf of Gabès, Oued Maltine, south of Tunisia), *Isochrysis aff galbana* (*T.iso*), *Isochrysis* sp (Gulf of Gabès, Boughrara),

*Tetraselmis suecica*, *Tetraselmis* sp (Lagoon of Khniss, Monastir).

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**Fig.9** The process of algal culture (Helm *et al*., 2004)
The main growth parameters
1. Nutrients (quantitative and qualitative aspects),
2. pH,
3. Light,
4. Aeration,
5. The temperature,

1- Nutrients (quantitative and qualitative aspects)

Table 2 Nutrients (quantitative and qualitative aspects) (Grobellaar, 2004)
The culture medium: nutrients

Medium include macronutrients (carbon, nitrogen, phosphorus) silicate (diatomic exoskeleton) and micronutrients.

**Carbon**

The carbon requirement is high 175 to 650 μg.mg⁻¹ dry weight, the need for CO₂ and / or HCO₃⁻ is therefore very important.

\[ \text{CO}_2 + 2\text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + 0_2 + \text{H}_2\text{O} \]

**Nitrogen**

The need is 10 to 140μg.mg⁻¹ dry weight. Nitrogen can be used in three forms: Nitrate (NO₃⁻), ammonia (NH₄⁺) or urea. No growth difference respective of the source of nitrogen used.

**Phosphorus**

Phosphorus is essential for growth. Its need is 0.5 to 33 μg.mg⁻¹ dry weight. The preferred form for microalgae is orthophosphates (PO₄³⁻). It is often supplied with nitrogen in a ratio of 1/6.

**Others Compounds**

The other important macro and micro nutrients are:

Sulfur (S), potassium (K), sodium (Na), iron (Fe), magnesium (Mg), calcium (Ca) and trace elements such as boron (Br), Manganese (Mn), zinc (Zn), molybdenum (Mo), cobalt (Co), vanadium (V) and selenium (Se).

Vitamins are also provided in medium culture: thiamine (B1) and cyanocobalamin (B12) and sometimes biotin.

Silica is necessary for the cultivation of the diatoms for their exoskeleton.

**Table 3 Conway medium (Walne, 1966)**

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Formule chimique</th>
<th>Quantité en g/litre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titraplex</td>
<td>Na₂EDTA</td>
<td>45 g</td>
</tr>
<tr>
<td>Nitrate de potassium</td>
<td>KNO₃</td>
<td>100g</td>
</tr>
<tr>
<td>Acide borique</td>
<td>H₃BO₃</td>
<td>33.5 g</td>
</tr>
<tr>
<td>Dihydrogenophosphate de Sodium</td>
<td>NaH₂PO₄</td>
<td>26g</td>
</tr>
<tr>
<td>Chlorure de Magnesium</td>
<td>MnCl₂(4H₂O)</td>
<td>0.36 g</td>
</tr>
<tr>
<td>Chlorure de Fer</td>
<td>FeCl₃</td>
<td>1.3 g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Formule</th>
<th>Quantité en g/100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorure de Zinc</td>
<td>ZnCl₂</td>
<td>2.1</td>
</tr>
<tr>
<td>Chlorure de Cobalt</td>
<td>CuCl₂</td>
<td>2</td>
</tr>
<tr>
<td>Heptamolybdate d’ammonium</td>
<td>(NH₄)₆Mo₇O₂₄(4H₂O)</td>
<td>0.9</td>
</tr>
<tr>
<td>Sulfate de cuivre</td>
<td>CuSO₄(5H₂O)</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Quantité en mg/100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dichlorure de thamine</td>
<td>B1 400 mg</td>
</tr>
<tr>
<td>Cyanocobalamin</td>
<td>B12 20 mg</td>
</tr>
</tbody>
</table>
2- pH

Fig. 11 pH (Sverdrup et al., 1942)

3. Light

The luminous intensity, its spectrum and the photoperiod influences the physiology of microalgae, the species and the size of the culture (Φ, depth).

4. Aeration

Culture mixing is necessary for the homogeneity of the cells with respect to light and nutrients. Avoid sedimentation of the algae (and there by create an area of degradation of organic matter that can feed a bacterial bloom). Avoid thermal stratification (external cultures). Increase the gaseous exchanges between the culture medium and the air (culture in an open environment). Depending on the volume of the culture, this mixing is done by hand (maintenance of the strains) or by supplying compressed air (balloon, cylinder).
5. Temperature

The temperature affects the Lag phase and the rate of cell division. Most commonly cultivated species can tolerate temperatures between 16 and 27°C. Temperatures <16°C will cause a slow growth, while values >35°C are lethal for most species. In practice, an average temperature of 20°C is generally used.

6. The salinity

Marine phytoplankton is euryhalin. Most species grow well at a salinity that is lower than that of their original habitat. Salinities of 20 to 24 ppm are considered optimal (diatoms).

