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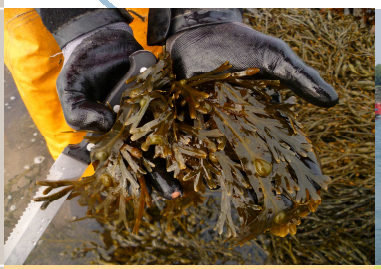
INTER-REGIONAL NETWORK TO PROMOTE SUSTAINABLE DEVELOPMENT IN THE MARINE ALGAL INDUSTRY

Seaweed industry in France

NETALGAE project • Interreg IVb
WP1 and 2 report



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NETALGAE ● Work Packages 1 and 2

March 2012

netalgae

INTER-REGIONAL NETWORK TO PROMOTE SUSTAINABLE DEVELOPMENT IN THE MARINE ALGAL INDUSTRY

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1. NETALGAE PROJECT

In 2009, more than 15 million tons of macroalgae (brown, red and green seaweed) were produced from global capture and aquaculture (based on the algal live weight equivalent; FAO, 2012). Worldwide, macroalgae production increases by 5.7 % every year. In 2008, 93.8 % of the global total production of aquatic plants came from aquaculture. Countries in East and Southeast Asia dominate seaweed culture production (99.8 % by quantity and 99.5 % by value in 2008; FAO, 2010). In contrast, the European macroalgae industry is based on the harvesting of natural resources of macroalgae, and the production has decreased in the last 10 years. The further expansion of the industry depends on stable access to raw material, the development of valuable products and the transfer of expertise between developed and less-developed regions.

Therefore, the project NETALGAE is designed to create a European network of relevant stakeholders within the marine macroalgae sector. The network is expected to make progress toward developing industrial, commercial and scientific links and to foster a culture of trade and cooperation among the members. The network will include primary producers, processors, technology suppliers, process consultants, research institutes, development agencies, local governments, relevant community groups and other stakeholders. A compilation of information from Norway, the United Kingdom, Ireland, France, Spain and Portugal will result in a wide-ranging policy study of the existing practices within the macroalgae industry. An analysis of these results will enable NETALGAE partners to establish best-practice recommendations and suggest policies for the successful sustainable commercial use of marine macroalgal resources.

The project NETALGAE extends from 2010 to the end of 2012 and is funded by the Atlantic Area Transnational Programme, the European Regional Development Fund and national co-funding. The partners in the project are from Ireland (1 and 2), United Kingdom (3), France (4, 5 and 6), Spain (7, 8 and 9), Portugal (10) and Norway (11).

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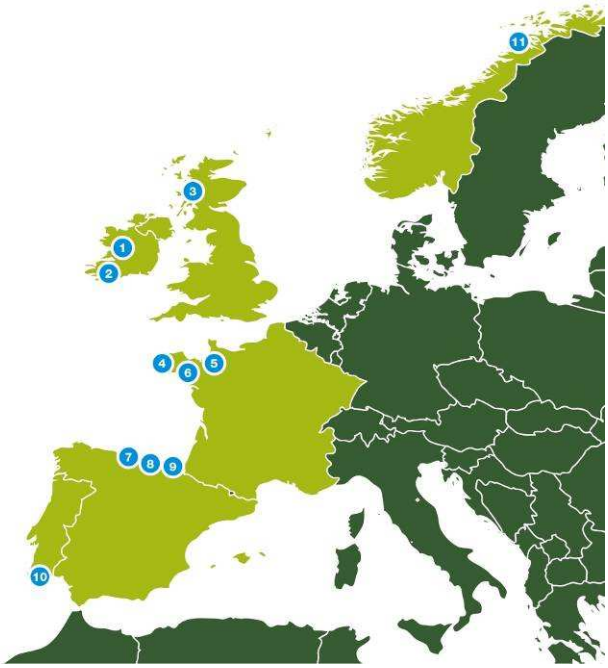

The project is organised into five work packages (WPs):

- ✓ WP1: General baseline study of all of the national algal industries across the project area.
- ✓ WP2: Assessment of the algal regulation, administration and management systems.
- ✓ WP3: Development of best-practice guidelines for the management and sustainability of algal resources.
- ✓ WP4: Development of a European algal industry database.
- ✓ WP5: Creation of a European algal industry portal and business tools.

The first step of the project NETALGAE is to make a general baseline study of the macroalgae industry in France and to assess the algal regulation, administration and management systems. Within WP1 and WP2, the main objectives are as follows:

- ✓ Describe algae-harvesting activities and uses based on a historical perspective.
- ✓ Describe the algae species that are harvested in France, including a description of the harvesting techniques and main uses.
- ✓ Provide an overall description of the current monitoring system of the resources. This component includes a description of the authority in charge, the monitoring system and the main stakeholders involved in the decision-making process regarding algae.
- ✓ Describe the legal framework concerning algae harvesting and its practical implementation, including the legal basis for access to the algal resources and a description of the regulatory system and legal status of harvesters and gatherers.
- ✓ Identify other organisations that work with the seaweed industry, describe the main issues highlighted by scientists regarding the impact of harvesting on the marine ecosystem and describe other projects to promote the French seaweed industry.

This report presents the WP1 and WP2 results on the French macroalgae industry. The following information has been gathered from existing literature on the subject and conversations with stakeholders.

ACKNOWLEDGMENT

We would like to thank the seaweed gatherers, scientists and other actors for their availability and their interest in this study.

2. HISTORICAL CONTEXT OF ALGAE HARVESTING AND GATHERING IN FRANCE

In France, seaweed gathering dates back to Neolithic times. In these times, the use of seaweed was common along the Atlantic coast. Residues of algae were found in fireplaces during archaeological excavations. Seaweed was used for heating, in mattresses, for cattle and for human food in times of starvation. The primary uses have evolved, but some traditional uses remain and are still observed in some coastal areas, for example the use of seaweed as food for cattle and for soil improvement. This is the case in Brittany, where seaweed gathering has held a prominent place in the history of coastal people (Arzel, 1987).

2.1. Soil improvement

In France, coastal populations exploited algae for soil improvement. Wreck seaweed gathered after storms was widespread in fields. Men collected algae from the sea even in winter with large rakes, and women carried algae with litter at the edge of shores. Then, the algae were spread on dunes to be dried for year-round preservation (Arzel, 1987). This activity experienced a sharp decline with the advent of chemical fertilisers and the increase of the size of agricultural land. Soil improvement using fresh seaweed is currently less practised, except in small private fields, such as on Batz Island in northern Brittany.

2.2. Extraction of soda

In the 17th century, the glass industry, which used wood, turned to algal resources. This change was constrained by the loss of wood resources after extensive deforestation. Algae replaced wood; specifically, sodium bicarbonate extracted from seaweed ashes was used to lower the temperature of fire to allow the fusion of silica (Arzel, 1987). This process was the first industrial use of algae that boosted gathering activity. Access to this resource was open and free, and it drew many people onto the coasts, causing serious disputes. Thus, in 1681, Colbert, in his order of the navy *(Book X of "ordonnance de la marine")*, regulated the harvest of seaweed between agriculture and the soda industry's uses (Arzel, 1987). In 1692, King Louis XIV granted to Saint-Gobain's manufacturer the privilege of gathering wreck seaweed along the Hague coast for 20 years (in Normandy). The harvesting season was fixed between the 15th of March and the 15th of September, and the ashes obtained were transported to Paris. This example is the first time that the use of seaweed ash for glass manufacturing was mentioned.

Since the 18th century, the cutting and burning of seaweed have increased; the increases drove seaweed gatherers to develop a manual cutting method (using fitted sickles) of seaweed at sea. Kelps were brought aboard flat-bottomed boats called "pigouillers" (Arzel, 1987). This new activity incited reactions of fishers, who feared that this activity would impact fish reproduction. In Brittany, the season of gathering kelp (wreck seaweed) was fixed from the 15th of January to the 15th of April, and the collection was set for 30 days in 97 villages of Normandy *(Royal Declaration of 30 May 1731).*

In 1739, the burning of kelp was allowed on the entire coastline. Previously based in Normandy, the industry extended to Brittany, where algal resources were more abundant. In the 1770s, factories producing soda established themselves along Brittany coasts and particularly in northern Finistère. This activity created a seasonal employment for gatherers, workers of soda units and transporters of soda extracts to Rouen (Normandy). Thus, the first ovens were dug along the coast. Once the algae were pre-dried over dunes, seaweed was burned in the ovens. With a length of 10 to 15 m and lined with stones, the ovens facilitated the collection of cinder blocks or loaves of soda after the seaweed was burned.

The use of kelp ash to make glass ended around 1789 with the discovery of a new method to obtain sodium carbonate from sea salt. Since then, seaweed activity has disappeared in Normandy.

2.3. Extraction of iodine

In 1812, Bernard Courtois discovered iodine and its therapeutic usefulness. This molecule dissolved in alcohol was the only disinfectant known at this time and was called tincture of iodine. In 1829, François Tissier, a chemical engineer, developed an industrial process to produce iodine in his factory at Guilhem Poul Conq (Le Conquet, Finistère). Tincture of iodine was used extensively during wars. Approximately 30 industry plants were created in northern Brittany and employed approximately 2,000 people and their families. This processing industry dominated the local economy because the industry employed skilled workers, sailors and ship-owners and gave work to shipbuilders and carters. In 1952, this industry ended because new processes for iodine production using nitrates were discovered (Arzel, 1987).

2.4. Extraction of hydrocolloids

The discovery of alginate in 1880 boosted the economy of seaweed harvesting. Alginate is a natural hydrocolloid extracted from brown seaweed (especially *Laminaria digitata*). Alginate provides gelling, thickening and film-forming properties for many food and non-food applications (Arzel, 1987). Alginate is produced from seaweed harvested by boat. Mechanical harvesting started in 1974, with the use of the "scoubidou"[1] trawl. Since then, the landings of *Laminaria digitata* have increased. Until 1978, seaweed was dried on dunes, which was then replaced by an industrial process. Another exploited species is *Ascophyllum nodosum,* which is used in the hydrocolloid industry or for alginate production. *Ascophyllum nodosum* is used mainly to produce fertilisers and animal food additives.

Other seaweed products are now used in the food-processing industry or chemistry, such as carrageenans and agar, which are used for gelling.

