

Suspended pearl-net rearing structures beneath a support rack.

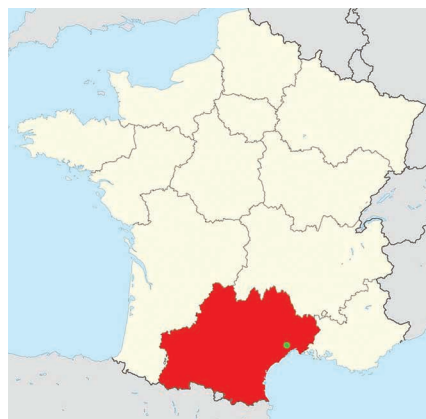
AQUACULTURE IN OCCITANIE, FRANCE

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The upcoming AQUA 2018 event #We R Aquaculture, co-organised by EAS and WAS, will take place in Occitanie. This is the name given to one of the new 'super regions' of France, created in 2016 from the former regions of Languedoc-Roussillon and Midi-Pyrénées. Occitanie comes from the historical name of the broader region of southern France and the historic use of the Occitan language and its various dialects.

Its aquaculture activities cover the production of marine and freshwater fish and shellfish cultivated in the Thau lagoon, a special focus of this article. The region also produces *Spirulina* and more recently other microalgae and macroalgae.

Overall, France is one of Europe's biggest aquaculture producers, with 262,012 t of production in 2015. The country has a long tradition of shellfish (216,917 t in 2015) and fish production (45,095 t in 2015). It was also the location of one of the precursors of the marine production sector, developing hatchery techniques for



The super-region of Occitanie in southern France. Montpellier is indicated by the green dot.

marine species, although production of market-size marine fish was just 4,567 t in 2015. France currently contributes about 17 percent of total EU aquaculture volume and value.

SHELLFISH PRODUCTION

Total shellfish production in 2015-2016 was 216,917 t, with 125,151 t of cupped oyster *Crassostrea gigas* and 87,894 t of stake-grown mussels (bouchot). Some 55 percent of oyster production is consumed over the Christmas and New Year holiday periods.

Production fluctuates each year from mortality events (juveniles and adults) that regularly affect the sector. Since 2008, massive mortality events of cupped oysters have been reported in almost all farming areas in France (Miossec *et al.* 2009, European Food Safety Authority 2010, Martenot *et al.* 2011, Pernet *et al.* 2012, Pernet *et al.* 2016). These epidemiological events are associated with infection of oysters with a newly described genotype (μ Var) of Ostreid herpesvirus 1 (Segarra *et al.* 2010) that has expanded along the

European coastline. Closely related variants have been detected from mortality events of Pacific oysters in Australia, New Zealand and Asia, posing a serious challenge for oyster production around the world (Pernet *et al.* 2016).

French shellfish production is governed by the National Shellfish Committee (CNC — Comité National de la Conchyliculture) and its seven regional organisations — the Comités Régionaux de la Conchyliculture (CRC).

FISH PRODUCTION

According to FEAP production data, the French fish farming sector declined from 2007 (50,191 t) to 2013 (40,705 t) but has increased in recent years (45,095 in 2015). France specialises in freshwater production of mainly rainbow trout, with portion-size and large trout, and common carp. There are about 500 production sites managed by approximately 300 commercial enterprises (Agreste Census 2007). The French regions of New Aquitaine, Hauts de France and Brittany account for 70 percent of national production. France is the third largest producer of freshwater trout in Europe with nearly 38,714 t produced in 2016. Rainbow trout production is 96 percent of the national salmonid production. Other species include fario or brown trout, brook trout or fountain salmon, and Arctic charr.

Trout is one of the top five fish regularly purchased by French consumers. About 72 percent of salmonid production is for direct consumption and 28 percent is dedicated to restock rivers, recreational fishing and trading. Approximately 50 national processors offer a wide range of trout value-added products, with very large trout mainly smoked, big trout offered as fillets or slices, and portion-size fish mainly sold fresh and gutted. Other products include trout roe and raw fish for sashimi, tartar or carpaccio.