Phase growth of microalgae culture

![Graph showing age culture phases](image-url)

**Fig. 12** Age culture (P1: Lag phase, P2: exponential growth phase, P3: end of exponential phase, P4: stationary phase, P5: decay phase)

Growth Study

Counting cell / Mallassez, cell/mL

![Microparticle counter](image-url)

**Fig. 13** Microparticle counter (Multisizer III)
Fig. 14 Growth in diatoms and flagellates Tunisian strains

Microalgae cultivation technique
- Culture indoors / closed system / opensystem / axenic / non-axenic / outdoor
- The batch
- The semi-continuous
- The continuous

Maintenance of algal strains in experimental hatchery of bivalves INSTM Center of Monastir

Fig. 15 Culture stock
Fig. 16 Small volume culture room (50mL to 5 L) INSTM, center of Monastir

Temperature: 18 - 20°C; Light: 10 to 70 μmoles/m² s⁻¹; PH: 7±0.4

Fig. 17 Culture in bag (120 L) large volume INSTM, Center of Monastir

Fig. 18 Outdoor culture in volume of 1 m³ in May INSTM, Center of Monastir
Argenton, 2L Bioreactor culture  \( T_{iso} \), 25°C, 30‰, 60 à 80 \( \times 10^6 \) cell/mL

Argenton, 300 L Batch culture  \( T_{so} \), 25°C, 20 à 25 30‰, 6 à 8 \( \times 10^6 \) cell/mL  \( C_{graci/s} \), 30‰, 4 \( \times 10^6 \) cell/mL (6 \( \times 10^6 \) cell/mL)

**Fig. 19** Continuous culture inside

Commercial hatchery 1 m³

Argenton, 300L

5 to 10 m³

Greenhouse culture 2 for 5 m³ 20 m³

**Fig. 20** Inside culture in large volume (batch)
Fig. 21 Outdoor culture in batch
Recall: Some specific physiological characteristics

Fish
- Cold Blooded vertebrates
- Extreme sensitivity to stress
- Importance of gills, skin and mucus roles in certain physiological functions
- Complexity of environment (physico-chemical parameters of water)

Bivalve molluscs
- Cold blooded invertebrates
- Extreme sensitivity to stress
- Filter invertebrates
- Immune system less evolved than fish: absence of immune memory
- Complexity of environment (physico-chemical parameters of water)

Contamination of the animal

Modes of contamination
- Direct contamination: physical contact (triage and transport of animals)
- Indirect contamination: water is the main vector, materials used for handling, transport, invertebrates, helminth intermediate hosts
- Vertical contamination (Fish): the bio-aggressors can be present in gametes or in eggs (case of some microsporidia, NPI virus)

Routes of entry of pathogens
- The digestive way: the main way,
- The respiratory way
- The transcutaneous way: following trauma of manipulation (open lesions) or external parasitism.

Factors modulating animal receptivity → Intrinsic and extrinsic factors

- Intrinsic factors
- Fish species: carp refractory to VHS
- The sex
- The age or size of the animal
- The physiological state: sexual maturity and stress increase the pathological risks
- Extrinsic Factors
- Virulence of the pathogen
- The components of the environment: in particular the temperature which acts on both the physiology of the host and that of the bio-aggressor.

- Others extrinsic factors:
  - Nutritional factors: quantitative and qualitative aspects
  - Zootechnical factors: (mismanagement, manipulation)
  - Biological factors (parasites, viruses, bacteria ...)

The fish respond to these extrinsic factors in a variable way according to the intrinsic conditions (age, species, physiological state: stress,)

**The importance of stress**

5 stages of stress response
1- ALARM phase: Hormonal regulations, glucose in blood
2- RESISTANCE phase: Following from alarm, fish try to adapt and use up more energy
3- EXHAUSTION phase: Fish can no longer cope and/or reserves are exhausted. Performances start to be seriously impaired (FCR, feed intake, growth, O2 uptake etc.)
4- DISEASE phase: Fish is no longer able to maintain physiological balance and vital functions. Becomes open to secondary pathogens
5- MORTALITY phase

**Condition of occurrence of diseases**

![Fig.1 The relationship between fish, environment and pathogen](image)

**The kinds of diseases**

**Diseases related to environmental conditions**
- Malformations (conditions of captivity)
- Disease of the bubble (waterfalls, inlet of underground water under pressure)
- Cataracts (nutritional deficiency, ...)
- External growth (chemical contamination, genetic ...)
- Poisoning by nitrates, ammonia (excess organic matter)
- Toxic algea

**Diseases related to bio agressors**
- Virus
- Bacteria
- Parasites
- Fungus

**Stages of diagnosis**
- Epidemiological investigation: history and memorial
- Verification of the quality of the environment
- Review of diseased fish in their environment
- Examination of the nature of the lesions: necropsy
- Sampling and laboratory analysis

**Notifiable Diseases OIE, 2015**

**Molluscs diseases**
- Infection à Bonamia exitiosa
- Infection à Bonamia ostreae
- Infection à Marteilia refringens
- Infection à Perkinsus marinus
- Infection à Perkinsus olseni
- Infection à Xenohaliotis californiensis
- Infection due à l'herpès-virus de l'ormeau

**Fish diseases**
- Herpès-virose de la carpe koi (HVC)
- Infection à Aphanomyces invadans (syndrome ulcératif épizootique)
- Infection à Gyrodactylus salaris
- Infection par des variants délétés dans la RHP du virus de l'anémie infectieuse du saumon ou aux variants RHP0 de ce virus
- Infection par l'alphavirus des salmonidés
- Iridovirose de la daurade japonaise
- Nécrose hématopoïétique épizootique
- Nécrose hématopoïétique infectieuse (NHI)
- Septicémie hémorragique virale (SHV)
- Virémie printanière de la carpe
Why do we make a diagnosis?

