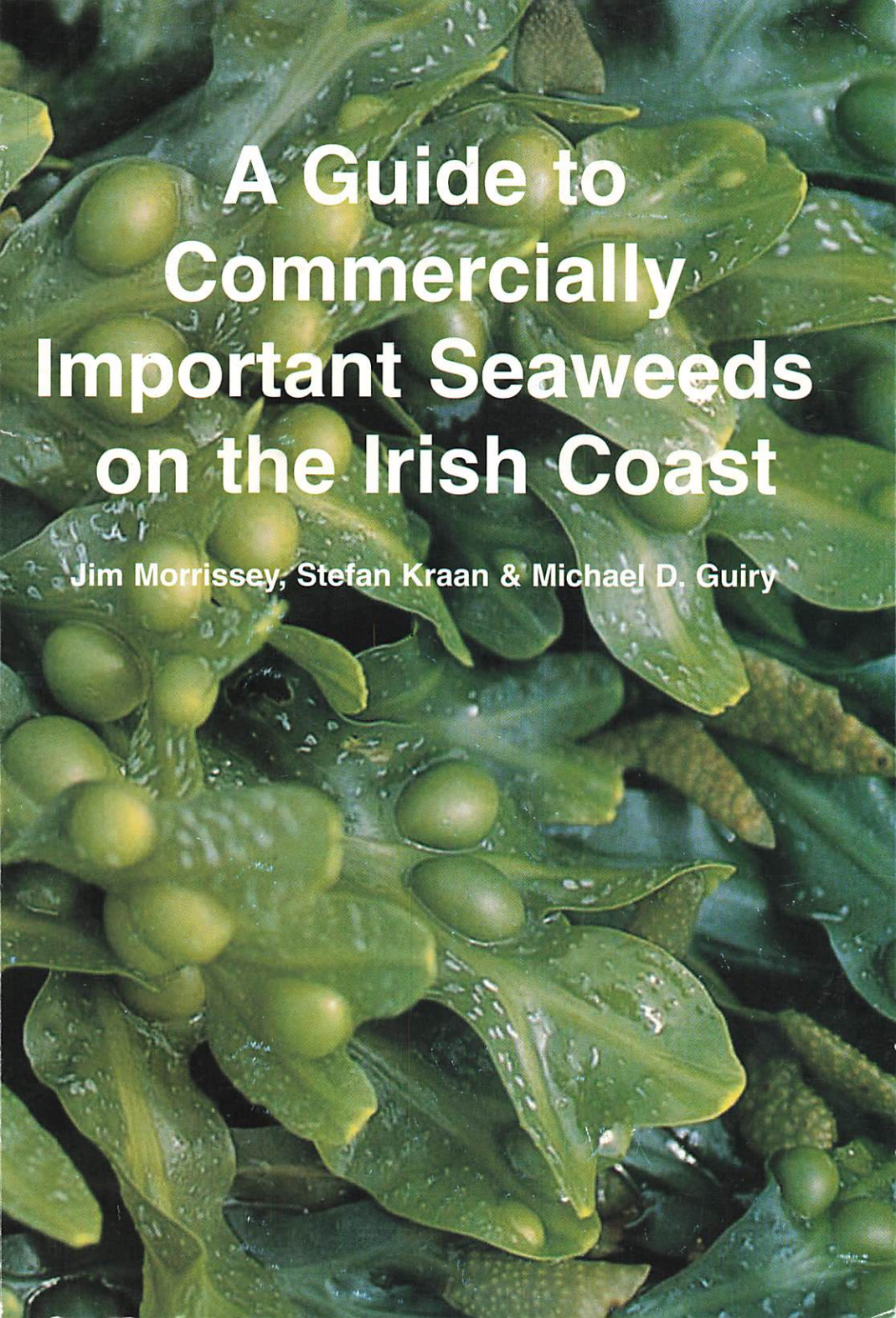

A Guide to Commercially Important Seaweeds on the Irish Coast

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NOTE

The nutritional valves presented in the above tables were sourced from scientific literature and a recent PESCA/BIM funded study of the nutritional valves of some Irish sea-vegetables carried out by Dept. of Botany, NUI Galway.

For more seaweed information visit the seaweed site at *www.seaweed.ie*

INTRODUCTION

Ireland, with an extensive coastline of over 3000 km, has a long history of seaweed use that continues up to the present day. Evidence exists that marine plants have been gathered for food in Ireland since at least the Middle Ages, while the use of seaweed as fertiliser and animal fodder dates back at least several centuries. In particular, Ireland's Atlantic seaboard, consisting of exposed open coast interspersed with many rocky bays and indentations, is ideal for the settlement of seaweeds and consequently is particularly rich in seaweed resources. On the West Coast seaweed is the basis for an industry that provides valuable employment in coastal areas that are geographically remote or otherwise severely disadvantaged economically.

Since the 18th century, when scientific investigations of Irish seaweed species began in earnest, over 500 different species of seaweed from Irish waters have been identified. Given the small area of the island, this relatively high number represents a very high diversity of seaweed for Ireland; France, with a considerably longer coastline and wider range of climates has about 690 species. One reason for this diversity is latitude. Ireland is located between 51 and 55° N, occupying a range of latitudes that straddle both the northern limit for some warm-water species and the southern limit for some cold-water species.

Only a small fraction of Irish seaweeds has been put to any commercial use, notably a dozen or so of the larger species which together account for a high percentage of the overall seaweed biomass. The present guide provides physical descriptions of these commercially important seaweeds and their habitats, as well as information on their current uses and applications, which fall into the following main categories:

- foods and food supplements (edible seaweeds are marketed as sea-vegetables);
- fertilisers, liquid seaweed extracts and soil conditioners;
- raw material for seaweed polymers (alginates); and,
- cosmetics, body-care, thalassotherapy and medicinal preparations.

The list of commercially useful species is not static, and additional species will be added as more research is carried out. Likely areas of growth in seaweed use include biotechnology, body-care products and functional foods.

Large marine algae commonly known as seaweeds, are divided into **three** major phyla or divisions which can conveniently be identified by colour as follows:

- brown algae (Phaeophyta);
- red algae (Rhodophyta);
- green algae (Chlorophyta).