Caviar production from reared Siberian sturgeon *Acipenser baerii* is about 27 t, which places France among the leading producing countries in the world with Italy (but behind China). The sturgeon sector is made up of ten companies spread over 18 production sites. Sturgeon meat represents 306 t.

Although France is a European pioneer in the breeding of marine species (i.e. seabass, sea bream, turbot, sole), thanks to control of reproduction, larval rearing and feeding of fish, it produces only 4,821 tons of market-size marine fish. Six species dominated this sector, with production in 2016 of 1,928 t of sea bass, 1,671 t of sea bream, 288 t of turbot, 236 t of meagre, 450 t of salmon and 248 t of sole. Some 113 million fry are produced in French hatcheries, with 90 percent of these exported to other Mediterranean countries for on-growing.

L'Aquatourisme — a New Way to Discover French Freshwater Fish Farms

The French Interprofessional Committee for Aquaculture Products has developed a new aquaculture tourism portal based on the idea that fish farmers are eager to share their knowhow and allow members of the general public to visit their farms. It gives people the chance to have a good day out and learn more about how fish are farmed. Visits are often combined with fishing possibilities and direct sales of aquaculture products. The interactive map on the portal allows people to select a region of town and see all the farms in that area, so as to be able to contact them and arrange a visit.

MICROALGAE — A GROWING SECTOR

In its 2014 national report (Brinker and Sternberg 2014), the EU Project EnAlgae and the national study carried out on behalf of ADEME (Kerlero de Rosbo and Bernard 2014) identified more than 200 private companies and about 30 academic institutions working with macroalgae and microalgae. The use of microalgae and macroalgae is very evenly distributed among French stakeholders (38 percent are working with microalgae and 38 percent are working with macroalgae). Nearly a quarter of all stakeholders (23 percent) are cultivating and processing both algae types (23 percent of the industrial stakeholders and 27 percent of research institutions). Based on the EnAlgae report,

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TABLE I. AQUACULTURE IN FRANCE IS DOMINATED BY SHELLFISH PRODUCTION, ESPECIALLY OF CUPPED OYSTERS AND MUSSELS. (PRODUCTION FIGURES FOR 2015-2016 IN T.)

Region	Cupped oysters	Stake mussels (bouchot)	Other mussels	Flat oysters	Cockles and clams	Total
Normandie – Mer du Nord	25,000	21,000	700		350	47,050
Bretagne Nord	21,551	17,494		908	14	39,967
Bretagne Sur	11,000	3,500		200		17,100
Pays de la Loire	8,000	10,000			2,400	20,400
Poitou-Charentes	4,400	4,000	1,200			49,200
Arcachon-Aquitaine	8,000					8,000
Méditerranée	7,600		30,000			37,600
TOTAL	125,151	87,894	31,900	1,108	2,764	216,917



Oyster racks in Thau Lagoon near Sète. Photo: Yves Harache.



Oyster racks in the Thau Lagoon.



Oyster pearl nets in Thau Lagoon. Photo: Patrik Le Gall, Ifremer.



Suspended pearl-net rearing structures beneath a support rack.

a considerable number of stakeholders work with cyanobacteria and, although they are not algae from a scientific perspective, they are often mentioned in the context of microalgae activities.

Production technologies are based on open or production systems:

- Open/ Half-open production systems — open ponds, raceways and longlines
- Closed photobioreactor systems (PBR) - flat bed/plate/panel reactor, tubular reactor, bag/flexible tube reactor, rain creating stack system (“horizon”) and fermentation (heterotrophic cultivation).

The major markets targeted by French macroalgae companies are primarily for food ingredients, pharmaceuticals, cosmetics and textile manufacturing, and secondarily for food products (animal and human sectors), produced from wild-harvested or open-pond grown product.

Microalgae in France are primarily used for food (e.g. *Spirulina*) and to a lesser extent for cosmetic and nutraceutical products and animal feed ingredients. Microalgae producers typically target more diverse markets than those dealing with macroalgae. The most promising markets for microalgae products are within the energy and chemical sectors in combination with bioremediation of industrial flue gases and wastewaters.