• Determine the cause (s)
• Favor the normal physiology of the animal
• Cut the transmission of pathogen
• Destroy the pathogen (infectious diseases)
• Improve water quality
• Improve breeding technique

The success of any intervention depends on the accuracy of the diagnosis

Diagnosis Tools

Epidemiological data
Examination of fish in their environment
Necropsy Review
Water Quality

Guidance on types of sampling and analysis
Laboratory analysis results

Diagnosis of the zoo sanitary situation of the farm

Importance of epidemiological data

Fig.2 % d’éch. infectés (par espèce et par saison)
Sampling
- Representativeness of the sample
- Sample quality (moribund individuals and healthy individuals)
- Orientation of the nature of the samples according to the type of analysis
- Compliance with fish transport and conservation conditions - Samples for bacteriological and virological analyzes should be kept in refrigeration between 0 °C and 4 °C,
  - Bacteriological analyzes: should be undertaken maximum 6 h after death (spleen, kidney, gills or lesions),
  - Virological analyzes: can be carried out up to 24 H. after death (spleen, kidney, heart and brain) freezing remains possible.
- Toxicological analyzes (fish, organs) can be pre-frozen and stored for up to several months at -18 °C. (The liver, the muscle, the brain, the gills, the gonads ...)
- The histological analyzes will be preserved in alcohol at 70 °C or in 10% formalin.
- Identification of samples (labeling)

Antibacterial treatments
- Bath / immersion mainly for parasitical diseases
- Oral mainly for bacterial diseases
- Parenteral: INJECTION
  - more accurate dose
  - Stress management, anesthesia
  - Animals of high commercial value (> 200gr.)
  - Methods:
    - Intraperitoneal: 24-hour fasting, needle length, risk of peritonitis.
    - Intramuscular: MUSC. Dorsal, max. 0.05 ml / 50 g.

Oral treatments
Flumequine and Oxolinic Acid (group quinolones, very employed)
- Good oral absorption, Gram negative
- 20-30mg / kg P.V., 8-10 days
Other quinolones: enrofloxacin, sarafloxacin,…

Trimethoprim 1/5 sulphonamides (Sulfadiazine, sulfoximethoxine, sulfamethoxazole)
- Gram negative, good solubility in water
- 30-50mg / kg P.V., 8-10 days

Oxytetracycline (highly employed),
- Gram negative (Flexibacter)
- Dosage: 75 mg / kg P.V., 8-10 days

**Amoxicillin** (Beta lactams)
- Flexibacter and Gram positive
- Doses: 80mg / kg p.v, 10-14 days

**Florfenicol** (Chloramphenicol analogue),
- Gram positive and Gram negative (Flexibacter, Pasteurellosis)
- Fast intestinal absorption and good distribution
- Doses: 10mg / kg p.v., 10-14 days

**Other:** Erythromycin (Gram positive); Nitrofurans (prohibited); Doxycyclin

**Injection treatments**

- **Quinolones**
  - **Flumequine:** 30mg / kg IM -10d.
  - **Enrofloxacin:** 10mg / kg IM -3d

- **sulphamides**
  - **Sulfadiazine:** 125mg / kg IP -4d
  - **Sulfamethoxazole:** 50mg / kg IP -7d

- **Oxytetracycline**
  - 25-50mg / Kg IM or IP -variable

**Antiparasitic treatment**

**Oral Treatments**

- **Fenbendazole**
  - gastrointestinal nematodes,
  - Dose: 50 mg / kg p.v.- 7 days

- **Praziquantel**
  - cestodes, monogeneas, larva digeneas,
  - Dose: 50 mg / kg P.V. 1-7 days.

- **Levamisole**
  - Nematodes, helminthes
  - Dose: 2.5-10mg / kg P.V., 7 days

- **Ivermectin**
  - ectoparasites (sea lice)
  - Dose: 0.2 mg / kg P.V., every 2-3 days for a total of 6 doses
**Bath Treatments**

**Praziquantel**
- Cestodes: 2 ppm - 3 hours
- Monogeneos: 10-20ppm - 1.5-3 hours

**Mebendazole (benzoimidazoles)**
- Gyrodactilus, Dactylogyrus
- Dose: - Closed short bathroom: 100ppm - 10min.

**Formalin**
- Volatile and irritating - stored in the dark and at T°> 4 °C
- Treatment of Protozoa and monogeneas
- Dose: 125-250ml / m3 - 30min.

**Copper sulphate:**
- Cheap - inactivated by organic matter
- Treatment of Amyloodinium, Criptocarion, Flexibacter, fungi; algaeceide
  1 g. Sulfato dilution in 250 ml of distilled water, dose: 0.4-1ppm 10 min.

**Hydrogen peroxide (H2O2)**
- Commercial 3% = 30 mg / l
- Flexibacter and ectoparasites
- Dose: 250-500ppm - 15min

**Injection treatments**

**Praziquantel**
- 25 mg / kg IP-1d (metacercariae Of digeneas)

**Levamisole**
- 8 mg / kg - lcardiaca-1d. (Angulicola)
SOME OF ASPECTS IN AQUACULTURE INTERACTION WITH ENVIRONMENT AND MONITORING PROGRAM

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Institut National des Sciences et Technologies de la Mer
Sami.zaafrane@instm.rnrt.tn

Global Aquaculture Production

- 76.64 million tonnes 2015.
- Increasing 7.8% per Year.
- 20000 employed
- One finfish in two from aquaculture.
- Two in three shrimp from aquaculture.
- 19.7 Kg by person
- Over 45% of seafood will come from aquaculture in 2016.
- 600 species are farmed.