Seaweeds are a large and diverse group of organisms with many different life-cycle strategies, a wide range of forms and occupy a range of habitats. For example, in size alone brown seaweeds vary from a few centimetres in length to extremes of >60 metres

in the Bull-kelp forests of California, South America and Australia. The largest seaweeds in Ireland are more modest reaching 4-5 metres at most.

There are several excellent well-illustrated shore guides such as *'Collins Guide to the Sea Shore'* (Collins, London), and *'Irish Sea Shores'* published by Sherkin Island Marine Station Co. Cork, both of which can be ordered from your local bookshop.

The three major divisions of large marine algae are listed below along with the most commonly used species from each. A description of each species named below follows in the main body of the guide.

● **Brown algae**

These are either olive-green in colour or any shade of brown from golden to dark brown. In Ireland some 147 species of brown algae have been reported, of which the kelps and wracks provide most of the biomass and most of the commercially utilised species.

Kelps (Laminarians)	**Wracks (Fucoids)**	**Other**
Alaria esculenta	*Fucus vesiculosus*	*Himanthalia elongata*
Laminaria hyperborea	*Fucus serratus*	
Laminaria digitata	*Ascophyllum nodosum*	
Laminaria saccharina	*Pelvetia canaliculata*	

● **Red algae**

These show a wide range of colours from red or bright pink to a dark purplish-brown, to almost black. They are often bleached to a light brown or yellow in bright sunlight and can be confused with brown algae. Some develop a calcareous covering and resemble coral. Some 274 species of red algae are found in Ireland. At the moment the commercially important species are:

Palmaria palmata
Porphyra spp.
Chondrus crispus and *Mastocarpus stellatus*
Asparagopsis armata
Maërl *(Phymatolithon calcareum, Lithothamnion corallioides)*

● **Green algae**

These are usually delicate plants with thin fronds of a grass-green colour. Some 80 species of green algae have been found in Ireland of which the following are those that have commercial potential.

Ulva rigida
Enteromorpha intestinalis and *E. compressa*
Codium fragile

THE BROWN SEAWEEDS (PHAEOPHYTA)

Brown seaweeds appear to be brown due to a masking pigment known as *fucoxanthin* that masks the green-coloured *chlorophyll* pigments responsible for most of the photosynthesis, and which makes plants look green. Like terrestrial plants, chlorophyll is present in all seaweeds but is readily visible only in the greens. As cast brown seaweeds decompose on the upper shore one can clearly see the green colour of chlorophyll appearing through the fading brown surface pigments.

The dominant brown seaweeds of rocky seashores generally grow in distinct horizontal bands, often called zones. Each species occupies a characteristic level on the shore in response to environmental conditions, the major factor probably being the time that the plants are out of water. Species intolerant of air exposure, such as the kelps, dominate the lower shore, whilst browns such as Channelled Wrack *(Pelvetia canaliculata)* can only live in the high intertidal shore and seem to need to be exposed for most of a tidal cycle.

Factors that appear to determine the type and abundance of seaweeds on a shore are intensity of wave action, tidal range, water turbidity, scour, type of substratum, and the slope and aspect of the substratum. Competition from other species and the extent of grazing activities from herbivores* are also important in determining the extent of zones and the presence or absence of particular species.

The extent and depth of the various seaweed zones in the subtidal area are determined by factors such as light penetration and grazing. In turbid waters (such as are found in estuaries and on the East Coast of Ireland) seaweeds rarely extend to 10-15 m below the low-water mark, but in clear waters such is found off the West Coast they reach depths in excess of 40 m.

Included in the brown seaweeds are the large kelps and wracks, which together account for a very high proportion of overall seaweed biomass. The *Seaweed Biomass Survey* carried out by the Irish Seaweed Industry Organisation in 1997 conservatively estimated that at least 2 million tonnes of Laminarans (Kelps) were present along the western seaboard (Hession *et al.* 1997). Any future attempts to exploit this resource must take into account the associated marine communities and ensure that it is not destabilised through indiscriminate harvesting. The same survey estimated the total biomass of *Ascophyllum nodosum* along the West Coast to be nearly 300,000 tonnes, with potential for an annual sustainable harvest of 75,000 tonnes, more than double the current annual harvest of 35,000 tonnes. Hence, a doubling of the existing harvest could be accommodated without interfering with the sustainability of the resource.

The Irish seaweed industry is almost unique in its sustainable exploitation of Ireland's natural resources. The use of sustainable harvesting practices that use a cutting frequency of 3-4 years to allow the target species such as *Ascophyllum nodosum* to regenerate has ensured this. For a resource that has been exploited for many centuries and especially intensively in the last century, Ireland's seaweed resources could accurately be described as well maintained with considerable potential for further sustainable development. * *(mostly limpets, periwinkles and sea urchins)*

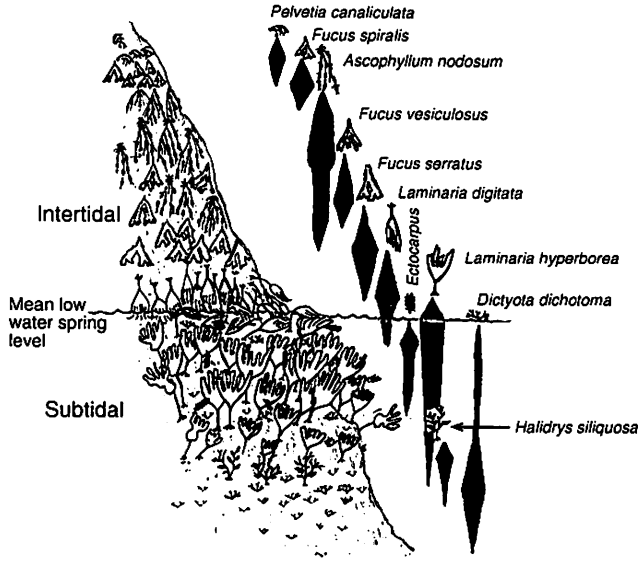


Fig. 1 Typical vertical zonation of brown seaweed on a semi-exposed rocky shore in Ireland. The kite diagram shows the abundance of different species at vertical intervals. The wider the band, the greater the abundance of a particular species at that shore level. (Jim Morrissey)