PLANNED GROWTH

Although production has stagnated in recent years and the oyster sector has been significantly affected by mortalities, the French government is placing a high priority on further developing the sector

and there has been significant activity over recent years on developing growth strategies in all sectors and integrated marine spatial planning.

The national growth objectives for 2014-2020 in France are to increase by 2020:

- Production volume from 218,000 t to 265,000 t in 2020, a 22 percent increase over the 2007-2012 baseline average values.
- Production value from 682 million euro to 1,025 million euro in 2020, a 50 percent increase.
- Mollusc production volume by 12 percent,
- Freshwater fish production volume by 28 percent, and
- Marine fish production volume by 233 percent.

L'ÉTANG DE THAU — ONE OF THE MAIN MEDITERRANEAN LAGOONS

The region of Languedoc-Roussillon currently has eight sites for shellfish production, four in lagoons (Thau, Leucate, Prevoist, Gruissan saline) and four directly on the coast (longlines). Representing 90 percent of the Occitanie production, shellfish farming is an important economic activity for the Thau lagoon, with both oyster and mussel production.

The Thau lagoon is located on the French Mediterranean coast, 40 km from Montpellier. It is one of the main Mediterranean lagoons in terms of its surface area (7,500 ha) and depth (4.5 m on average). The lagoon has a strong marine influence and is connected to the sea by the canal of Sète (90 percent of exchange) and by the Grau de Pisse Saumes (10 percent of exchange). The residence time of water masses



A specialty pink oyster from l’Huître Spéciale Tarbouriech in Thau Lagoon.



Oyster racks in Prévost Pond, near Ifremer Palavas. Photo: Yves Harache.



Farmed rainbow trout. Photo: Yves Harache.



Raceways for trout production.

mainly depends on wind and tidal effects and is estimated to be around three months.

Lagoon function is highly dependent on contributions from the watershed, with nutrient inputs from the catchment basin mainly supplied from freshwater runoff and from human activities such as agriculture (mainly vineyards), industries and domestic wastewater. About 80,000 people live around the lagoon, half of whom live in Sète, whose population doubles during the summer.

During the last decades, with water framework directives and Water Agency action, decreasing nutrient input from the watershed has long dominated management objectives for the Thau lagoon ecosystem. Today, the Thau lagoon is in the ecological restoration phase and about to reach the goal of being in good condition, as requested by Europe.

For a long time, this trophic context resulted in high growth rates of shellfish. Indeed, one of the main economic activities of the Thau lagoon is shellfish farming. Other activities are artisanal fisheries (seabass, seabream, mullet, eel), tourism (sailing, thermal cures), fish farming (three sites for pre-growing of juveniles and on-growing are currently listed), land-based microalgae production (two sites) and engineering consulting firms.

Concerning the shellfish sector, the Thau lagoon provides 10 percent of the total French Pacific oyster *Crassostrea gigas* production (Robert *et al.* 2013). There are 500 companies currently listed, producing around 7,371 t of oysters and 2,959 t of mussels per year (census from Departmental direction of the territories and the Sea,

DDTM 2017), providing direct employment for about 1,700 people (Denis Regler, Comité Régional Conchylicole de Méditerranée, personal communication). The Leucate lagoon is the second major production area of the region.

Because of urban pressure, the catchment basin needs a permanent control of the water quality to ensure to quality of the products. The French institute for exploration of the sea (Ifremer) is one of the operators of monitoring networks for evaluation of environmental quality of water bodies (REPHY for microalgae in water, ROCCH for chemical contaminants, Water framework directive for ecological status of water bodies). Until 2018, the state’s devolved services (seaproduct and veterinary services) have charged the Hérault Department to follow the sanitary quality of shellfish produced in classified areas. They operate the shellfish sampling and the Laboratoire Départemental Vétérinaire (LDV34) in Montpellier and Laboratoire Analyses (LDA13) in Marseille conducts microbiological analysis of shellfish and phycotoxins, respectively.