Fig.1 Aquaculture actually and future

Fig.2 Data from principal protein source feed conversion
Fig. 3 Fish change with environment

Fig. 4 Nitrogen and phosphorus in aquaculture (D’après Gowen et al., 1990)

Fig. 5 Environmental bilan in myticulture associated N and P budgets in % of the intake
Fig. 6 Environmental bilan in fish associated N and P budgets in % of the intake

Fig. 7 Environmental bilan in shrimp associated N and P budgets in % of the intake

**PRINCIPAL IMPACT OF AQUACULTURE**

Aquaculture generate impacts on several biological levels, from genes to ecosystems;

- Change in water (plankton etc.) and sediment quality constitution (pH, Organic Charge, Chlorophyll ecc.),
- Destruction of some paysage (mangrove, posidonia),
- Reduction of biodiversity,
- Genetic impact,
- Dissimination of pathogen,
- Affected a structure of natural bacteria,
- Modification of nitrogen, phosphorus and carbon cycle.
**Fig.8** Environmental effect of fish farming

**Fig.9** Correlation of waste dispersion with depth (D'après Gowen, R. J and Bradbury,

**Fig.10** Effect of current in waste dispersion (D'après Gowen et al., 1989)

**Example of model used to simulate waste dispersion and carrying capacity**

**FjordEnv** which calculates water exchange and carrying capacity for fjords.

**MOM** (Modelling Ongrowing fish farm - Model System), optimizes the setup of the number and size of cages, taking into consideration factors affecting fish welfare and environmental conditions, such as disease transmission and particle transport.

**Depomod**, simulates discharges from fish farm facilities. The model simulates the point load in a facility as a result of the sinking of feed and faeces.
**Meramod**, simulates particulate footprint for seabass and seabream cage farms in the Mediterranean.

**Tropomod**, simulates particulate footprints related to Milkfish and Tilapia cage farms in the tropics.

**BENOSS**, is used to simulate the spread and impact of discharges to sea from pipelines from fish farm facilities.

**Environmental Monitoring**

Aquaculture generate impacts on several biological levels – from genes to ecosystems and affects habitats and ecosystem, geochemical characteristics of the coastal environments (plankton, benthos benthic organisms, biodiversity).

Depending on practice and site characteristics

Site location - Sampling Frequency - Station choice - Conservation - Statical Data - Result expression

Parametre

Water Quality and Frequency

Sediment quality and frequency

Biological parametre and frequency

Isotop radioactif

Analyse of life cycle

<table>
<thead>
<tr>
<th>Single Random</th>
<th>systematic</th>
<th>stratified</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Sampling design consideration" /></td>
<td><img src="image2" alt="Sampling design consideration" /></td>
<td><img src="image3" alt="Sampling design consideration" /></td>
</tr>
</tbody>
</table>

**Fig.11** Sampling design consideration

**Fig.12** Sampling instrument
Table 1 Water quality and frequency measurement (Current measurement at three level)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
<th>Method</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>monthly</td>
<td>multisond</td>
<td>Water colon profil</td>
</tr>
<tr>
<td>pH</td>
<td>monthly</td>
<td>multisond</td>
<td>Water colon profil</td>
</tr>
<tr>
<td>Oxygen</td>
<td>monthly</td>
<td>multisond</td>
<td>Water colon profil</td>
</tr>
<tr>
<td>Salinity</td>
<td>monthly</td>
<td>multisond</td>
<td>Water colon profil</td>
</tr>
<tr>
<td>Transparency</td>
<td>monthly</td>
<td>Secchi Disc</td>
<td>Water colon profil</td>
</tr>
<tr>
<td>Turbidity</td>
<td>monthly</td>
<td>multisond</td>
<td>Water colon profil</td>
</tr>
<tr>
<td>Nitrate</td>
<td>seasonal</td>
<td>Chemical or KIT</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>Nitrite</td>
<td>seasonal</td>
<td>Chemical or KIT</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>Ammonium</td>
<td>seasonal</td>
<td>Chemical or KIT</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>seasonal</td>
<td>Chemical or KIT</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>N.O.D</td>
<td>seasonal</td>
<td>Chemical</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>Organic Phosphorus</td>
<td>seasonal</td>
<td>Chemical</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>Silica</td>
<td>seasonal</td>
<td>Chemical</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>Organic silica</td>
<td>seasonal</td>
<td>Chemical</td>
<td>Three level (S-M-B)</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>seasonal</td>
<td>Chemical or multisond</td>
<td>Three level (S-M-B) or water colon profil</td>
</tr>
</tbody>
</table>

Table 2 Sediment quality and frequency

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size</td>
<td>Bi annual</td>
<td>AFNOR Method</td>
</tr>
<tr>
<td>Potential Red/ox</td>
<td>quarterly</td>
<td>Instrumental method</td>
</tr>
<tr>
<td>Mineral nitrogen</td>
<td>quarterly</td>
<td>chemical</td>
</tr>
<tr>
<td>Organic Nitrogen</td>
<td>quarterly</td>
<td>chemical</td>
</tr>
<tr>
<td>Organic matter</td>
<td>quarterly</td>
<td>chemical</td>
</tr>
<tr>
<td>Mineral phosphorus</td>
<td>quarterly</td>
<td>chemical</td>
</tr>
<tr>
<td>Organic phosphorus</td>
<td>quarterly</td>
<td>chemical</td>
</tr>
<tr>
<td>Sulfid</td>
<td>quarterly</td>
<td>chemical</td>
</tr>
<tr>
<td>Isotope of nitrogen and phosphorus</td>
<td>option</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Evaluation grid of sediment quality (European Directive Framework)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Excellent</th>
<th>Good</th>
<th>medium</th>
<th>mediocre</th>
<th>bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter %</td>
<td>3.5</td>
<td>5</td>
<td>7.5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Total Nitrogen g/kgPS</td>
<td>1</td>
<td>2.0</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Total Phosphorus mg/kg PS</td>
<td>40</td>
<td>500</td>
<td>600</td>
<td>700</td>
<td></td>
</tr>
</tbody>
</table>