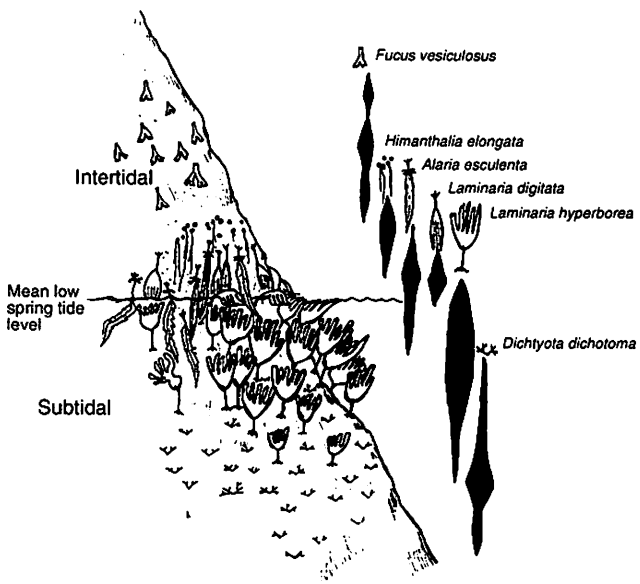


Fig. 2 Typical vertical zonation of brown seaweed on a wave-exposed rocky shore in Ireland. (Jim Morrissey)

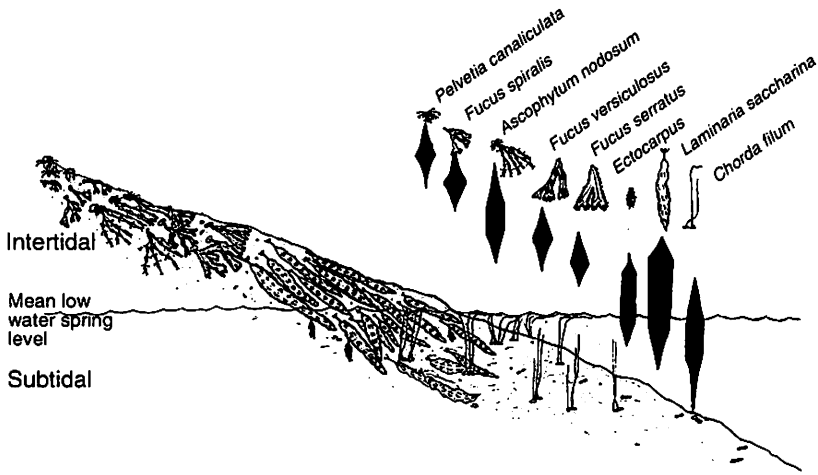


Fig. 3 The vertical zonation of brown seaweed at a very sheltered gravel and shingle shore in Ireland. The kite diagram shows the abundance of different species at vertical intervals. The wider the band, the greater the abundance of a particular species at that shore level.
(Jim Morrissey)

Alaria esculenta

Common names

English: Atlantic wakame, Tangle, Dabberlocks, Wing kelp, Honeyware, Murlins.

Gaeilge: Láir, Láracha.

Distribution

Alaria esculenta is a common kelp of exposed rocky coasts in Europe and North America. It has been recorded at exposed sites around Ireland except for some parts of the East coast. It is found on the extreme lower shore and below, on rocky substrata and especially in gullies where it hangs from sheer or steeply sloping rock walls. On less steep shores it colonises flat rocky terraces of the lower intertidal shore where it appears mixed in with other lower-shore species such as *Laminaria digitata.*

Description

Alaria esculenta (Fig. 4) consists of a long, thin, golden to greenish-brown undivided frond rising from a short stipe. The most obvious distinguishing feature is the highly visible yellow midrib, which is a continuation of the rounded stipe. Often the edge of the frond is torn in as far as the midrib, which may assist the plant in withstanding violent wave action. The stipe is short with distinct fleshy, flat, round-ended reproductive 'leaflets' growing perpendicularly from the stipe in older plants. These are specially produced reproductive structures called sporophylls and their protected position at the base of the plant rather than at the tip (like many fucoids) is another likely adaptation of the species to its exposed habitat. The claw-like holdfast is small but extremely tenacious to withstand the pounding of surf. *Alaria esculenta* may reach over 4 m in length but is normally less than 2 m.

(Stefan Kraan)

Fig. 4 ***Alaria esculenta*** **growing on ropes in Co. Galway, note the distinguishing yellow midrib.**

Harvesting and commercial uses

Alaria is a tasty, slightly sweetish, sea-vegetable commonly known as Atlantic Wakame. In Japan the name Wakame applies to the kelp *Undaria pinnatifida* which is very similar in taste to *A. esculenta*. Processing of harvested plants involves rinsing (if needed), drying and packing. Plants that are underwater at low tide are said to be best preserved and of the highest quality. *Alaria* plants harvested from these areas are generally already clean, needing no additional washing. Before sale they are hung across ropes or racks indoors (or in a covered outside area) to air dry thoroughly before being cut into strips and packaged. Special seaweed drier units based on the design of tobacco driers are used by some Irish processors to improve the drying process.

Alaria esculenta is at its nutritional prime during mid-late Spring and the beginning of Summer. Plants are in pristine physical condition at that time after which a gradual deterioration of the frond commences. By mid summer and at the onset of autumn, most *Alaria* fronds have died back almost completely. Consequently, late spring is the best time to harvest and this is when fronds are at their nutritional best.

Unlike the brown wracks, *Alaria* grows from the base of the frond and not the tip of the plant. Generally only the young section of the blade is harvested and the old growth at the tip is discarded. Sustainable harvesting techniques involve the cutting of the main blade well above the fleshy sporophylls, leaving sufficient material to regenerate into new plants. The removal of the complete plant from its rocky attachment will delay the process of re-growth for a period of years so it is important for any potential harvesting to be carried out in a careful and sustainable manner.

Currently, about 9 tonnes of Wakame are produced annually on longlines in Britanny for the existing limited European market. *Alaria* cultivation trials on longlines have taken place at an exposed site off the Isle of Man with the plants successfully adhering to the ropes. Recently, cultivation trials by NUI, Galway in Galway Bay have started to produce hybrid strains of fast-growing, disease-resistant *Alaria esculenta* (Fig. 4).