The main actors of the regional aquaculture sector are the Occitanie Regional and Department governments, the French water agency, state agencies, private producers and companies, the research units Marine Biodiversity, Exploitation and Conservation (MARBEC) and Interactions Hôtes-Pathogènes-Environnements (IHPE). The Mixed Syndicate of Thau Bassin (SMBT) is in charge of coordination among different regional management plans:

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Aerial view of the Palavas research station of Ifremer. Photo: Drone STUDIO, Ifremer.



Microalgae research production tank at the Palavas research station of Ifremer. Photo: Olivier Dugornay, Ifremer.



Red algae culture. Photo: Raymond Kaas, Ifremer.



Red algae culture in the Mediterranean Sea.

The Territory Coherence Scheme (SCOT) fixes the local policy framework for the next 20 years (2010-2030), with objectives of economic development and preservation of the environment and sociocultural traditions, including shellfish farming, fishing in the lagoon, and recreational activities. The Water Planning and Management Scheme (SAGE) is the local water management plan for implementation of the EU Water Framework Directive. These management plans define the issue of water quality in terms of specific objectives and translates them into operational decisions.

AQUACULTURE RESEARCH SECTOR

In addition to a dozen universities spread all around France, four main organisations lead national aquaculture research in fish and shellfish, all of which are present in the Occitanie Region.

INRA. The National Institute of Agricultural Research is the leading agricultural research institute in Europe and the second largest in agricultural sciences in the world. It contributes 90 percent of the national research effort on farmed fish, most on freshwater species.

Ifremer. The French Research Institute for the Exploitation of the Sea contributes with its work and expertise to the knowledge of the oceans and its resources, to surveillance of marine and littoral environments and to the sustainable development of maritime activities. In aquaculture, it essentially works on marine species and brings together 90 percent of the research effort on shellfish.

CIRAD. The Center for International Cooperation in Agricultural Research for Development is an organization for agricultural research

and international cooperation for sustainable development of tropical and Mediterranean regions.

IRD. The Research Institute for Development brings an original approach of research, expertise, training and knowledge sharing for the benefit of territories and countries that make science and innovation one of the first levers of their development.

For algae, French research institutions address issues mainly relating to development of better, more efficient production systems, optimisation of growth conditions and development of biorefineries for biofuels and other new energy products such as algae-based hydrogen. Other research-based activities include environmental impact modeling and LCA analysis, abiotic and biotic interactions, bioprospecting and (to a much lesser extent) genetic engineering. In Occitanie, research on algae is growing fast and now is structured under the Algado Network (presented in figure).

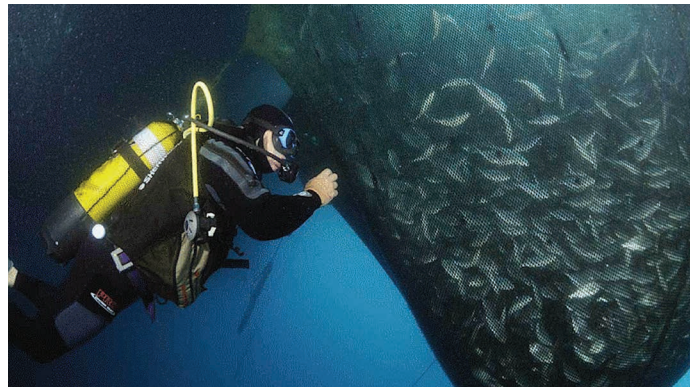
Innovative companies are established in the region in the microalgae production sector, for the sectors of chemistry, food, health, and cosmetics. The Trimatec Competitiveness Cluster organizes each year the event Algo'Réso, the rendezvous for microalgae in the Mediterranean, the appointment of researchers and industrialists of the sector.

Notes

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Biofouling on suspended mussel lines increases biodiversity.



European seabass cage. Photo: Béatrice Chatain, Ifremer.



European seabass cage adjacent to the Frioul Islands near Marseille. Photo: Béatrice Chatain, Ifremer.



European seabass broodstock at the Palavas research station of Ifremer. Photo: Béatrice Chatain, Ifremer.

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