Biological monitoring
- Water and sediment bacteria
- Vibrionacea
- Total mesophil bacteria
- Antibioresistance test
- Natural and toxic microalgua
- Polychet indice (sediment)
- Seafloor video
Table 4 Evaluation of water quality for aquaculture monitoring in some of the other countries

<table>
<thead>
<tr>
<th>parameter</th>
<th>Australia</th>
<th>Canada</th>
<th>New Zealand</th>
<th>Malaysia</th>
<th>Philippines</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH M</td>
<td>5.9</td>
<td>5.9</td>
<td>6.5-6.9</td>
<td>6.5-8.5</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>pH F</td>
<td>6.9</td>
<td>6.5-9</td>
<td>6.9</td>
<td>6.5-8.5</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>Oxygen M</td>
<td>&gt; 5</td>
<td>6-9.5</td>
<td>&gt; 5</td>
<td>3-7</td>
<td>5</td>
</tr>
<tr>
<td>Oxygen F</td>
<td>&gt; 5</td>
<td></td>
<td>&gt; 5</td>
<td>3-7</td>
<td>5</td>
</tr>
<tr>
<td>NH₃ N/mg M</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₄ N/mg F</td>
<td>&lt; 1</td>
<td>1.37</td>
<td>&lt; 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₃ N/mg M</td>
<td>&lt; 0.03</td>
<td>&lt; 0.03</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₂ N/mg F</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₂ N/mg M</td>
<td>&lt; 0.1</td>
<td>0.06</td>
<td>&lt; 0.01</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>NO₃ N/mg M</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₂ N/mg F</td>
<td>50</td>
<td>7</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₃ N/mg F</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PO₄ mg/L F</td>
<td>&lt; 0.1</td>
<td>0.05</td>
<td>&lt; 0.1</td>
<td>0.1</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>PO₄ mg/L M</td>
<td>0.05</td>
<td>&lt; 0.05</td>
<td>0.2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>T.S.S F (mg/L)</td>
<td>&lt; 40</td>
<td>&lt; 10</td>
<td>&lt; 40</td>
<td>25-150</td>
<td>&lt; 30</td>
</tr>
<tr>
<td>T.S.S M (mg/L)</td>
<td>&lt; 10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Biological Index

Shannon index \( H' = -\Sigma P_i \ln P_i \)

\( p_i \) is the proportion of individuals found in species \( i \).

\( p_i = \frac{n_i}{N} \), where \( n_i \) is the number of individuals in species \( i \)

\( N \) is the total number of individuals in the community.

Simpson’s index \( D = 1 - \Sigma P_i^2 \)

Jaccard’s index \( J = \frac{S_{a\cup b}-S_c}{S_{a\cup b}+S_c} \)

where \( S_a \) and \( S_b \) are the numbers of species unique to samples a and b, respectively, and \( S_c \) is the number of species common to the two samples.

Table 5 Classification of \( H' \) indice (Simboura and Zenetos, 2002)

<table>
<thead>
<tr>
<th>Label</th>
<th>Ecological state</th>
<th>( H ) Values</th>
<th>Pollution state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bad</td>
<td>( 0 &lt; H' \leq 1.5 )</td>
<td>Azoïque extremely polluted</td>
<td></td>
</tr>
<tr>
<td>Médiocre</td>
<td>( 1.5 &lt; H' \leq 3 )</td>
<td>Polluted</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>( 3 &lt; H' \leq 4 )</td>
<td>Moderately Polluted</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>( 4 &lt; H' \leq 5 )</td>
<td>Transition Zone</td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>( H' &gt; 5 )</td>
<td>Reference Site</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental rearing class</th>
<th>Sediment sulfide (total ( S^2 ))</th>
<th>Effect on marine sediment</th>
<th>( \mu M )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxic A</td>
<td>( &lt; 750 )</td>
<td>Low effects</td>
<td></td>
</tr>
<tr>
<td>Oxic B</td>
<td>( 750-1500 )</td>
<td>Low effects</td>
<td></td>
</tr>
<tr>
<td>Hypoxic A</td>
<td>( 1500-3000 )</td>
<td>May be causing adverse effects</td>
<td></td>
</tr>
<tr>
<td>Hypoxic B</td>
<td>( 3000-4500 )</td>
<td>Likely causing adverse effects</td>
<td></td>
</tr>
<tr>
<td>Hypoxic C</td>
<td>( 4500-6000 )</td>
<td>Causing adverse effects</td>
<td></td>
</tr>
<tr>
<td>Anoxic</td>
<td>( \geq 6000 )</td>
<td>Causing severe damage</td>
<td></td>
</tr>
</tbody>
</table>
**Tunusian Experience in Environmental Monitoring of Aquaculture Activity**

**Novel strategy in aquaculture environmentally friendly**

*Goal:* Reduce environmental impact of aquaculture without decreasing production

- **Funding for research**
- Improve feed conversion ratios (FCR) – ratio of gain in wet body weight to the amount of feed fed
- Improve organism-specific feeds to increase nutrient retention.