[1] "scoubidou": curved iron hook that is suspended from a hydraulic arm mounted on the boat

3. SEAWEED HARVESTED IN FRANCE

In the past, less than ten algal species were gathered along French coasts (Table 1). Traditional species are still gathered today, in addition to new species. Currently, more than twenty species are gathered in France. These species are part of three groups: brown algae, red algae and green algae.

Table 1: Algal species harvested in France (2010)

	Past	Present
BROWN ALGAE	*Ascophyllum nodosum*	*Ascophyllum nodosum*
	Fucus serratus	*Fucus serratus*
	Fucus vesiculosus	*Fucus vesiculosus*
		Fucus spiralis
	Laminaria digitata	*Laminaria digitata*
	Laminaria hyperborea	*Laminaria hyperborea*
		Laminaria saccharina
		Himanthalia elongata
		Pelvetia canaliculata
RED ALGAE		*Asparagopsis armata*
	Chondrus crispus	*Chondrus crispus*
		Corallina officinalis
		Delesseria sanguinea
		Dilsea carnosa
		Gracilaria sp.
		Gelidium sesquipedale
		Laurencia pinnatifida
	Mastocarpus stellatus	*Mastocarpus stellatus*
	Palmaria palmata	*Palmaria palmata*
		Porphyra umbilicalis
GREEN ALGAE		*Ulva species*
		Enteromorpha species

These three groups are divided among different depths along seashore. Some brown algae are emersed from the sea almost twice a day, including *Pelvetia canaliculata, Fucus spiralis, Fucus vesiculosus and Fucus serratus. Laminaria* are found deeper into the water and are out of sea only during the low-water period of spring tides. Red algae and green algae are almost always in the water.

3.1. Brown seaweed

The brown seaweed group can be divided into two groups: “Laminariales” and “Fucales”.

3.1.1.Laminariales

Laminaria digitata

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L. digitata is a dark brown alga with a smooth, flexible stipe and can reach 3 to 4 m in length. *L. digitata* can grow to be 4 to 5 years old. Fixed with a root-like holdfast, this kelp grows on rocky bottoms in the upper subtidal zone in sheltered to moderately exposed areas from 1 to 25 m in depth (Cabioc’h *et al*., 2006).

Laminaria hyperborea

L. hyperborea can reach 3 m in length. The kelp often reaches ages over 10 years (Cabioc’h *et al*., 2006). The reproductive period is between November and April (Loiseaux de Goër, 2003). *L. hyperborea* grows on rocky bottoms in subtidal zones in exposed areas from 2 to 20 m in depth (Cabioc’h *et al*., 2006).

Saccharina latissima (ex-Laminaria saccharina)

S. latissima, called “sugar Laminaria” or “Kombu royal”, has a full wrinkly lamina with wavy edges. Fixed by a short stipe, the kelp can reach 3 m in length. The species name comes from the crystallised sugars that appear as *S. latissima* is dried. In Atlantic and Channel areas, the growth of this kelp is continuous, and its life duration is still unknown. *S. latissima* is present in low littoral rocky pools to a depth of 20 m in subtidal areas (Cabioc’h *et al*., 2006).

Undaria pinnatifida

U. pinnatifida is an introduced species from Japan also known as “wakame”. *U. pinnatifida* is the first species cultivated at sea between the surface and 1 m depth. *U. pinnatifida* has a thin, full leaf-like lamina. The stipe is flattened and runs to the middle of the lamina. The thallus is yellowish brown and is usually 60 to 120 cm but can reach 2 m in length (Cabioc’h *et al*., 2006).

3.1.2. Fucales

Ascophyllum nodosum

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Ascophyllum nodosum is long-living species with a slow demographic development, fronds might be 10 years old and the basis constituted by the holdfasts is considered to a perennial structure older than a century. *A. nodosum* has a long, flexible forked frond with several blades from 1 to 1.5 m in length. Floats are present all along of the blades, which help *A. nodosum* rise at high tide to receive more light. *A. nodosum* is distributed in intertidal sheltered areas (Cabioc’h *et al.*, 2006).

Fucus serratus

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Fucus serratus, the toothed wrack, is a robust, shrubby olive-brown seaweed that grows in high densities low on the seashore. The fronds do not bear air bladders. The whole plant typically grows to approximately 60 cm in length. The fronds have a serrated edge and grow from a short stalk. *F. serratus* is found on hard substrata on the lower shore in sheltered areas of coastline (Jackson, 2008).

Fucus vesiculosus

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The bladder wrack *Fucus vesiculosus* is a large brown algae, common on the mid-shore often found with *A. nodosum*, below *Fucus spiralis* and in a zone further up the shore from *Fucus serratus*. This species is found on intertidal rocky shores in a wide range of exposures and can be found in high densities living for approximetely 4-5 years. Under sheltered conditions, the fronds have been known to grow up to 2 m in Maine, America (White, 2008a).

Fucus spiralis

Fucus spiralis is an intertidal seaweed that is found on the upper shore below the zone of *Pelvetia canaliculata* and above *Fucus vesiculosus* and *Ascophyllum nodosum*. This species attaches to rocky substrata on sheltered to moderately exposed shores. The alga grows up to 40 cm in length, does not bear air bladders and lives for up to 4 years. The species can tolerate a high level of desiccation. The fronds have a characteristic ridge along the edge of the receptacles (White, 2008b).

Himanthalia elongata

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This species is found attached to hard substrata on moderately exposed shores. This alga is found at the the low limit of the intertidal zone, where it forms a band below *Fucus serratus* and above laminarians (White, 2008c).

Pelvetia canaliculata

Pelvetia canaliculata, also called channelled wrack, is a common brown seaweed found high on the shore. This species is very tolerant of desiccation and can survive up to 8 days out of the water. *P. canaliculata* lives for approximately 4 years and grows up to 15 cm in length. This alga grows attached to hard substrata on the upper shore. This species is found in a band above *Fucus spiralis* and can tolerate ultra-sheltered to moderately exposed conditions (White, 2008d).

3.2. Red seaweed

Chondrus crispus and Mastocarpus stellatus.

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In France, *Chondrus crispus* grow from the littoral fringe to 20 m below mean low water, depending on the wave motion, sea transparency and rocky structure available. *M. stellatus* grows just upper than *C. crispus* and may be mixed with *C. crispus*, but only in the intertidal zone and it is not present subtidally. Usually, these species are most abundant from mean low water to the mid-sublittoral zone. They grow best on stable rock ledges and large boulders and prefer horizontal shelves. The strongest growth of these species is in the late spring and summer; the least growth occurs during the winter (Mc Hugh, 2003).

Palmaria palmata

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Gervais FOLLIARD

Palmaria palmata is a foliose red algae with a tough flat frond usually between 20 and 50 cm, but sometimes up to 1 m, in length. *P. palmata* is found in the littoral and sublittoral zones to a depth of 20 m in both sheltered and moderately exposed areas (Hill, 2008).

Porphyra umbilicalis

Porphyra umbilicalis, also called purple laver, is a small red alga (up to 20 cm across) with an irregularly shaped, broad frond that is membranous but tough. This alga is highly adaptable to conditions on different parts of the rocky shore and is able to withstand prolonged periods of exposure to the air and a greater degree of wave action than most other red algae. This species occurs singly or in dense colonies throughout the intertidal but is found most frequently at upper levels (Pizzolla, 2008a).

3.3. Green seaweed

Ulva species

Ulva species are small green algae (up to 30 cm across) with a broad, crumpled frond that is tough, translucent and membranous. The alga attaches to rock *via* a small holdfast. The sea lettuce *Ulva lactuca* is found at all levels of the intertidal zone. In very sheltered conditions, plants that have been detached from the substrate can continue to grow, forming extensive floating communities. The plant tolerates brackish conditions and can be found on suitable substrata in estuaries (Pizzolla, 2008b).

Codium

Codium is a small green alga (up to 30 cm in length). The frond is solid and spongy with a felt-like touch and has many colourless hairs that can be seen when the plant is immersed in water. The holdfast is disc-like and formed from many fine threads. This species attaches to exposed rocks and occurs in rock pools on the lower shore (Pizzolla, 2007).

4. SEAWEED PRODUCTION IN FRANCE

Most French seaweed production comes from Brittany (western France). Almost 60 000 tons of seaweed is produced annually, and only 50 tons come from seaweed aquaculture; the rest comes from wild seaweed located offshore or onshore and from wrecked seaweed.

4.1. Harvesting techniques

In France, wild seaweed harvesting is conducted either by boat or foot gathering. Each species require a specific harvesting technique.

4.1.1. Seaweed harvesting by boat

Harvesting on board boats includes three kinds of harvesting techniques that depend on the target species.

Laminaria digitata is harvested by boat with a gear called "scoubidou" (Figure 1), invented at the end of the 1960s. This gear looks like a hook that turns around itself and uproots *L. digitata*.

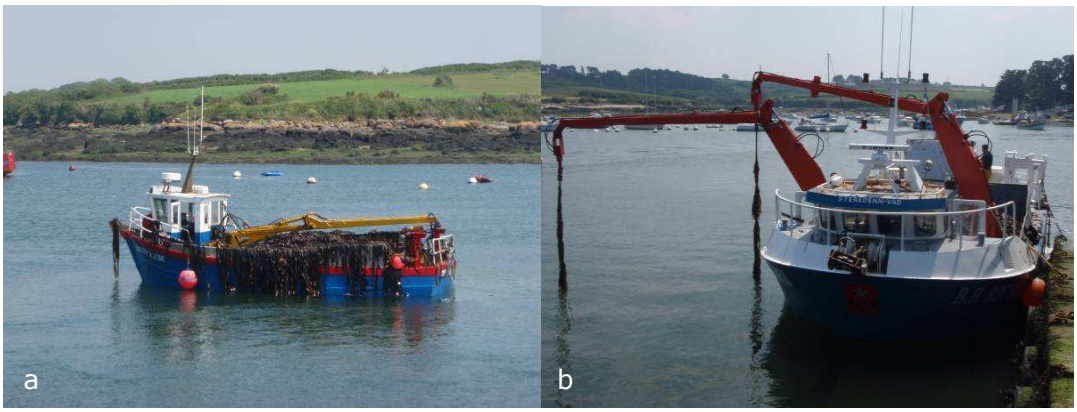

Figure 1: a) a day's harvest of *Laminaria digitata*. b) a boat with two scoubidous (© Julie Maguire, Indigo Rock Marine Research Station)

Laminaria hyperborea is also harvested by boat. Fishers drag a large rake-like device through seaweed beds, where the rake uproots larger plants. The rake is fixed to a crane on the boat, and after approximately two minutes of dragging, the crane lifts the rake and its catch (approximately 2 tons) into the boat. Laminaria species are delivered directly to companies from boats in Lanildut harbour and in a few other small harbours. Then, the seaweed is sent by trucks to two factories located in the vicinity of Brest (Landerneau for Dupont-Danisco and Lannilis for Cargill).