There are a number of advantages in farming seaweed as opposed to harvesting from a natural seaweed population, namely:

- Harvesting cultivated seaweed from longlines is easier, more efficient and probably less dangerous than harvesting from exposed, uneven, slippery rocky shores.
- Seaweed aquaculture can offer 24 hour, all-weather access to the seaweed crop, which compares favourably to the restricted access to natural seaweed beds, from weather and tide. It has been shown in Asia that much greater yields per effort are possible from cultivating seaweeds than from the hand picking of wild populations.
- In Ireland the average age of hand harvesters of sea-vegetables (and other seaweed) is rising steadily with little recruitment of younger people into this tough demanding work. In order for the sea-vegetable industry to remain viable a guaranteed supply is necessary. For a younger generation, seaweed aquaculture rather than hand harvesting is probably a more attractive method of procuring seaweed.
- Control over the whole life-cycle in seaweed cultivation should result in better quality sea-vegetable products, i.e. less variation in age, size, and quality, all factors that facilitate the presentation of a uniform high-quality seaweed product. Through hybridisation seaweed aquaculture can produce favourable hybrids that grow larger, exhibit quicker growth, are nutritionally superior, and more disease resistant in comparison to wild stocks.


(Stefan Kraan)

Fig. 5 Cultivation trials of *Alaria esculenta* on longlines, Co. Clare.

Nutritional analysis

Optimum time of harvest is between Spring and early Summer. Like all sea-vegetables the vitamin and mineral content varies through the year. Vitamin C content is normally highest in late spring, while higher vitamin K values are found in early Summer. *Alaria* has high levels of vitamin B6, vitamin K, iodine and bromine. It also contains sugar, starch, nitrogen, boron, radium, rubidium, cadmium, cobalt, nickel, and other trace elements.

Table 1. Nutritional analysis of *Alaria esculenta*.

Protein	9-20%
Fat	1-2%
Carbohydrates	46-51%
Vitamin C	100-500 ppm
Carotene	4-5 ppm
Retinol	0.7-0.8 ppm
Vitamin B2	0.3-1 ppm
Vitamin B3	5 ppm
Vitamin B6	0.1 ppm
Vitamin B12	<5 ppb
Calcium	11,670-12,900 ppm
Iodine	165-275 ppm
Iron	50-126 ppm
Magnesium	8.960 ppm
Manganese	<1-14 ppm
Sodium	4.6%

ppm = parts per million
ppb = parts per billion
(billion = 1 thousand million)

Laminaria hyperborea

Common names
Due to the nature of usage of this kelp there are separate names for the stipe and frond parts, as well as the complete plant in many areas.

English: Forest kelp, Cuvie, May-weed (detached blades), Sea-rods or Rods (stipes).

Gaeilge: Ceanna slat, Múrach bealtaine, Múrach fómhair (May-weed & Autumn-weed, Feamainn bhuí, Leathach dearg, Barraí raic, Sraith bhuí, Slat(a) mara, Stúmpa (for stipe only).

Distribution
Laminaria hyperborea is present throughout the North Atlantic extending from Norway south to Northern Portugal. Dense beds are present along a large part of the North, West and South Coasts of Ireland sometimes extending over a kilometer from the shore. It is less common on the East Coast. This kelp exclusively colonises rocky areas to a depth determined by the level of light penetration, which can be as much as 30 m. It becomes increasingly scarce as one moves away from exposed coasts of full salinity seawater towards the mouth of rivers.

Description
The word 'kelp' originally referred to the burnt ash of the brown seaweed and only subsequently became applied to the seaweed itself. This is a large, erect, brown-gold kelp (Fig. 6) that forms dense forests below the low water mark and can reach a length up to 3 m. It has a long stiff, rough-textured stalk or stipe that holds the frond erect, usually covered with epiphytic red seaweeds growing on its surface. The stipe is round in cross-section and can be snapped by hand when fresh. Well-developed stipes are about 1 m in length and 3-5 cm in diameter. The top end of the stipe abruptly forms into a broad rubbery, smooth frond with finger-like blades similar to the frond of *L. digitata* (p.18). This abrupt junction between the stiff, round in section stipe, and the frond is one of the identifying features that differentiates *L. hyperborea* from *L. digitata*.

During Spring old growth (the end or distal part of the frond) gradually withers and is usually separated by a narrow neck of frond from the bulge of new growth below. At this stage the frond has a distinctive hourglass or figure of eight shape. Eventually the narrow band tears and the old frond is broken off allowing the new frond to establish. Discarded old fronds known as Mayweed are cast up in drifts on the shore.

The blades are often torn and indented by the pounding action of waves. The stipe area has mucus-producing pores. Many smaller, epiphytic red seaweeds such as *Palmaria palmata* and *Phycodrys rubens* grow on the rough surface of the stipe. What gives the plant stipe both its stiffness and flexibility is a polysaccharide known as alginic acid that serves the same purpose in brown algae as cellulose does in terrestrial plants; very little cellulose occurs in these kelps. On high-energy exposed coasts there is a higher proportion of alginate present in the kelp than on more sheltered coasts. This extra alginate serves to increase stiffness of the stipe to withstand the rigours of increased wave action on exposed coasts.

Fig. 6 ***Laminaria hyperborea*** **exposed during a very low spring tide**

Harvesting and commercial uses

Reproduction of *L. hyperborea* occurs during the Winter from October to March inclusive. Most kelps live from 3-5 years and in this time grow from a tiny plantlet to a fully-sized adult suitable for harvesting. As a general rule when considering seaweed harvesting, a sustainable yield is worked out based on the re-growth capacity of the target seaweed species. In order to work out the annual sustainable harvest of seaweeds the total estimated biomass for an area is divided by the number of years required for the seaweed plants to recolonize an area and to reach harvestable size.