**Educate Farmers on:**

- Method benefits and drawbacks
- Integrated aquaculture techniques
- Multitrophic aquaculture.
Fig. 14 Turbidity results (important turbidity in the bottom)

Fig. 15 Oxygen results (decrease in the bottom)

Fig. 16 Organic nitrogen results (increase in the bottom column)
Fig. 17 Organic phosphorus results (increase of concentration in water colon)

Fig. 18 Chlorophyll results (decrease near the cage farm creasing activity)

Fig. 19 Sediment aspect and texture (increase of fine fraction)
Fig. 20 Phyto and zooplanktons (important diversity especially in the vicinity of the cage structures but with the presence of some dangerous species)

Fig. 21 Environmentally responsible aquaculture

Fig. 22 New production system
During the last three decades, aquaculture has expanded, diversified and intensified to increase production under farm conditions, the most common practices to:

- Increase the number of fish per culture unit and
- Increase GR and FCE (feeds and feeding).

All these efforts focused on increasing growth in order to improve productivity/profitability but did not pay much attention to the question how the animal would cope with these new husbandry conditions. Welfare gained only very recently some interest in fish farming.

What is fish welfare?

FAWC declare five freedoms that the animals must have;

1. Sufficient quantity and quality of feed,
2. Suitable water quality (temperature, good oxygen level, water free of pollution),
3. A stocking density which takes into account normal swimming and social interaction,
4. Good possibilities to avoid perceived danger and
5. Good monitoring of the health status of the fish.

Why focus on fish welfare?

Understanding and documenting welfare of farmed fish is essential for:

- Performance
- Survival

A "welfare" fish is a healthy and fast-growing animal

- Quality improvements
- Acceptability of aquaculture in the public eye.

Good welfare practices may improve muscle quality and freshness and this can open new niche markets for “sustainable” products

Operational Welfare Indicators (OWI)

OWIs must be robust, efficient, provide a valid reflection of welfare, must be repeatable and comparable, and easy to measure on a farm.

- Appetite, growth, condition and FCR
- Uniformity of size
- Feeding behaviour and swimming activity
- Intraspecific aggression (e.g. Fin erosion/damages)
- Stress hormones (in blood and water)
- Primary barriers and histopathological changes (e.g. Gill damages)
• Immune parameters after stimulation/challenges
• Molecular biomarkers: e.g. gene expression profiles (Micro arrays)
• Quality of end product

How can we measure welfare?

Fish welfare is influenced by e.g.:
- Physical and chemical environment (e.g. diss O₂, temperature …)
- Feed availability (e.g. feed ration, feed particle size)
- Feed quality (e.g. nutrient composition…)
- Social interactions (e.g. stocking density…)
- Occurrence of pathogens, parasites and predators
- Procedures during handling, transport, vaccination and slaughtering.

Endocrine mechanisms of physiological stress

Stress is a condition in which the dynamic equilibrium (homeostasis), is disturbed as a result of the actions of intrinsic or extrinsic stimuli, commonly defined as: stressors.

The response to a stressor

- Acute: Short perturbation
- Chronic: long perturbation

Duration of the stressor

- Primary
- Secondary
- Tertiary

The primary response (Endocrine system level)
The assessment of potential methods to reduce stress responses in aquaculture species is an active area of research. The investigation into the feasibility of selectively breeding fish to minimise their responsiveness to stressors: Trout (DiBattista et al., 2005), Seabass (Maillot et al., 2011).

**Table 1. Welfare issues**

<table>
<thead>
<tr>
<th>Abiotic</th>
<th>Biotic</th>
<th>Feed &amp; Feeding</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Stocking density</td>
<td>Balance major nutrients</td>
<td>Sorting and handling</td>
</tr>
<tr>
<td>Salinity</td>
<td>Aggression?</td>
<td>Vitamins, minerals and additives</td>
<td>Biomass monitoring</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Predators</td>
<td>Pellet size/type</td>
<td>Health monitoring</td>
</tr>
<tr>
<td>Metabolites</td>
<td>Pathogens</td>
<td>Feeding regime</td>
<td>Disease/parasite treatments</td>
</tr>
<tr>
<td>Water current</td>
<td>Toxic algae</td>
<td>Feed amount</td>
<td>Vaccination</td>
</tr>
<tr>
<td>Waves</td>
<td>Jelly fish etc</td>
<td>Starvation periods</td>
<td>Environment monitoring</td>
</tr>
<tr>
<td>Light</td>
<td>Bio-fouling (affecting flow)</td>
<td><em>Alternative diets (e.g. Soya)</em></td>
<td>Net change and cleaning</td>
</tr>
<tr>
<td>Enclosure size/</td>
<td>(Escapes)</td>
<td>Medicines and vaccines in feed</td>
<td>Transport</td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
<td>Dietary toxins (e.g. fungal toxins)</td>
<td>Emergency killing</td>
</tr>
<tr>
<td>Access to air</td>
<td></td>
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</tbody>
</table>

**Fig.1** Feed additive: 1- Tryptophane (Hseu et al., 2015 (Grouper))
The results indicated that CVs of groupers could be mitigated by the oral administration of TRP. The recommendation on supplementary TRP level to be used is 0.5% of dry diet.

![Fig. 2 Supplementary tryptophan (% of dry diet)](image)

Cannibalism among juvenile could be mitigated by the oral administration of TRP. Increased brain 5-HT activity is associated with inhibition of aggression and subordinate behaviour in fish.

![Fig. 3 Feed additive: ArA (20: 4n-6) (Van Anholt et al., 2003, Aquaculture)](image)

The cortisol response of sea bream larvae exposed to stressor (exposed to air for 90 sec). Larvae were fed Artemia enriched with ArA prior to exposure. Feeding the high ArA Artemia strongly reduced the cortisol response.