The extraction of *Lithothamnium calcareum* also requires the use of a boat called a "sablier", which sucks *L. calcareum* from the sea bottom with a suction dredge. In Brittany, several concessions are given to two companies. However, this exploitation seems to negatively impact the ecosystem and the resources. It must be noticed that this species is part of the OSPAR[2] list of threatened and/or declining species and habitats (*OSPAR agreement 2008-6*). The species also provides a nursery refuge for many marine species, and for this reason, exploitation should be forbidden before the end of 2013.

Gelidium sesquipedale can be harvested by boat. Five fishers, in Basque County, harvest drift seaweed from September to January using a net near the foreshore.

[2] The OSPAR Convention is the current legal instrument guiding international cooperation for the protection of the marine environment of the North-East Atlantic.

4.1.2. Manual harvesting techniques used by foot gatherers

The gathering techniques used by foot gatherers depend on the target species. *Chondrus crispus* and *Mastocarpus stellatus* are the only algae, along with *Laminaria sp.,* that can be uprooted. These species are harvested manually; the gatherers fill bags and pull them on their back up to the rocks. Another method is to fill a small boat that can be pulled to the shore with the rising tide.

Ascophyllum nodosum (Figure 2) and *Fucus sp*. must be cut above the holdfast using a sickle. Some gatherers in Côtes d'Armor use a fork to uproot algae. The algae are loaded on a trailer pulled by tractors (Bouvet, 2010). In 2003, experiments were conducted for mechanically harvesting using a flat-bottom vessel, the same boat and gears as are used in Norway, but only one boat is currently in activity. All of the other fishers practice manual gathering.

Figure 2: Gathering of *Ascophyllum nodosum* on shore, Brittany, France

Gelidium sesquipedale can be gathered after storms when the algae are uprooted. Two main methods of gathering are available: gatherers use a net from the shore dragged by a bulldozer in a few centimetres of water, or in areas with difficult access, gatherers collect wreck seaweed using a fork (Perez, 1997).

Laminaria hyperborea is also gathered by foot in north of Finistère, where stipes are gathered using forks and loaded in trailers. This activity completes the alginate supply (Boncoeur, 2005).

4.2. Seaweed landings

The following data are published by the "Chambre Syndicale des Algues et des Végétaux Marins", a union that groups local processing industries in Brittany. Each of the industry members of this union reports the annual purchase quantities and average prices paid for each species to this organisation (Table 2).

Laminaria digitata is one of the most harvested species in France. Between 40 000 and 60 000 tons are harvested annually for a turnover of 1.7 to 2.7 million €. The total landings for *L. digitata* are dictated by the processing industry in relation with their capacity to process fresh algae (with treatment plant capacities ranging from 40 000 to 47 000 tons). The total amount of seaweed required by the industry is divided among the boats, and a contract is established between the industry and individual fishers.

For *L. hyperborea,* the total amount of catches is fixed at a maximum of 26 000 tons (in reality, only 11 000 tons are currently harvested). There are fixed fishing areas, and in each area, the total amount of catches is fixed by year, and each area is closed to fisheries for 5 years.

The next most-harvested species are the fucales resources (*Fucus* spp. and *Ascophyllum nodosum*), with almost 6 000 tons gathered in 2008. The global landing of *A. nodosum* is 6 000 tons in all of

Brittany. In Côtes d'Armor (North Brittany), the *A. nodosum* total landings are fixed at 3 000 tons, and there is a principle of resting areas closed for 2 years after a harvest. In Finistère, this rule does not exist because the *A. nodosum* fields are not concentrated in the same territory. However, it seems that the seaweed gatherers imposed the rotation system for the fields on themselves.

Concerning seaweed gathering by hand, a survey conducted in 2008, with companies that buy seaweed, was used to generate the following estimations. Fucales are harvested from the foreshore by professional gatherers (approximately 20 persons). This work is an annual job with a turnover of approximately 300 000 €. Edible seaweed is harvested by some professional gatherers but is more commonly harvested by occasional gatherers. Until now, this activity was relatively unsupervised, but much work has been conducted since June 2007 to perpetuate this activity, manage the resource and find a status for these gatherers. Approximately 300 occasional gatherers harvest seaweed for a turnover of 300 000 €.

In 2011, from September to January, five fishers have harvested about 1 116 tons of drift *Gelidium sesquipedale* (in live weight equivalent) but more than 70 % of the landings come from gathering of wrecked seaweed on shore (Dejeans, 2011).

Table 2: Seaweed production in Brittany

Algae group	Species	2008 (in tons)*	2009 (in tons)*	2010 (in tons)*	2011 (in tons)*
BROWN ALGAE	*Ascophyllum nodosum*	2 890	1 444	1 030	
	Fucus serratus	581	268	2 681	
	Fucus vesiculosus	NA	NA	NA	
	Fucus spiralis	NA	NA	NA	
	Laminaria digitata	47 252	35000	45 000	47 000
	Laminaria hyperborea	NA	11 226	NA	13 000
	Laminaria saccharina	10	11	13	
	Himanthalia elongata	285	86	60	
	Pelvetia canaliculata	NA	NA	NA	
	Undaria pinnatifida	NA	NA	NA	
RED ALGAE	*Asparagopsis armata*	NA	NA	NA	
	*Chondrus crispus Mastocarpus stellatus***	386	74	182	
	Corallina officinalis	NA	NA	NA	
	Delesseria sanguinea	1,4	1	0.5	
	Dilsea carnosa	none	0.3	0.4	
	Gelidium sesquipedale	NA	NA	NA	
	Gracilaria sp.	NA	NA	NA	
	Laurencia pinnatifida	NA	NA	NA	
	Palmaria palmata	179	308	181	
	Porphyra umbilicalis	8	10	53	
GREEN ALGAE	*Ulva specie*	72	101	77	
	Enteromorpha specie	3	3		
	Others	17	33	15	

* Landings are in live equivalent weight; ** The 2 species are collected together; NA=Not Available

Source : Chambre Syndicale des Algues et Végétaux Marins (comm pers.) and Ifremer (comm.pers)

4.3. Main geographical areas where macroalgae are exploited

Currently, macroalgae are mainly harvested in Brittany on shore and at sea (Figure 3). Mechanical harvesting by boat of *Laminaria sp.* is conducted in the Iroise Sea (west of Brittany). There are also unexploited kelp beds in other parts of Brittany and Normandy.

Seaweed foot gathering takes place from Lampaul-Plouarzel in North Finistère to Paimpol in Côtes d'Armor. Few gatherers can be found along Brittany's coast.

The Basque country is another French area where seaweed is harvested. The species harvested in this area is *Gelidium sesquipedale*.

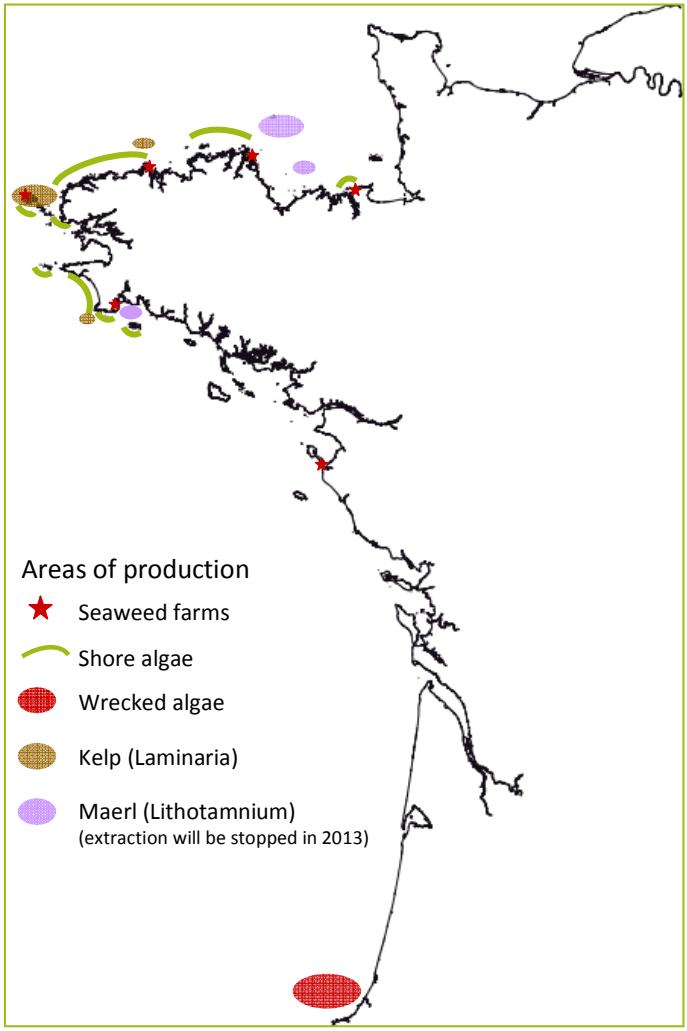

Figure 3 : Areas of seaweed production in France

4.4. Aquaculture of algae

Seaweed aquaculture exists in Brittany, but only two species are grown: *Undaria pinnatifida* (wakame) and *Saccharina latissima* (kombu). Six seaweed farms can be found in Brittany (4 in North and 2 in South), and one farm is located in Vendée.

Furthermore, two hatcheries in North Brittany are producing plantlets.

5. SEAWEED SECTOR

The use of seaweed depends on the species. Some seaweed can be eaten as a vegetable, while others are used as fertilisers or processed for hydrocolloid production. Because most of the harvested seaweed comes from Brittany, many companies have been established within this area.

5.1. Uses of seaweed

Seaweed can be used for many applications. The final products depend on the processes used. The food-processing industry, chemistry and microbiology are the main markets for seaweed in France, with 75 % of the harvested seaweed (domestic production and imports) used for this sector (Figure 4). Approximately 25 % of the seaweed is used in the agricultural, health and well-being sector (CEVA, 2009).