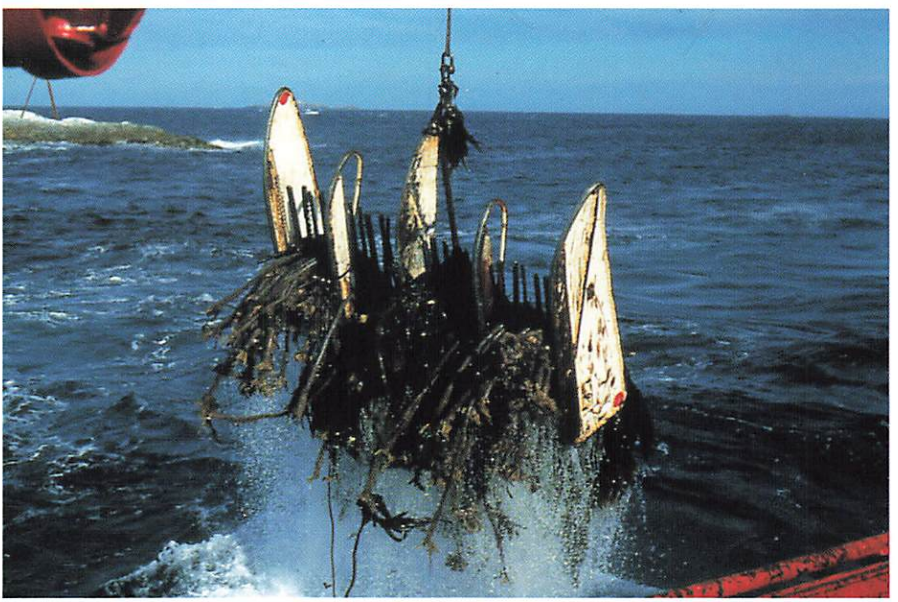
Therefore, if this time is 4 years, the annual sustainable harvest in an area with 60 tonnes of biomass will be in the region of 15 tonnes. This method has been applied to calculate potential sustainable harvest weights for some of the commercially important species along the Irish Coast. Importantly, *Laminaria* beds are also breeding grounds for various fish, and shellfish stocks. When harvesting, this should be taken into account.

In Europe, *L. hyperborea* is one of the most exploited species of seaweed for the production of gelling alginates. Its stipe is mainly used by the alginate industry while the blades are generally dried, and then powdered for use in animal feeds and liquid seaweed extracts. Harvesting of this species in Norway for this purpose is carried out by purpose-built dredging vessels. These pull cutting dredges (Fig. 7), which chop the plant near the holdfast and collect the stipe and frond in a cage on the dredge, which is then hauled and unloaded into the vessel's hold.

No direct large-scale harvesting of whole *L. hyperborea* plants for the alginate industry has taken place in Ireland but widespread collection of cast stipes known as 'sea-rods' or 'slat(a) mara' took place. As recently as the late 1990's, a small amount of these sea-

rods were still gathered, air-dried and transported whole to Scotland for processing into high-grade alginates. Sadly, this sea-rod market has sharply declined. In Ireland, the intertidal brown wrack *Ascophyllum nodosum* (see p. 32), is harvested on a large scale as alginate raw material and for other uses such as fertiliser, liquid seaweed extracts and animal fodder supplements.

Historically, there has been widespread use of cast *L. hyperborea* as a fertiliser in Irish coastal areas. Along with other drift seaweeds it was layered with sand to create "lazy beds" of "soil" on otherwise bare rock. This driftweed was torn from rocks by gales, mainly in Spring and Autumn and collected from certain beaches such as Quilty, Co. Clare, on which large drifts were regularly deposited. This storm-cast weed composed of *L. hyperborea* fronds (Mayweed) and other seaweeds was known collectively as driftweed or blackweed and was frequently of poor quality being variously decomposed and frequently contaminated with plastic bottles and other beach debris. High bacterial counts were a regular feature. It was used for a time as raw material for low-grade fertiliser and animal meal but this practice has stopped since the 1980's. The fodder supplement and fertiliser market is now being supplied with vastly superior quality seaweed meal made by Arramara Teoranta from freshly harvested *A. nodosum*.



(Mentz Indergaard)

Fig. 7 **Harvesting *Laminaria hyperborea* by dredge off Western Norway.**

Nutritional analysis

Like all kelps, *Laminaria hyperborea* is rich in iodine, several vitamins and many trace minerals. For chemical constituents, see *L. digitata* (p.18) as there is little real difference between the two kelps.

Laminaria digitata

Common names

English: Oarweed, Kombu, Tangleweed, Sea girdle, Sea tangle, Sea ribbon. In English 'oarweed' is used to describe both *L. hyperborea* and *L. digitata*, wheras in Irish separate names are allocated to these individual species.

Gaeilge: Leathrach, Feamnach dhubh, Coirrleach (also applied to *L. saccharina* in some places)

Distribution

Laminaria digitata is a very common kelp at low water around the Irish, North European, and Eastern North American Coast. Moving down the shore, *L. digitata* is normally first encountered at low water neaps extending down below the low water Spring mark to the *L. hyperborea* zone. In clear waters it can be found growing to a depth of 10 m; hence on steep gradient shores it tends to form narrower beds than the very similar *L. hyperborea*, which grows in deeper water. Variable densities of *L. digitata* have been noted around the whole extent of the coast generally less than the amount of *L. hyperborea* present. A biomass survey carried out by the ISIO in 1997 (Hession *et al.*, 1997) estimated that 56% of the coastline from Donegal to Cork had some form of kelp coverage. *L. digitata* thrives in fairly exposed areas or in more sheltered areas with strong tidal currents and is sensitive to lower salinities, generally preferring salinities above 20%.

Description

Laminaria digitata is golden-brown in colour and up to 2.5 m long (Fig. 8) and 60 cm wide across the frond.

(M.D.Guiry)

Fig. 8 ***Laminaria digitata*** **lying flat on the lower shore during low spring tide.**

The holdfast is a cluster of thin, branching, intertwining, root-like processes. The frond is flat, large, rubbery and smooth with finger-like sections, which may be torn or indented by wave action. It is generally very similar in appearance to *L. hyperborea* and the two were confused for a long time. Particular distinguishing features for *L. digitata* are its position higher on the shore, the smooth, flexible, oval (in cross section) stipe and a less abrupt junction between stipe and frond. Also in Spring, differentiation between new and old growth is not as obvious as in *L. hyperborea*. The shiny oval stipe is not rigid enough to bear the weight of the frond in air, so when the plant is exposed during low water it lies prostrate on the flat or hangs limply from rocks. *L.digitata* can be fertile throughout the year but has a peak period of reproductive activity between June and October with local variations in various European countries.