![Fig. 4 Alternative diets (Azaza et al., 2010, Aquaculture Research)](image)
Figure 4 shows specific activities of superoxide dismutase (SOD), glutathione S-transferase (GST), catalase (CAT) and glutathione peroxidase (GPx) in the livers of juvenile Nile tilapia fed on experimental diets containing graded levels of tuna by-product meal. The substitution of FM by TBM in diets of Nile tilapia at high levels (20 to 30 %) induced an oxidative stress.

Fig. 5 Rearing water temperature (Abiotic/uniformity of size (OWI) Pangasius hypophthalmus (Raynaud, 2005, Aquaculture)

Fig. 6 T° opt reduce growth dispersion, Clarias gariepinus (Daffé, 2002)
Thermal regimes that produce the slowest growth also produce the highest size heterogeneity.

Fig. 7 Growth of juvenile *O. niloticus* depending on the extent of daily thermal fluctuations (*F*)

Small fish gain growth advantage when exposed to strong daily fluctuations, whereas large fish incur a major penalty and perform much better at constant or slightly fluctuating temperatures.
The distribution of feed particles larger than optimum size resulted in an increase of the coefficient of variation of wet body mass.

Large particles are scarcer, more easily defended, and their use facilitates the settlement or continuation of dominance hierarchies, which generally benefit the largest individuals. GH is originated from heterogeneity of feed intake among individuals.
Increasing stocking density results in higher variation in individual growth.

**X-ray method**

- Marqued Feed
- Glass beads (ballotini, type H, 450-600 µm diameter) were mixed (1.5%) with the ingredients before compressing them into pellets.
- After the meal, fish were X-rayed (Kodak, X-OMAT MA).
- The amount of feed in the gastro-intestinal tracts of fish is back-calculated from the calibrated relationship (FM/Nb).
In each graph, the closed circles stand for the mean of feed intake in each group. Whiskers indicate the smallest and largest quantity of individual ingested feed in each group (g). Radio-graphic studies demonstrate that increasing stocking density is accompanied by increasing inter-individual variation of FI, and thus by growth heterogeneity.

**Social hierarchy: Dominant/Dominated Relationship**

Dominant fish are characterized by their ability to acquire superior rank in a population, which would allow them to monopolize a disproportionate share of the meal.

Dominated fish: are ranked low in the hierarchy may experience stress, reduced appetite, higher metabolic costs and reduced feeding opportunities.

Social stress leads to marked behavioural and physiological changes in subordinates, who often show a general behavioural inhibition of food intake, aggressiveness, locomotory activity, changes in skin colorations and higher levels of plasma cortisol and thus impaired welfare.

Some examples of new improved production systems that can decrease stress and hence increase fish welfare.

Example 1: Cage size

Bigger and deeper cages give fish better possibilities to choose optimal environment and improve welfare.

Fig. 13 Example 2: No fibre nets
Fast and efficient underwater feeding (approx. 50kg/min.)

- Good feed distribution
- Good hygiene

Fig. 14 Example 3: Surface spreaders

Fig. 15 Example 4: Subsea feeder

Fig. 16 Example 5: Sorting and grading of fish
Fig. 17 Example 6: Slaughter fish.

Commercial electrical stunners lead the slaughter fish at a rested state. Inhumane (slow/painful/distressing) commercial methods of killing farmed fish should be avoided. Good welfare practices throughout the production chain should go hand in hand with a responsible and humane slaughtering process.

Fig. 18 Example 7: Feed system software

**Biological approach**

Feed system software with biomass regulated feeding regimes based on accurate monitoring of fish appetite and environmental data. Develop technology/tools that will enable real time estimation of total number of fish and size distribution and do not impose the fish to any stress through handling or any other stressful factors. Facilitate correct feeding management in cages and tanks.
The environmental conditions in the cages are the most vital parameters for top health and quality life of fish. Reduced marine fouling improves the environmental conditions. Strong fouling on the net will reduce the oxygen supply and algae growth can increase bacterial loads and cause diseases and stress.

A basis for a continued healthy environment for the live fish in the cage is that all morts are removed as soon as possible.

Summary (1)

- Fish welfare is an important issue for the industry, not just for public perception, marketing and product acceptance, but also often in terms of production efficiency, quality and quantity
- Consistent monitoring of welfare parameters can enable each farmer to discover suboptimal conditions and intervene at an early stage.
- Increased research efforts on welfare related issues (Identify areas for improvement).
- The assessment of potential methods to reduce stress responses in aquaculture species is an active area of research.
The effects of stocking density, also an area of welfare concern, are complex and appear to comprise of numerous interacting and case specific factors.

Stocking density, diet, feeding schedule, and management procedures all have strong effects on stress responses, subsequent stress tolerance, health, and the occurrence of aggressive behaviour.

Fish handling operations are often very complicated and lead to stressed situations for fish. Handling is therefore regarded as critical for fish welfare, with still a large potential for improvement.

The establishment and exchanging codes of best practice is the best way towards a further improvement of fish welfare in all aquaculture operations.

Stressors in aquaculture are unavoidable and reducing stress and its harmful effects is a fundamental goal for successful growth and production as well as welfare.

Specialised staff and adapted systems are needed for feeding, harvesting, dead fish removal and maintenance.

Summary (2): Research needs

Some OWIs have already been developed and tested for fish and need to be validated and benchmarked on farms.

Highlight and address areas where data is lacking to support good on-farm management.

A better understanding of physical and behavioural needs of fish to tune conditions during production to the needs of the fish.

Implement a quality assurance system that is focused on fish welfare. The QA system is process oriented. Prevention of hazards that impair welfare is the key.