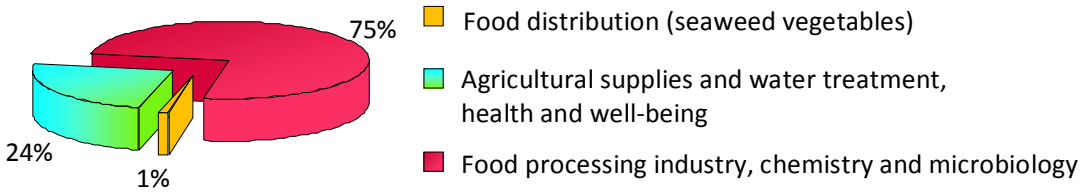

Figure 4: Main uses of seaweed in France (French production and imports). From CEVA (2009)

5.1.1. Seaweed used for food-processing industries, chemistry and microbiology

Alginates

In France, *Laminaria digitata* is exploited for alginate production. Since 1995, *Laminaria hyperborea* is also harvested to extend alginate production. Alginates are used in numerous domains, such as thickening, gelling, absorbing, varnishing, agglutinating and waterproofing (Table 3). The production of alginates serves mainly as stabilisers of colouring agents and for waterproofing in the global textile industry. Alginates are also used in food-processing industries, in particular for the manufacture of reconstituted products. Alginates are also used in the processing of paper, the manufacturing of baguettes of weld, biotechnologies and other numerous products (Pérez, 1997).

Agar-agar

Agar-agar is obtained from *Gelidium* spp., *Gracilaria* spp. and *Porphyra* spp. Agar-agar is a gelling agent that is stable at relatively high temperatures (Table 3). This product is thermoreversible over 85°C and re-gels when cooled. These properties make agar-agar useful as a substrate for culturing media for microbiological work. Agar-agar is also used in the food-processing industry, acting as a thickener and stabiliser for tarts, ice creams and prepared foods. Furthermore, agar does not contain calories; it is a slimming dietary product very renowned in Asia because it cuts hunger. Agar is also used to make candy because it has no taste, and sugar increases the strength of the gel (Mc Hugh, 2003). Agar is an alternative to animal gelatine.

Carrageenans

Chondrus crispus and *Mastocarpus stellatus* are used to produce specialty carrageenans (Table 3). Carrageenans are especially used in the manufacturing of dairy products for thickening, gelling and stabilising. One of the applications in the dairy industry is the stabilisation of flavoured milk; without carrageenans, the chocolate would not stay suspended in cold milk. Carrageenans from imported red algae (*Kappaphycus* and *Eucheuma* from Southeast Asia) are also used in pet food. Meat reconstitution, especially ham manufacturing, requires the addition of carrageenans because carrageenans enable the cooking water to remain in the meat and make it softer. Carrageenans can also be used in low-fat products (Mc Hugh, 2003).

Table 3: Industrial uses of seaweed

ALGAE SPECIES	PROCESS	PRODUCTS	PROPERTIES	USES
Laminaria digitata	Hydrocolloid extraction	Alginate	Absorbs water quickly Gelling agent Thickening Increases viscosity	Additive in dehydrated products Manufacture of paper and textiles Thickening drinks, ice cream and cosmetics. Pharmaceutical preparations Preparation of dental impressions …
Laminaria hyperborea				
Gelidium sesquipedale		Agar-agar	Gelling agent Stability at relatively high temperatures	Substrate to culture medium for microbiological work Jellies, puddings, and custards thickener Intestinal regulator Impression material in dentistry. …
Chondrus crispus		Carrageenan	Thickening and stabilizing agents Increase viscosity	Vegetarian and vegan alternative to gelatin Desserts, ice cream, cream thickener Processed meats …
Mastocarpus stellatus				

5.1.2. Seaweed used for agricultural supplies and water treatment

The primary applications of algae in agriculture are as fertilisers and cattle food. Several processes facilitate the production of powders or liquid extracts. Fertilisers are spread on grounds in powder form, as microballs or pulverised in liquid form. The main algae species used are *A. nodosum, Fucus* spp. and maërl, which favour the growth of plants and resistance against diseases. Indeed, seaweed produces defensive substances in response to aggression by gastropods (Pérez, 1997). The fucales can also be used as nutritional supplements in animal food for their digestive qualities; they are processed in flours mixed with food (Arzel, 1987). The maërl are also used by water-treatment plants for correction of the pH.

5.1.3. Seaweed used for health and well-being products

The seaweed used in the cosmetic and pharmaceutical sector is often the same as those used in food. However, research and development continually expose new applications for new species.

In the cosmetic sector, seaweed is used as a plant extract, crushed (for example, for peels) or as a colouring agents. The active principles are especially sought and differ according to the species as follows:

- ✓ *Himanthalia*: C vitamins.
- ✓ *Fucus vesiculosus*: tensor effect and beta-glucans.
- ✓ *Fucus spiralis*: draining properties
- ✓ *Chondrus crispus*: polysaccharides, C vitamins and soothing effect.
- ✓ *Ascophyllum nodosum*: polyphenols, antioxidants.
- ✓ *Pelvetia*: amino acids, E vitamin
- ✓ *Corallina*: magnesium, calcium, soothing effect.
- ✓ *Laminaria digitata*: draining properties.
- ✓ *Palmaria palmata*: soothing effect, C vitamins *(pers. comm. Océalys, 2010)*

Generally, cosmetic companies process products for large brands. Because marketing holds an important place in the cosmetics industry, seaweed is often used to create an image of natural products with benefits from the sea.

There are many outlets for seaweed in the pharmaceutical sector, and researchers continue to discover new virtues of seaweed. Seaweed is recognised for its benefits against high blood pressure and cardiovascular diseases. Several pharmaceuticals utilise active principles from seaweed.

5.1.4. Edible seaweed

Some seaweed species can be eaten like vegetables. In that case, the food processing uses the entire alga. Various algal conservation processes can be used: algae can be dried or served fresh, frozen, canned or salted. These products are sold as raw materials or are mixed in ready meals. Currently, 20 macroalgae species are considered edible as raw material or an intermediate product for the food-processing industry (CEVA, 2011) (Table 4). These species are often cultivated or gathered on shore by foot gatherers.

Table 4: Edible macroalgae species (CEVA, 2011)

Scientific Name	Name in French
BROWN ALGAE	
- *Ascophyllum nodosum*	- Corde à noeuds
– *Fucus vesiculosus*	- Goémon à ampoules
– *Himanthalia elongata*	- Haricot ou spaghetti de mer
– *Undaria pinnatifida*	- Wakamé ou fougère de mer
– *Laminaria digitata*	- Laminaire
– *Laminaria saccharina*	- Kombu breton
– *Laminaria japonica*	- Kombu royal
RED ALGAE	
– *Palmaria palmata*	- Dulse
– *Porphyra* spp. (7 species)	- Nori
– *Chondrus crispus*	- Petit goémon ou pioka
– *Gracilaria verrucosa*	- Gracile ou agar
– *Lithothamnium calcareum*	- Maërl
GREEN ALGAE	
- *Ulva lactuca*	- Laitue de mer
– *Enteromorpha*	- Aonori ou cheveux de mer

There are different techniques to process seaweed depending on whether the algae are fresh or dried and on their final use (e.g. eaten directly or added to dishes). Most seaweed is dried before being processed. Seaweed can be added to many dishes such as tartars, mustard, beer and traditional Japanese foods. However, seaweed is not yet a component in mainstream French food habits.

5.1.5. Organic seaweed

Since the implementation of the European regulation CE n°710 / 2009, the production of organic seaweed has been followed according to European regulations on organic farming. Currently, approximately 10 operators of the seaweed industry in Brittany already have an organic certification, either for foodstuffs that contain seaweed as an ingredient, for inputs (i.e., amendments of ground, fertiliser) or for cosmetics (under private specifications). There are many organic foodstuffs containing seaweed such as, salty fresh seaweed, salt with seaweed, tartars of seaweed, bread and cheese with seaweed, and dehydrated seaweed, among others. A company in Brittany sells organic agar-agar. Similar to companies that incorporate seaweed into cosmetics, these food companies are certified according to private specifications (charters Cosmébio, Nature and Progress, BDIH).

The European regulation of organic farming and its interpretation by the National Institute of Origin and Quality (INAO) stipulates that seaweed can be organic only if the algae are harvested or cultivated in water bodies with a "good ecological state" or "very good ecological state" according to the water-framework directive and if they correspond to good sanitary and chemical criteria (Reydet and Bohm, 2011).

The technical data sheet at this link provides more information on organic seaweed for seaweed gatherers and farmers who are willing to certify their production as organic (European regulation CE 834/2007): http://www.interbiobretagne.asso.fr/upload/File/Publications/LePointSur/LePointSur-Fiche-Conversion-Algues-Marines-Bio-IBB-2011.pdf

5.2. Algae industries

Nearly 90 companies process or sell products made using seaweed in France. Among these companies, more than 40 companies within health and well-being sectors use seaweed. Almost one-quarter of these companies work within the agricultural supply and water-treatment sectors. One quarter of the companies provide seaweed as vegetables for human consumption. A total of 7 companies use algae to produce hydrocolloids (Figure 5).

The enterprises using edible seaweed for human consumption are small or medium in size. These new types of industry have been developed in the last few years because of the demand from European consumers. All edible algae are harvested manually.