Harvesting and commercial uses

Despite the massive resources of *L. digitata* in Ireland only a tiny percentage is harvested by hand or rake to supply the sea-vegetable market and for use as feed for algivores in the mariculture of abalone and sea urchins. Harvesting of *L. digitata* for sea-vegetables in Ireland is done by hand during low Spring tides and is carried out all year round. Sustainable harvesting practices consist of cutting only the upper three-quarters of the frond by knife, leaving the stipe and lower part of the frond intact to regenerate quickly. Unlike France, where *L. digitata* forms the basis of an alginate industry, there is no mass market for this species in Ireland so no mechanisation of harvesting has taken place.

As mentioned above, small amounts of *L. digitata* are harvested in Ireland, dried, and sold as a sea-vegetable. In Asian cooking, Kombu* is used in the manufacture of a stock that is the basis for many dishes. *L. digitata* accounted for a large part of the 'drift weed' mix that was widely gathered until the late 1980's as a fertilizer. Small-scale gathering of drift-weed by coastal farmers and in particular organic gardeners continues around the coast. Like all the kelps, *L. digitata* is rich in iodine that is widely used as a health supplement for under-active thyroids (myxoedema), and for the treatment of goitre. At various stages in the past 200 or more years, *L. digitata* was burnt in kilns as a source of iodine or potash. However, with the discovery of alternative sources of these products the practice of kelp burning mostly died out in the first half of the 20th century.

Currently, alginate extraction is the most important use for this kelp, but no harvesting of *L. digitata* for this purpose has been carried out in Ireland. As mentioned above, the French alginate industry, which is based in Brittany, uses large quantities of locally harvested *L. digitata* as raw material. Annual harvests have not increased from 60,000 tonnes per annum in the last ten years, suggesting that the maximum harvest limit may have been reached. Harvesting in France was traditionally carried out by hand using long-handled sickles, but is now carried out mechanically using the 'scoubidou', a grapple-like apparatus fitted on licensed harvesting boats (Fig. 9). Also used till recently was a harvesting system using divers to hand cut the kelp, which was then transported to a surface vessel via suction pump.

In both France and the USA, *L. digitata* has been used in bioconversion trials to produce methane gas.

* Japanese word for kelp.

(John Huisman)

Fig. 9 'Scoubidou' apparatus on harvesting vessels in France (Brittany)

Nutritional analysis

The nutritional qualities of this species are given in Table 2.

Table 2. Nutritional analysis of *Laminaria digitata*

Protein	8-14%
Fat	1%
Carbohydrates	48%
Vitamin C	12-18 ppm
Vitamin B1	5 ppm
Vitamin B2	22 ppm
Vitamin B3	34 ppm
Vitamin B12	0.6-0.12 ppm
Laminaran	0-18%
Mannitol	4-16%
Calcium	12,400-13,200 ppm
Iodine	800-5,000 ppm
Iron	50-70 ppm
Magnesium	6,400-7,860 ppm
Manganese	1-16 ppm
Sodium	2-5.2%

Laminaria saccharina

Common names

English: Sweet kombu, Kombu royale, Sugar kelp, Sugar wrack, Sea belt, Sea tangle, Oarweed, Poor man's weatherglass.

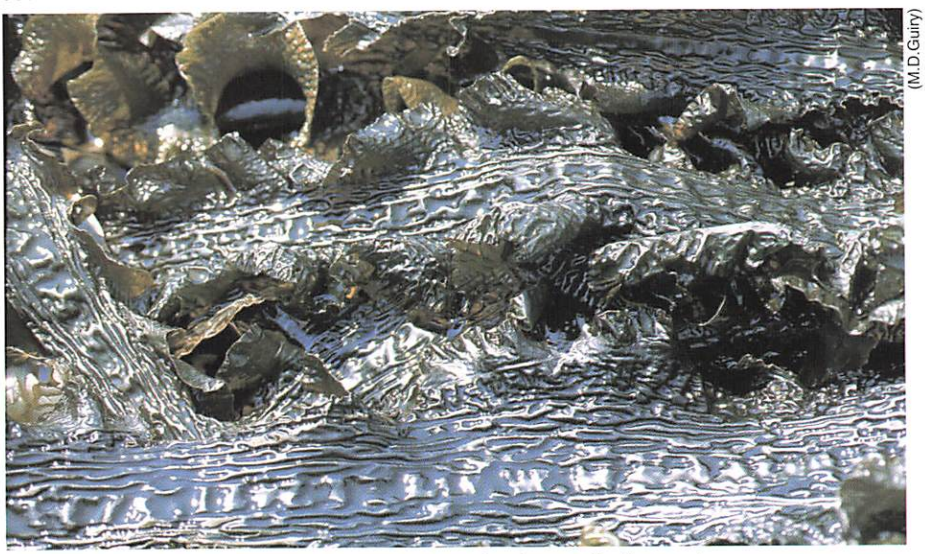
Gaeilge: Cupóg na gCloch, Lásaí, Rufaá, Fruill, Réabán, Madraí, Madraí rua, Coirrleach (also applied to *L. digitata* in some places)

Distribution

Laminaria saccharina is a common kelp of the lower shore in north Atlantic and Pacific. In Europe it is found from Norway down as far as Northern Spain at depths down to 10 m in clear waters. In Ireland, this kelp is present in a range of habitats, ranging from the outer reaches of estuaries to gently sloping semi-exposed rock shores. It can be found growing in the mouths of sheltered estuaries on stones, shingles and gravel. Unlike *L. hyperborea* and *L. digitata* it generally does not occur in a distinct band but rather grows in patches near channels, in gullies and in deep rock pools. It sometimes forms a jumbled brown carpet at the water's edge, or is torn loose and cast up on the higher zones of the shore. It is generally absent from very wave-exposed shores.