A better understanding of pain mechanisms and the potential use of anti-inflammatory drugs.

Develop the efficacy and broaden the range of vaccines for aquaculture.
1. Introduction

Cage aquaculture has grown rapidly in recent decades and is currently undergoing swift changes in response to pressures from globalization and an escalating worldwide global demand for aquatic products. There has been a move towards clustering existing cages as well as towards the development and use of more intensive cage-farming systems. In particular, the need for suitable sites has resulted in cage aquaculture accessing and expanding into new untapped open-water culture areas such as lakes, reservoirs, rivers and coastal brackish and marine offshore waters. The ever-increasing competition for land and water space, along with the growing market demand for marine fish and other sea products, as mentioned above, are some of the elements that are motivating the aquaculture engineering industry and entrepreneurs in the development of farming structures in open waters. In the past couple of decades, a variety of fish containment structures, typically referred to as fish cages, have been designed, tested and commercially produced. These structures vary in design, size and materials used as they are intended for diverse environments, ranging from relatively protected to highly exposed and dynamic sites, either as floating or submerged underwater structures and adopting a number of technological solutions to facilitate fish stock husbandry and management (Cardia and Lovatelli, 2015).

2. Basic of the Cage Culture

High density polyethylene (HDPE) pipes are widely used as the main material for the construction of floating cages. High-density polyethylene is a class of plastic resins obtained by polymerizing ethylene gas. Pipes made of HDPE are widely available because they are commonly used for liquid and gas transfer (irrigation systems, gas pipelines, etc.). Moreover, HDPE pipes are an excellent material for cage construction because they are durable, flexible, shockproof, resistant to ultraviolet (UV) light and require relatively little maintenance, if installed correctly (Cardia et al, 2017).

The reasons of the cage culture can summarized according to the below information:

- Relatively lower investment cost when it is compared with the other constructive and recirculation systems;
- Higher production via increased stocking density, higher dissolved oxygen at the off-shore systems; because of the current;
- Live food possibility, as small fish can come into the cage systems, particularly the cages that have been carnivorous species;
- Possibility of movement and re-location; and
- Reducing the pressure on land based production systems.
3. Routines of the cage culture systems

3.1. Construction and welding

The main construction material of net cage systems is high density polyethylene. Therefore, the ease with which this type of material can be shaped using temperature applications can provide easy workmanship and renewal in both the production and repair phases (Photo 1 and 2).

3.1.1. Brackets and mooring

3.1.2. Brackets

One of the important components of net cages that have been used for aquaculture activities in marine and freshwater environment are brackets. The bracket is a structural element of the cage collar that binds the pipes together to form the cage collar. Bracket robustness is essential to cage reliability. A wide range of brackets are available from different net cage manufacturers, and the design should be chosen taking into consideration the site exposure and the required strength of the cage. Rotation system have been used to produce brackets for a long time; but as plastic process technology has just well developed, using of injection method has become more popular (Photo 1). At the same time, injection systems can use the second hand plastic material; so it means that it is such a more environmental friendly bracket production system (Altan and Galipoğlu, 2018).

Photo 3. A rotation system bracket on the left, an injection system bracket on the right (Original).
3.1.3. Mooring

Mooring is required to hold cages against the forces generated by wind, currents and waves, and to allow the fish stocks, and the cages and nets the best chance of survival. Different mooring system applications are shown in figure 1 and 2.

![Figure 1 and 2. Different mooring application from the commercial business models.](image)

3.2. Feeding

Feeding is one of the most important activity of the net cage systems. One side the location of the cage farm is away from the coast line, the other side some different external effects like currents, waves and different physico chemical conditions can easily effect the successful feeding in the field. Feeding automation and the feeding barge systems have used by the fish farms to increase the feeding rates. Different feeding automation and barge systems are given in the photos 3 and 4.

![Photo 4 and 5. Different feeding automation and barge systems to feed the fish effectively.](image)

4. Site Selection

Site selection criterias can be identified one by one according to the below information;

a. Present situation of the water body (if it is inland), giving the answers of below questions

*Who is the owner of the water body?*

Who would be the authority to initiate the business?

Enough experts to evaluate the field?

b. Water related issues, primarily water depth and water quality;

c. Industrial and agricultural activities around the coast and assessment of the contamination;

d. Existing of other cage farms, their distance from the current cage farms.
5. Characteristics of Fish Species for Cage Culture

It is quite difficult to say every fish species is available to be cultured in the cages. The below criteria have been giving to the possible investors about the cage culture possibility;

a. Fast growth rate;
b. Stress resistance;
c. Tolerance for crowded conditions;
d. Native to the region; and
e. Good market value.

6. Cage Material

A net cage system can consists of below elements;

a. **Floating system**: provides buoyancy and holds the system at a suitable level in the surface of water (Photo 5);

b. **Service system**: is required for providing operation and maintenance services: feeding, cleaning, monitoring or grading (Photo 6);

c. **Cage bag – the net**: protects the fish and provides a marine habitat;

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Photo 5. A sample of floating system.

Photo 6. Service system with wooden ma-

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Photo 7. Net material of the cage
d. **Mooring system**: keeps the cages in the suitable position according to the direction and depth decided in the design, and sometimes helps to maintain the shape of the cage.

![Photo 8](image1.png)

**Photo 8.** Different components of a mooring system

e. **Anchor system**: holds the cage and all the components in a particular site in the seabed and is connected to the cage by the mooring system.

![Photo 9](image2.png)

**Photo 9.** A sample of an anchor system.

References