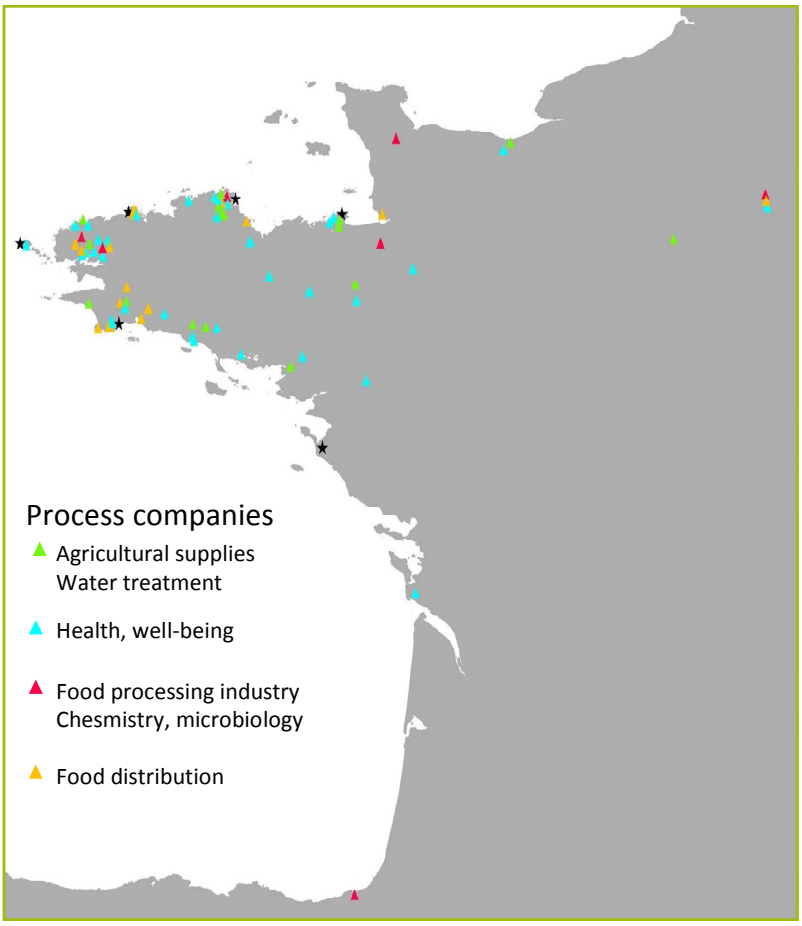

Figure 5: Process companies that use seaweed in France

The proximity to the harvesting areas is the main factor defining the factory location for the processing industry. In France, the production of alginate and cattle feed requires vast quantities of raw seaweed. Seaweed cannot successfully be transported to other regions by road because of the large number of trucks required to move the vast volume of material. Such transportation costs would make the seaweed product uncompetitive compared to the dried products imported from abroad. For this reason, the main industries working with raw seaweed are located near the main areas producing the seaweed. Nevertheless, processing industries that have access to raw material locally also import dried seaweed when the local resource is out of season. The French seaweed industry imports consist of fresh or dried seaweed from Chile (4 478 tons) and the Philippines (3 660 tons) (Table 5) (FranceAgriMer, 2011).

Table 5: Imports of seaweed products in 2010 (FranceAgriMer, 2011)

	IMPORTS		
Products	**Weight (tons)**	**Value (1000€)**	**Price (€/kg)**
Fresh and dried seaweed	15 936	21 716	1,36
Fresh agar-agar	373	5 685	15,25
Fresh alginate	1 624	9 961	6,13
TOTAL	**17 933**	**37 362**	

6. MAIN REGULATORY FRAME CONCERNING SEAWEED MANAGEMENT

In France, the beach, foreshore and sea are included in the maritime public domain and are under the responsibility of the state. The use of this maritime space is at the discretion of public authorities. In France, seaweed harvesting is managed by administration with fisher's organisations. Seaweed gathering onshore or at sea is regulated at the national and regional scale.

6.1. Main administrations and stakeholders linked to seaweed harvesting

In France, seaweed gathering by boat and by foot is managed by administration and fishers' organisations, which play an important role in ensuring the transfer of information between the administration and seaweed gatherers.

6.1.1. Administrations

Maritime prefect

The post admiral is the representative of the state at sea. The admiral's competence extends from the bottom of the watermark to the end of the waters within French jurisdiction (the exclusive economic zone, 200 nautical miles). The admiral leads and coordinates all of the actions concerning this zone (Article 2, Decree n°2004-112).

The post admiral has the power of general administrative police and the responsibility of the state action at sea and is also in charge of the protection of the marine environment and the coordination of the struggle against illegal activities. The admiral is responsible for the regulation of different uses, such as fisheries, dredged sediments in ports, granulate extraction and offshore windmills.

Interregional Direction of the Sea ("Direction Interrégionale de la mer, DIRM")

At the interregional level, the Interregional Direction of the Sea represents the decentralised department of the ministry in charge of the environment and is meant to design and lead the state policies related to the sea and coasts within its geographical area. This group's main missions are as follows:

- ✓ driving state policy of the sea in terms of the sustainable development of maritime activities, management of marine resources and regulation of maritime activities,
- ✓ participating in the management and protection of the coastal and marine environment, the integrated coastal zone and the maritime public domain ("Domaine Public Maritime, DPM") and in planning sea activities,
- ✓ control of ship safety,
- ✓ protection of human life at sea,
- ✓ training of the marine population,
- ✓ fighting against marine pollutions on the coast and at sea,
- ✓ maintaining the maritime signs,
- ✓ providing economic support of the fishing industry and maritime cultures,
- ✓ regulating maritime uses and activities.

The District Directions of Territories and Sea ("Directions Départementales des Territoires et de la Mer, DDTM") are under the authority of the district prefects and implement the policies of the ministries of environment and agriculture. Their missions are mainly the following:

- ✓ professional supervision of people employed at sea,
- ✓ management of the maritime public domain,
- ✓ monitoring of maritime activities,
- ✓ coastal water monitoring and marine environment conservation (additional tasks).

6.1.2. Fishers organisations

The National Committee of Marine Fisheries and Mariculture ("Comité National des Pêches Maritimes et des Elévages Marins, CNPMEM") is the national organisation representing fishers and marine fish-farming interests. This committee is an inter-professional organisation of maritime fisheries and aquaculture to which all of the members concerned in the production, first purchasing and aquaculture and fisheries product-processing activities must join. This organisation is the main interlocutor of the French administration. At regional and local levels, regional and local committees are elected and represent fisheries industry interests.

These **Regional Committees of Marine fisheries and Mariculture (CRPMEM**) have the following missions (redefined by the 2010 reform of the rural Code, Law n° 2010-874 of July 27th 2010):

- ✓ ensuring the representation and promotion at a regional level of the fishers' general interests,
- ✓ participating in the elaboration and implementation of the regulations in terms of resource management for the species not subjected to a Total Allowable Catch (TAC),
- ✓ participating in the elaboration of the regulations supervising the device uses and cohabitation between maritime activities,
- ✓ participating in the realisation of economic and social actions in favour of their members,
- ✓ participating in the regional public policies in favour of the environment,
- ✓ providing scientific and technical support for their members.

Seaweed commission of CRPMEM

In Brittany, the regional committee of fisheries has a specific working commission on seaweed harvesting. The main mission of this commission is to effectively contribute to seaweed management. The seaweed commission organises two meetings per year where all of the problems faced by seaweed boats are discussed. The commission is composed of 22 elected fishers representing fishers' unions and the seaweed-processing industry. Following the law, representatives of District Direction of Territories and Sea follow the works of the commission as competent authorities. Some other participants are invited to the commission, such as IFREMER (a scientific institute) and the two main processing industries (the main buyers). All of the decisions concerning seaweed management must be approved by the Interregional Direction of the Sea and validated by the prefect of the region.

Foot gatherers working group

Since 2003, a new working group for "shore algae" was established within the seaweed commission. This group is in charge of the "shore algae" and seaweed gatherers on foot and addresses the following issues: quota system, harvesting seasons, and rest areas, among others. This group includes the same members as the above group except that harvesters are replaced by foot gatherers.

Regulation and management systems can be summarised with the following scheme:

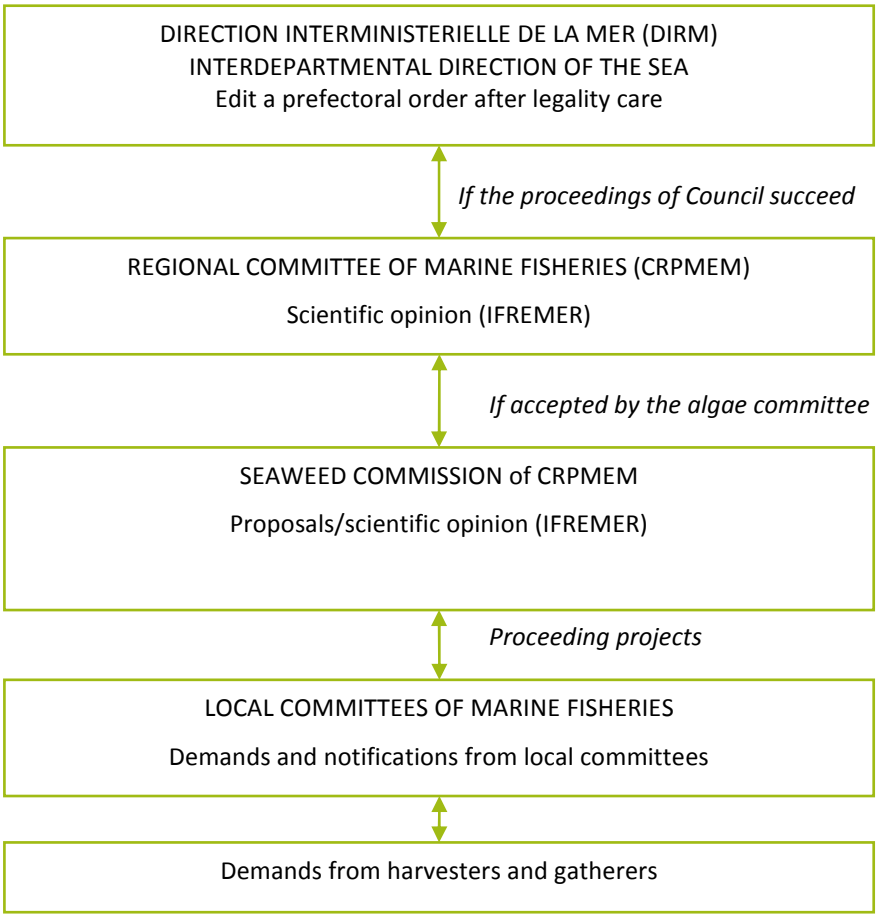

Figure 6: Scheme of the administrative and management functioning in Brittany

6.2. Regulations

Seaweed activity is regulated at the national level by 2 laws, and the detailed rules are enforced at the local level.

6.2.1.National scale

Listed bellow are the main regulations for managing seaweed gathering at the national scale.

The Decree of 9 January 1852 regulating fisheries activities has been replaced by **Ordinance n°2010-462 of 6th May 2010,** which creates book IX of the rural code concerning fishing and marine culture.