Description

Laminaria saccharina (Fig. 10) is easily recognisable by its relatively short stipe (< 60 cm), and the elongated frilly-edged, crinkled fronds that extend tongue-like to 2-4 m in length. The yellow-brown fronds are undivided, and in older specimens the surfaces are heavily pitted, often torn and heavily indented. The stipe is flexible, smooth, round in cross-section and the holdfast is a cluster of strong, flat, spreading, branching, root-like tissues.



(M.D.Guiry)

Fig. 10 A typical 'carpet' of *Laminaria saccharina* on the lower shore.

Laminaria saccharina is generally found in the lower shore on rock or in gullies and is the most tolerant of kelps to muddy conditions and lower salinities found in estuaries. In appearance, juvenile *L. saccharina* plants can be easily confused with young *Alaria esculenta* being of similar shape, colour and size. However, the presence of a distinct midrib in *A. esculenta* is diagnostic.

L. saccharina has a tendency to go particularly limp as humidity increases (supposedly indicating a rise in humidity portenting rain), and to become dry and brittle as the air becomes dry; hence the common name Poor man's weatherglass. The development of reproductive tissue in *L. saccharina* can occur at any time of the year but is most common in the Winter and is visible as dark blotches/ patches on the frond.

Harvesting and commercial uses

Traditionally, this species was gathered as part of the total drift weed used for fertiliser purposes in coastal areas. Small quantities of *L. saccharina* are currently hand-picked as sea-vegetables using a sharp knife at low tide. As a dried sea-vegetable it is sold as Sweet kombu or Kombu royale. Dried *L. saccharina* is arguably the most palatable of all the kelps, due to the presence of mannitol (a polyhydroxyalcohol), imparting a sweet taste to the plant. In some areas the young, tender fronds of *L. saccharina* are eaten fresh but are also used dried in a variety of cooked dishes.

Nutritional analysis

An analysis is given in Table 3 (below).

Table 3. Nutritional analysis of *Laminaria saccharina*

Protein	6-11%
Fat	0.5%
Carbohydrates	61%
Vitamin C	13-18 ppm
Calcium	8910-9282 ppm
Iodine	800-4500 ppm
Iron	22-40 ppm
Magnesium	5670-6944 ppm
Manganese	1-16 ppm
Sodium	3-3.4%

Himanthalia elongata

Common names

English: Sea spaghetti, Spaghetti de mer, Thongweed, Buttonweed, Sea haricots, Sea thong.

Gaeilge: Rúalach, Rúanach, Ríseach, Imleacán cloch, Raif.

Distribution

Himanthalia elongata is a common seaweed of a semi-exposed lower shore. The species is known only in the Eastern Atlantic from Southern Norway down to Northern Portugal, but is most common in Scotland, Western Ireland, and South-Western Britain. In Ireland, it is generally found between the low water of neap tides and low water Spring tides on relatively exposed coasts where a suitable rocky substratum is present. On steeply inclined coasts this results in the formation of a narrow zone, but abundant beds can be found on areas of flat rock, particularly on wide wave-cut platforms.

Description

Young plants of *H. elongata* (Fig. 11) initially appear during the winter as shiny greenish-yellow buttons about 2 cm in diameter attached to rock surfaces, normally with small yellow forked shoots of the new frond visible. These initially yellow-coloured fronds arise from the centre of these buttons and divide into the long paired strap-like branches. This species should not be confused with *Chorda filum* (bootlace weed; not treated here), which is thinner, more transparent, generally unbranched and round in cross section (unlike the more substantial, flat strap of *H. elongata*).

(M.D.Guiry)

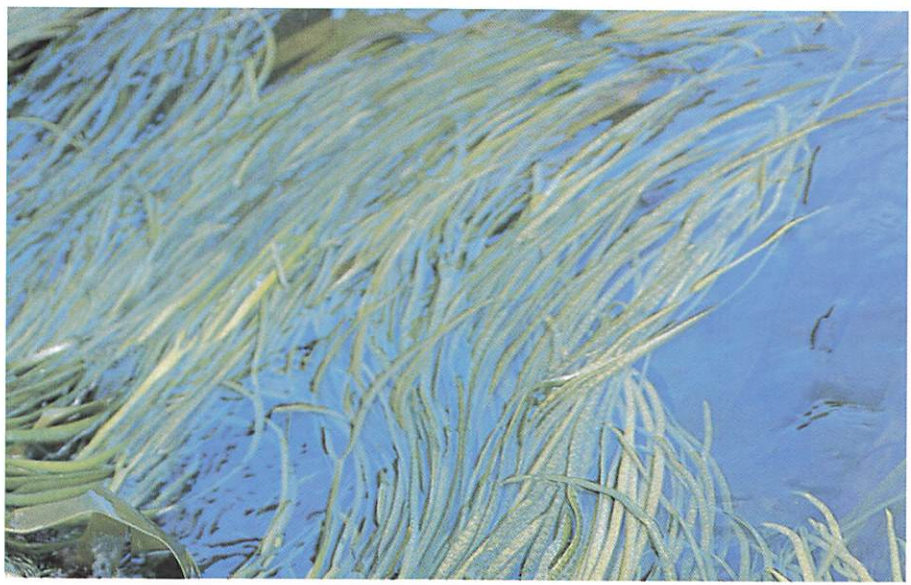
Fig. 11 Young button-like *Himanthalia elongata* plants surrounded by mature fronds.

The long yellow-brown, strap-like fronds of *H. elongata* are the reproductive receptacles that grow during the Winter and bear the conceptacles (small pits) which will ripen during the Summer. In Spring, dark spots on the fronds indicate the plant is fertile although another epiphytic seaweed *(Elachista)* may form larger tufts also. The fronds may grow up to 3 m long but 1-2 m is more common. Often the strap-like fronds are torn away from the button-like base and are found cast up in beach drifts.

Himanthalia elongata is very distinctive during low tide as long, strap-like fronds hanging down in tangled masses from rocks on the lower shore. At high tide the fronds float in extensive tangled mats on the surface (Fig. 12) where they can obstruct progress of small craft.