Decree n°90-719 of 9th August 1990 determines the conditions of fishing, harvesting and gathering seaweed in France. Three kinds of seaweed are classified:

- ✓ Shore seaweed: all seaweed reachable by foot at low tide requires an authorisation to be harvested.
- ✓ Seaweed at sea: *Laminaria* harvested by boats corresponding to the technical characteristics require a kelp-harvesting licence.
- ✓ Wrecked seaweed: all wrecked seaweed can be gathered by all participants.

Order n°2009-0329 (23/04/09) concerns the sustainable exploitation of seaweed at sea.

6.2.2. Regional scale: Brittany

National regulations must be applied everywhere, but considering that most seaweed produced comes from Brittany, specific regulations are made at the regional scale and even at the local scale. This section is about the management and regulation of seaweed gathering in Brittany.

The texts below define the annual campaign organisation concerning several items: environmental protection policies by areas, licence fees, number of licences, periods of harvest, restricted areas, quotas and specific conditions during the campaign.

Deliberation "Seaweed-NF-2005-A" (03/12/2010) addresses the allocation conditions of *Laminaria digitata* fishing licences on Brittany's coasts.

Deliberation "Seaweed-NF-2010-B" (03/12/2010) is used to set the number of licences and the organisation of the fishing season for *Laminaria digitata* on Brittany's coasts.

Deliberation "Seaweed-NF-2010-B2" (02/04/2010) is used to set the organisation of the fishing season for *Laminaria hyperborea* on Brittany's coasts.

Order n°2009-319 of 17th April 2009 concerns the sustainable exploitation of seaweed on the shore of Brittany and defines the conditions to obtain an authorisation to gather seaweed on shore (by hand).

COTE D'ARMOR

Order n°2011-2257 (2010-1051) regulates foot gathering in Côtes d'Armor in 2011.

FINISTERE

Order n° 2011-2334 (2010-1146) regulates foot gathering in Finistère for 2011.

ILLE-ET-VILAINE

Deliberation "Seaweed-SM-2008-A" (28/03/2008) addresses the allocation conditions of seaweed-gathering licences for seaweed species other than Laminaria on Ille-et-Vilaine coasts.

Deliberation "Seaweed-SM-2011-B" (03/12/2010) is used to set the number of licences and the organisation of the fishing season for seaweed species other than *Laminari*a on Ille-et-Vilaine coasts.

Deliberation "Seaweed-SM-2011-C" (03/12/2010) is used to set fees for the allocation of licences for seaweed species other than Laminaria on Ille-et-Vilaine coasts.

The specific regulations for seaweed gathering by foot in Brittany are summarised in the following table.

Table 6: Specific regulation for seaweed gathering by foot in Brittany (Philippe, 2011)

Macroalgal species harvested	Uprooting authorised	Minimal size	Harvesting period authorised for foot gathering	Quotas
GREEN ALGAE				
Ulva spp.	*NO*[i]	*No restriction*	*Year-round*	*NO*
BROWN ALGAE				
Ascophyllum nodosum	*NO*[i]	***Côte d'Armor, Morbihan, Ille-et-Vilaine**: Cutting should be conducted at a minimum height of 30 cm in 2011*[ii] ***Finistère**: Cutting should be conducted at a minimum height of 20 cm in 2011*[iii] ***Other parts of France**: Cutting should be conducted at a minimum height of 20 cm in 2011*	*Year-round: No restriction (but rest areas vary according to the year in Finistère and Côte d'Armor)*	***Côte d'Armor**: maximum of 3000 tonnes of fresh algae in the whole district and 3000 tonnes around Bréhat Island in 2011*[iv]
Fucus serratus	*NO*[i]	*No restriction*	*Year-round*	*NO*
Fucus vesiculosus	*NO*[i]	*No restriction*	*Year-round*	*NO*
Himanthalia elongata	*NO*[i]	***Côte d'Armor**: algae should be cut above the sucker in 2011*[iv] ***Finistère**: Harvesting is allowed only when the algae measure more than 80 cm in 2011*[iii]	*Year-round*	*NO*
Laminaria digitata	*YES*[i]	*No restriction*	*Year-round: regulation concerns only boat harvesting*	*NO*
Saccharina latissima	*YES*[i]	*No restriction*	*Year-round*	*NO*
RED ALGAE				
Chondrus crispus	*YES*[i]	*No restriction*	*May to October*	*NO*
Mastocarpus stellatus	*YES*[i]	*No restriction*	*May to October*	*NO*
Palmaria palmata	*NO*[i]	***Finistère**: algae less than 25 cm may not be harvested in 2011*[iii]	*March to December*	*NO*
Porphyra spp.	*NO*[i]	***Côte d'Armor**: algae should be cut above the sucker in 2011*[iv] ***Finistère**: algae less than 25 cm may not be harvested in 2011*[iii]	*March to August*	*NO*

[I] Order n° 90-719, [ii] Order n° 2009-319, [iii] Order n° 2011-2334, [iv] Order n° 2011-2257

6.2.3.Regional scale: Pyrenees Atlantiques

Order of 19/09/05 regulates the harvesting seasons and closed areas in this region; the harvesting of *Laminaria sp.* from the sea is strictly forbidden on the entire public maritime domain.

G. sesquipale collection is authorised only at night to avoid conflict between tourism and harvesting activities. The authorisation of harvesting is given by the local district authorities (prefecture) and concerned town halls.

6.3. Status of seaweed gatherers

It is important to address the social dimension of this industry in France.

The harvesters working on board seaweed boats are considered as fishers and have a legal status, which gives them access to health insurance, retirement pensions and other social benefits. In France, because this activity is seasonal, seaweed harvesters fish scallops or fish during the rest of the year. French fishers have their own social security fund, the "Etablissement National des Invalides de la Marine" (ENIM- maritime social Welfare), to which they contribute monthly.

For seaweed gatherers on foot, the situation is different. There are two categories of harvesters: professional gatherers and temporary workers who are employed casually by the processing industries. In Brittany, seaweed harvesting is conducted only by persons who hold an administrative authorisation given by the District Direction of Territories and Sea of the district where the gatherer will practice their job. To obtain this authorisation, harvesters should fulfil one of the following conditions (Philippe, 2011):

- be affiliated to a social security system, either that of fishers or of the agriculture system and produce a certificate detailing to whom the harvester is selling the production,
- be employed by a seaweed industry, such as trade and processing, and be affiliated to the general system of social security,
- be employed by a seaweed industry, such as trade and processing, and be affiliated to another social security system (TESA[3] or agricultural social security).

Harvesting authorisations are renewable annually and should be requested between the 1st and 30th of November. The authorisation can be requested either by individuals (fishers's social security [ENIM] or agriculture social security [MSA]) or by the industries in a case of the general system social security or TESA (the exact number of people working under TESA status is not well known). To claim the authorisation, the harvesters should address a letter to the District Direction of Territories and Sea declaring the species, the quantities to be harvested, the location and the period of harvesting (Philippe, 2011).

For those declared as TESA (a system existing in agriculture), the owner of the industry must make a demand indicating the provisional number of TESA employees who will be employed and the season (trimester). Then, he/she should inform the administration of the real number of TESA employees employed by the company and of their personal address (Philippe, 2011).

Since 2002, independent foot gatherers have had to opt for a social security system. Seaweed gathering on foot constitutes an additional activity for the coastal population looking to increase their income. These foot gatherers generally opt for the agricultural social security "Mutuelle Sociale Agricole" (MSA), which is less expensive than the fishers' social security system.

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[3] Titre Emploi Simplifié Agricole (TESA): system used in agriculture to employ people for short periods only three times a year

For the temporary workers who are employed casually by the processing industries, local processing industries must request an authorisation to employ a specific number of gatherers as temporary workers every year. The workers' social security is paid by the industry to the farmers' social security system. During the year, each company provides the fisheries administration with the name of all of the people employed by the company. The same person can be employed by different industries because their salary is based on the quantity harvested. Permanent employees of the processing industries can also be seaweed gatherers, provided they obtain prior authorisation from the fisheries authorities (Philippe, 2011).

In 2011, 35 licences for harvesting on board boats were delivered. The licences are mainly located in Lanildut in northern Finistère for Laminaria gathering. In 2010, 56 authorisations for independent gatherers on shore were delivered by the District Direction of Territories and Sea. In 2009, approximately 500 on-shore gathering authorisations were given to three main processors.

6.4. Main regulations of seaweed aquaculture

In France, applicants for seaweed aquaculture must follow **Decree n°83-228** of 22 March 1983 amended by **Decree n°2009-1349** of 29 October 2009 and **Order of 6 July 2010**. The applicants must fulfil all the conditions, including a plan of installation the species cultivated. The applicants must be more than 18 years old and be European. The applicants must warrant their professional abilities, *i.e.,* marine-culture bachelor's degree or equivalent, to the District Direction of Territories and Sea. Then, a public enquiry is required before the application is granted.

7. MAIN SCIENTIFIC AND TECHNICAL STAKEHOLDERS

Beyond professional and administrative stakeholders, other stakeholders are involved in the seaweed industry either in research, development or industries.

7.1. Research institutions

The French Research Institute for the Exploitation of the Sea **(Ifremer**) monitors the kelp harvest in the Iroise Sea, advises administrations involved in the management of seaweed exploitation (e.g., the prefecture and fishers' organisations) and has a laboratory designed for seaweed biology and genetics, addressing the impacts of harvesting on algal populations. Ifremer is involved in aquaculture research and provides support for the different stakeholders to promote sustainable development and product quality. The overall aim is to acquire knowledge and develop technologies that will enable the development of an aquaculture sector capable of producing and maintaining a protein supply to complement the supply produced by other fisheries sectors.

More information is available at http://www.ifremer.fr/aquaculture.

"Station biologique de Roscoff" is a research and education centre in marine biology and oceanography, jointly operated by the French National Centre for Scientific Research (CNRS) and the Pierre and Marie Curie University (UPMC). The fields of research of this institute are "marine vegetables and bio-molecules", "adaptation and biodiversity of marine ecosystems", "sea and health" and "phosphorylation of proteins and human pathologies".

More information is available at http://www.sb-roscoff.fr/

"Station biologique de Concarneau" was the first research centre in marine biology and oceanography created in 1859. Since 1996, the station has been administrated by the " Muséum National d'Histoire Naturelle " (MNHN, French Natural History Museum) in collaboration with the "Collège de France". The main research areas are ecogenetics, endocrinology, inventories of algae, ichthyology, ecology of rocky shores, estuarine ecology, molecular evolution (EPHE) and the development of biological and fishery products from aquaculture.

More information is available at http://concarneau.mnhn.fr/

European Institute for Marine Studies (IUEM) is a multidisciplinary organisation that aims to increase the understanding of the marine environment and to study and observe the interactions between the ocean, the atmosphere and the coast. Within IUEM, UBO AMURE is a joint research unit designed to provide economic and legal analyses of public policies concerning maritime activities and the use of marine and coastal zones. The IUEM also includes the laboratory of environmental sciences (LEMAR), which is designed to bring together biologists, chemists and physicists to understand and model marine systems and to define ecosystem characteristics and interactions.

More information is available at http://www-iuem.univ-brest.fr/

University of Caen includes a laboratory of the physiology and environmental physiology of marine molluscs with a macroalgae department. The laboratory members contribute to several programmes concerning algae.

More information is available at http://www.unicaen.fr

The **University of South Brittany** (Vannes et lorient) has a laboratory that conducts research on the biological properties of seaweed extracts and molecules such as antimicrobial or antiviral and develop also some algal biotechnology.

More information is available at http://www-lbcm.univ-ubs.fr/

AGROCAMPUS OUEST is a higher education and public research institute under the authority of the French Ministry of Food, Agriculture and Fisheries. Within AGROCAMPUS OUEST, the Fisheries and Aquatic Sciences Centre is a pluridisciplinary organisation for teaching, research and transfer of knowledge. This team works on the exploitation of aquatic living resources, fisheries ecology, ecosystem modelling, data dissemination and fisheries economy.

More information is available at http://halieutique.agrocampus-ouest.fr/

7.2. Technical centres

The Center for the Study and Promotion of Algae (**CEVA)** is a technical centre that was created in 1982. The centre organises research applied to algae (macro and micro), seagrasses and marine biotechnologies. In particular, the centre ensures the transfer of scientific knowledge from the academic world to the industry sector. CEVA is a private research organisation and a technical centre belonging to the ACTIA network, labelled as an agro-industrial technical institute (ITAI) by the French Ministry of Agriculture and Fisheries.

More information is available at http://www.ceva.fr/eng

Synergie Mer Et Littoral (**SMEL)** is a public establishment active in Normandy with a mission of promoting the expansion of economic activities that rely on living marine resources. SMEL is active in all of the stages of the production of marine products from natural resources, exploitation and their development. SMEL monitors kelp beds in the western part of Normandy and participates in a project that promotes seaweed farming on oysters' concessions.

More information is available at www.smel.fr/

7.3. Unions of the processing industry and seaweed farmers

The "Chambre Syndicale des Algues et des Végétaux Marins" is a professional organisation regrouping 19 seaweed-processing industries that originated in Brittany. These industries are working in different fields including cosmetics, nutraceutics, pharmaceutics, agriculture, alginates and edible seaweed. The role of this organisation is to ensure the professional interests of its members, represent the profession within formal structures associated with their activity and facilitate relations between its members and administration. Representatives of the union are members of the seaweed committee of the regional fisheries committee.

More information is available at www.chambre-syndicale-algues.org/

"Syndicat des récoltants d'algues" is a professional organisation for self-employed gatherers on shore, which is a member of the "onshore algae" workgroup (cf 6.1.2).

"Syndicat Carrageen" is also a professional organisation for the *C. crispus* casual gatherers employed by processing industries who have a TESA. This organisation represents casual gatherers at the "onshore algae" workgroup.

7.4. Other organisations

The **"Parc naturel marin d'Iroise"** (Natural Park of Iroise Sea) is the first marine park in France. One of the largest kelp forests in Europe can be found within its territory. For this reason, the park organisation significantly cares about seaweed classified as natural heritage. One of the park's main goals is to preserve these resources critical for the associated fauna and flora but also for local populations harvesting kelp. In collaboration with the CEVA, beds of *Fucus* have been delimited inside the Iroise Marine Park to study their evolution. These data will feed the Rebent database (an Ifremer network concerning data on coastal habitats and associated flora and fauna).

More information is available at http://www.parc-marin-iroise.gouv.fr.

The enterprise development agency of Brittany region (**Bretagne Développement Innovation**) is an agency that aims to improve the attractiveness and competitiveness of Brittany with common initiatives and sharing with economic-development actors. Within this agency, a business cluster called "Seafood products, nutrition and health" brings together some of the companies working in these sectors.

More information is available at http://www.bdi.fr/.

8. SCIENTIFIC PROJECTS

All of these stakeholders take part in the seaweed industry through technical and research projects.

8.1. Biomass evaluation and monitoring

REBENT is a national network coordinated by IFREMER in partnership with scientific and technical centres. The objectives of this network are to collect and organise data concerning marine habitats and benthic biological communities in the coastal zone to provide relevant and coherent data to allow scientists, administrators and the public to better determine the existing conditions and detect spatiotemporal evolutions. Within this project, mapping of seaweed beds of the main species has been conducted in several areas of Brittany. More information is available at http://www.rebent.org/

ECOKELP is an international programme (in Portugal, France and Chile) designed to study the biodiversity dynamics of kelp forests in the northern and southern hemispheres. The aims of this programme are the following: (1) to understand biodiversity dynamics and predict changes, (2) to assess the ecological, economic and social impacts of changes in biodiversity and (3) to develop practices for the sustainable use and conservation of species and their habitats. The Station Biologique de Roscoff coordinates this project funded by the National Research Agency.

8.2. Evaluation of the impact of harvesting gear on the ecosystem

Seaweed mechanical harvesting and gathering by foot are controversial issues among scientists, fishers, processing industries and environmental NGOs. Therefore, impact evaluations on species have been made by IFREMER in collaboration with the Station Biologique de Roscoff and the Marine Natural Park of Iroise Sea. The impacts of "scoubidou" on *Laminaria digitata* and the impacts of Norwegian kelp trawls on *Laminaria hyperborea* are studied by these institutes.

Scoubidous can turn up to 10 % of the rocks in an area where *L. digitata* is exploited. This impact can lead to a recolonisation with a more important proportion of *Saccorhiza polyschides*, a species that grows faster than other species. Nevertheless, because this species is annual, this impact is quickly dispersed (the biodiversity and the density are similar at the end of one year and the biomass after two years) (Arzel, 1998).

Few studies concerning the gathering of *L. hyperborea* have been published. It seems that kelp beds recover close to their initial state 3 to 4 years after being exploited (Rinde *et al.,* 1992). Furthermore, macrofauna and -flora are more diversified in non-exploited areas (Mac Laughlin *et al.,* 2006). Species of community interest are not directly affected by the trawls used to gather *L. hyperborea* (Mac Laughlin *et al.,* 2006).

As for the impact of seaweed gathering on shore by hand, some gatherers that have gathered seaweed for 20 years have never observed any impact on the regrowth of algae species. There is no impact on the ecosystem because the gatherers cut seaweed with knives and sickles above the limited size that enables the seaweed to re-grow. Currently, the CNRS monitors three species of *Porphyra*, *Palmaria* and *Fucus* in Roscoff and studies the impact of seaweed gathering on the ecosystem and the species (using a before/after controlled-impact method).

8.3. Development of seaweed farming

For the past few years, a growing concern about seaweed farming has been raised. A few projects have emerged in Brittany and Normandy.

The **BREIZH'ALG** project is designed to develop sustainable seaweed aquaculture in Brittany. This project is led by the Région Bretagne and Bretagne Développement Innovation. Within this project, ten studies will be conducted on 5 axes targeting all of the stages of construction of this new industry: governance of the project and the future seaweed industry, the production of seaweed, processing, research and development on quality aspects and development of markets and communication.

In the context of the difficulties met by oyster farmers because of abnormally high death rates of young oysters during the summer, the **NORMAND'ALG** project, supported by the region Basse-Normandie, University of Caen and SMEL, is designed with the objective of developing seaweed farming within the framework of the diversification of the oyster industry in Basse-Normandie. This project relies on collaboration of the laboratory BIOMEA of the University of Caen, SMEL and three oyster farmers. The culturing systems of culture of seaweed will be adapted to the present structures in oyster parks. Then, techniques will be transferred to professionals who will be supported in their approach of diversification in seaweed farming.

8.4. Seaweed biological resources and biotechnology

IDEALG is a 10-year project funded by the French National Research Agency. The partnership is composed of research institutes (UEB, Station Biologique de Roscoff [CNRS-UPMC], Ifremer, Universities of Bretagne Occidentale, Bretagne Sud, Rennes I and Nantes, ENSC Rennes, AGROCAMPUS OUEST and INRA), technical centres (CEVA) and 5 industries (C-Weed aquaculture, Aléor, France Haliotis, Bezhin Rosko and Danisco). The aim of IDEALG is to use genomics research to generate new tools to improve algal bioresources and the domestication of seaweed species and to boost seaweed biotechnologies. IDEALG will also anticipate the economical, social and environmental impacts of such developments in the context of other maritime activities, conservation, biosafety issues and competition for space and water in a larger frame.

The Energetic Algae project (**ENALGAE**) is a 4 year Strategic Initiative of the INTERREG IVB North West Europe Programme, engaging 19 partners and 14 observers across 7 EU Member States. The aim of EnAlgae is to reduce CO_2 emissions and dependency on unsustainable energy sources in North West Europe. This will be achieved through the development of sustainable technologies for algal biomass production, bioenergy and greenhouse gas (GHG) mitigation, from pilot phase to application and marketable products, processes and services. The CEVA takes part in this project and is testing the production of macroalgae at sea.

More information is available at http://www.enalgae.eu/

Research carried out within the **AZOSTIMER** project will focus on the effects of algae in stimulating the metabolism of plants and their capacity to absorb fertiliser input. AZOSTIMER will offer decision-making tools for a structured approach to fertiliser use. AZOSTIMER partners are AFI (Roullier Group), FORCE-A, ANAXIMANDRE, EVA Laboratory, UMR INRA/University of Caen and the Ecole Nationale Supérieure de Chimie (Chemistry selective higher education institute) in Rennes and its "Organic and Supramolecular Chemistry" and "Chemistry and Process Engineering" laboratories.

The **SUDALAB** project will analyse and treat contaminants contained in edible seaweed to ensure product conformity and to guarantee the economic development of the industry. The aim of SUDALAB project is to standardise control methods and validate related reference materials to provide quality assurance measurement protocols for edible seaweed. Treatment processes will be perfected to reduce contaminant content while preserving nutritional properties. SUDALAB partners are seaweed producers (Aléor, Algues Services, Algues & Mer, Biocéan) and the CEVA (Centre for the Study and Economic Development of Algae Production).

The aim of **AQUACTIFS** project is to select several species of macroalgae for their potential as sources of active molecules. The genetic profiling of these algae will allow selecting the most promising varieties. These algae will be farmed and no longer just harvested at sea to ensure regularity of supply and to preserve natural resources. This project is carried out in collaboration with a laboratory (Station Biologique de Roscoff) which has developed sound skills and expertise in the field of genetics and three companies (Agrimer, C-Weed Aquaculture, Biocean).

The **WINSEAFUEL** project is funded by the French National Research Agency. The aim of WinSeaFuel project is to produce biomethane (and of bioproducts) from macroalgae cultivated on the open sea. WinSeaFuel partners are Biocar, Aléor, CEVA, LBE (INRA -UR050), Naskeo Environnement and Montpellier SupAgro.

The aim of **ULVOLIGO** project is to find a way to extract “ulvans” contained in the algal cell which are of particular interest in the areas of health, immunity and cosmetics. Using this ulvanolytic process, oligosaccharides can be produced and then incorporated into cosmetic formulae and tested with potentially promising results on skin and in particular on elastin and the collagen-hyaluronic acid synthesis. ULVOLIGO is funded by the French National Research Agency. ULVOLIGO partners are the research centres CEVA, Roscoff Biological Research Station and the company Bioeurope (Solabia Group).

The aim of **POLYMODE** project is to isolate the enzymes - i.e. the tools used by red algae to produce their superior quality carrageenan - and optimize them using state-of-the-art molecular genetic methods. These enzymes should then be suitable to be used in a biotechnological process to convert the inferior quality carrageenan from other widespread red algal species into a superior quality product. The PolyModE project partners are universities, research centres, multinational and small biotech companies from Germany, France, Denmark, the Netherlands, Sweden and Bulgaria.

Numerous other projects are carried out such as Marinexus, Phlortann’ing, Crazy Polysaccharides, Innovaralgues, Gastralg, etc.

8.5. Development of the seaweed industry

The aim of the **ALGMARBIO** project is to set up a sustainable industry for organic seaweed (wild or farmed resources). InterBio Bretagne, which is an organisation of the organic industry, leads this project. Algmarbio’s partners are the union of seaweed foot gatherers, CSVAM, CNRS, IFREMER, UBO, AGROCAMPUS OUEST, Parc Naturel Marin d’Iroise, CRPMEM de Bretagne and seaweed industry companies. The project is designed to draft a good-practices guide for seaweed producers and regulate the creation of the organic seaweed industry.

More information is available at http://www.interbiobretagne.asso.fr/documents-utiles-2-774.html#algues

The **BIOTECMAR** project supports the development of a chain for the production of valuable ingredients using underexploited marine products. The project is co-funded with the support of the European Union (ERDF) in the framework of the transnational programme for the Atlantic area. Biotecmar members are analysing the current blocking points for by-product use and studying the possible exploitation by value chains (by species and by product). The project also establishes an Atlantic network with connections among scientists, marine resources providers, manufacturers and users.

More information is available at http://www.biotecmar.eu/spip.php?article41&lang=en

ALGASUD is a collective action which aims at structuring and developing seaweed industry (microalgae and macroalgae) in Languedoc-Roussillon. Algasud is led by the pole of competitiveness Trimatec, in partnership with the network of technological transfer "Transferts LR" and the chair of green chemistry "ChemSud". This project is funded by Europe, DIRECCTE and the Region Languedoc-Roussillon.

More information is available at http://www.algasud.fr/

9. SUMMARY

LA FILIÈRE FRANCAISE DES MACROALGUES

Poster réalisé par AGROCAMPUSOUEST (2011)

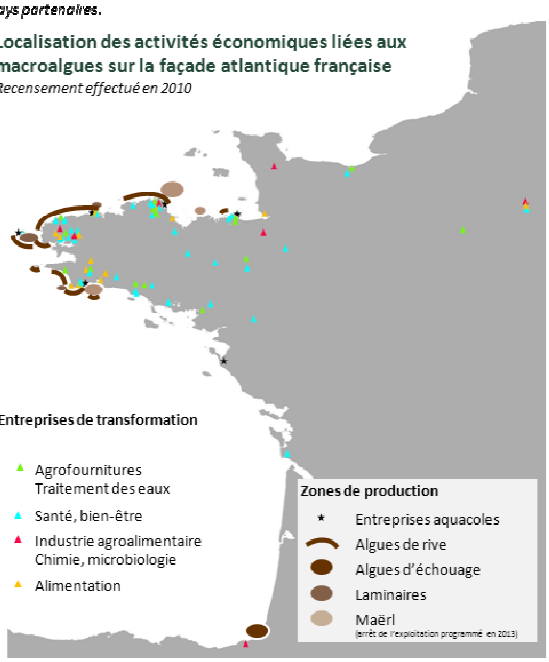
Réseau Inter-régional de promotion du développement durable dans l'Industrie de l'algue marine

Au sein d'un marché mondial en pleine expansion, la filière européenne des macroalgues reste relativement stable depuis les années 60. Dans ce contexte, le projet Netalgae vise à mettre en réseau les multiples acteurs de cette filière pour en favoriser le développement industriel, commercial et scientifique.

Ce poster synthétise les résultats français de la première étape du projet, à savoir la réalisation de l'état des lieux des filières des macroalgues dans les différents pays partenaires.

Localisation des activités économiques liées aux macroalgues sur la façade atlantique française

Recensement effectué en 2010



La filière française des macroalgues se caractérise par :

• Des matières premières issues de la récolte d'algues sauvages

Sur environ 60 000 tonnes d'algues produites annuellement (hors Maërl et Gelidium), 50 tonnes proviennent de l'aquaculture, le reste étant récolté à l'état sauvage sous forme de goémons poussant en mer, goémons de rive ou goémons épaves (Gelidium).

• Une prédominance de la région Bretagne

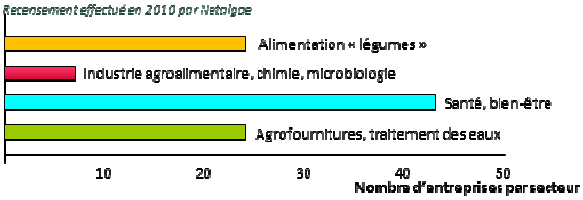
La quasi totalité de la production française vient de Bretagne (excepté le Gelidium récolté au Pays basque et des algues issues d'une entreprise aquacole vendéenne).
Environ 85% des usines de transformation de macroalgues sont localisées dans cette région.

• Des débouchés variés

- alimentation humaine (algues légumes et additifs pour l'industrie agro-alimentaire)
- agrofournitures (produits phytosanitaires, engrais, aliments pour bétail)
- traitement des eaux (filtres et solutions)
- cosmétique, nutraceutique, pharmaceutique
- chimie, microbiologie (milieux de culture...)

Débouchés des entreprises de transformation

Recensement effectué en 2010 par Netalgae



Usages de la production en tonnes humides en 2005

Source : CEVA – importations comprises

Organisation de la filière, des algues à leurs usages

Catégorie d'algues	Algues de fond		Algues d'échouage	Algues de rive			Algues de culture
Autorité et Gestion	Ministère chargé des mines Préfecture du département	DDTM (1) CRPMEM (2)	DDTM - CRPMEM				
Systèmes de gestion	Titre minier + Autorisation domaniale + Autorisation d'ouverture de travaux	Licence	Autorisation de récolte				Concession
Producteurs	Sabliers	Goémoniers embarqués	Récoltants à pieds				Algoculteurs
Espèce d'algues	Maërl - *Lithothamnion* (arrêt de l'exploitation en 2015) ****	Laminaires *L. digitata* *L. hyperborea* ***	Gelidium *G. sesquipedale* *Non communiquée*	Petit goémon *C. crispus* *M. stellatus* *	Goémonnoir *Fucus sp* *A. nodosum* **	Algues diverses *P. palmata, P. umbilicalis, U. pinnatifida...* *	
Transformation	Séchage et broyage	Extraction de phycocolloïdes			Séchage et broyage	Macération, extraction...	Préparation culinaire, conditionnement
Produits	Filtres, traitements €€ / Farines et poudres additives €€€	Alginates €€€€	Agar-agar €€	Carraghénanes €€€€	Farines, poudres additives, engrais liquides €€€	Produits à façon €€€	Produits alimentaires €

LEGENDE : usages des produits

- Agrofournitures et traitement des eaux
- Industrie agroalimentaire, chimie et microbiologie
- Santé, bien-être
- Alimentation « légumes »

Production annuelle approximative (en tonnes humides) :
**** : ≥ 100 000; *** : 50 000; ** : 5 000; * : ≤ 1000

Part dans le chiffre d'affaires (en euros) :
€€€€ : très importante; €€€ : importante; €€ : moyenne; € : faible

(1) Direction Départementale des Territoires et de la Mer
(2) Comité Régional des Pêches Maritimes et des Elevages Marins

Partenaires français

Autres partenaires

Projet financé par

Un avenir en commun

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For more information about seaweed industry in France, please refer to the following:

- ✓ Algae base : http://www.algaebase.org/
- ✓ CEVA : http://www.ceva.fr/eng/PRESENTATION
- ✓ Chambre Syndicale des Algues et des Végétaux Marins :

  http://www.chambre-syndicale-algues.org/
- ✓ FAO statistics: http://www.fao.org/corp/statistics/fr/
- ✓ IFREMER : http://archimer.ifremer.fr/
- ✓ NETALGAE : http://www.netalgae.eu/
- ✓ Regional Committees of Marine fisheries and Mariculture : http://www.bretagne-peches.org/
- ✓ Station Biologique – Roscoff : http://www.sb-roscoff.fr/INVENTAIRES/InvAlgues/index.algues.php

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This report presents the results of the study conducted in France by the Pôle halieutique - AGROCAMPUS OUEST and the University of Brest AMURE (UBO) in the framework project – NETALGAE – INTERREG IVB, work packages 1 and 2.

The objectives of these work packages are to realise:

- General baseline study of algae industry in France.
- Assessment of algae regulation, administration and management systems.

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netalgae
INTER-REGIONAL NETWORK TO PROMOTE SUSTAINABLE DEVELOPMENT IN THE MARINE ALGAL INDUSTRY

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