Harvesting and commercial uses

The species is mostly annual so may be harvested from the button up. Buttons on the rock should be left undisturbed with the strap-like fronds suitable for harvesting from late Spring to Autumn. Large quantities of *Himanthalia elongata* were once gathered and burned for kelp on the Aran Islands. Today, however, this considerable resource remains almost completely untouched. Harvesting at high water should be relatively straightforward as the seaweed floats making it accessible to boats.



(M.D.Guiry)

Fig. 12 Fronds of *Himanthalia elongata* floating on the sea surface

Currently, small amounts of *H. elongata* are hand-picked and sold (on account of their appearance) as Spaghetti de mer or Sea spaghetti. In France, it is normally sold under this label dried, or marinated in jars to increase its shelf life. Unlike some other sea-vegetables such as dulse, sea spaghetti lacks a strong 'sea taste' but instead has a rather nutty flavour. Potential for expansion of this market exists within Ireland.

In North-Western France, considerable quantities of 'button weed' *(Himanthalia elongata),* have been collected and used as manure on artichoke fields and for barley with the resultant crop being highly desirable for brewers.

Nutritional analysis

A nutritional analysis is given in Table 4 (below)

Table 4. Nutritional analysis of *Himanthalia elongata*.

Protein	6-11%
Fat	0.5%
Carbohydrates	61%
Vitamin C	13-18 ppm
Calcium	8910-9282 ppm
Iodine	185 ppm
Iron	22-40 ppm
Magnesium	5670-6944 ppm
Manganese	1-16 ppm
Sodium	3-3.4%

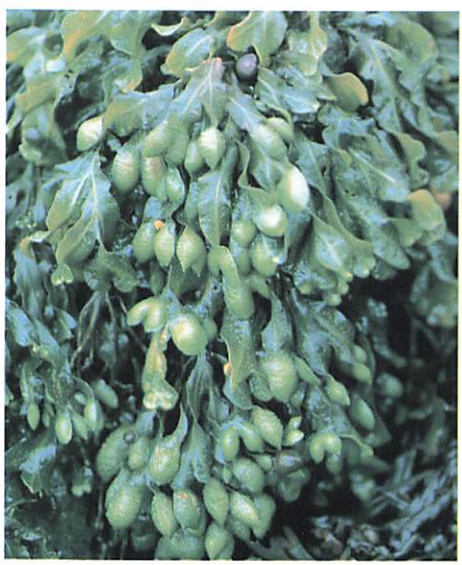
Wracks or Fucoids (*Fucus* spp.)

Fucoids occur on most rocky surfaces in the intertidal, ranging between the splash zone just above the high water Spring tide level, down to the low neap tide level, below which the laminarians dominate. Distinct zoning within the wracks occurs (see Figs. 1-3), starting from the top of the shore and progressing down the shore as follows:

- ***Pelvetia caniliculata*** which needs to be uncovered for much of the tidal cycle
- ***Fucus spiralis*** in a narrow band below ***Pelvetia***
- ***Fucus vesiculosus*** in a broader band in the mid-shore
- ***Ascophyllum nodosum;*** either a co-dominant species mixed in with ***F. vesiculosus*** or else it is replaced by it on wave-exposed shores.
- ***Fucus serratus*** forming a broad band below ***F. vesiculosus*** that merges into the kelp zone.

Individual *Fucus* species can be very difficult to identify for several reasons:

- Fucoids adapt to a wide range of environmental conditions apparently by adopting frond shapes to suit their environment. For example, on exposed coasts ***F. vesiculosus*** normally lacks bladders, perhaps in order to withstand heavier wave action. By contrast, the same species has many bladders on sheltered shores, probably to float the plant upwards to maximise available light for photosynthesis.
- Some species form hybrids freely with other species so the resultant plants may exhibit characteristics of both parents and thus are confusing to identify on the shore. These hybrids may further hybridize, adding to identification problems. This is a particular problem with *F. spiralis, F. vesiculosus* and *F. ceranoides* (not treated here) and less so with *F. serratus*.
- To identify some species properly it is necessary to examine them at the time of year in which they are mature.



(M.D.Guiry)

Fig. 13 ***Fucus spiralis***

Fucus vesiculosus

Common names
(These are many due to the wide usage and varied morphology of this common wrack around the coast, some of the Irish names are used to describe both F. vesiculosus and F. serratus.)

English: Bladderwrack, Seawrack, Bladder fucus, Dyers' fucus, Red fucus, Swine tang.

Gaeilge: Feamainn bhuilgíneach, Feamainn dhubh, Feamanach na gclog, Cosa cruadha, Cosa dubha, Barrchuanla, Feamla, Feamra, Múrach dubh, Clogach, Dúlamán.

Distribution
Fucus vesiculosus is a very common seaweed of the mid-intertidal around the North Atlantic basin south to the Canary Islands. It is present in an extremely wide range of habitats, both exposed and sheltered, on the Irish Coast and as a result is probably the most common seaweed species encountered in the intertidal. It can tolerate a fair degree of wave exposure and as such can be found in exposed locations occupying the mid-shore on rocks, piers, and wave-cut platforms. In sheltered areas it may be co-dominant with *Ascophyllum nodosum,* and it is also very common in the brackish water of estuaries and associated creeks. It is normally absent from mud flats unless there are isolated rocks to which it can attach. In certain western and north-western areas of Ireland, the deliberate laying of stones on bare sand or mud was used to encourage attachment and growth of both *Fucus spp.* and *A. nodosum* in otherwise unproductive areas.

Description
F. vesiculosus (Fig. 14) is a very common brown wrack of the middle shore zone normally found mixed in with *A. nodosum* between the *F. spiralis* and *F. serratus* zones. It is normally an olive-brown colour drying to greenish black, but in certain areas, notably Connemara, it can be bright yellow drying to a deep russet colour. It grows up to 60-80 cm in length although it can be considerably shorter and sparser on very exposed, high-energy coasts. The common form has a short thick stipe and a strong, lobed, wavy-edged frond, dichotomously (paired) branched with a prominent mid-rib. The ends of the branches bear the bulbous fruiting receptacles. On either side of the midrib there are oval gas-filled bladders (often in pairs), which float the seaweed up towards the light, apparently to maximise photosynthesis.

On the most wave-exposed coasts plants of this species tend to be sparse, without bladders, and much smaller compared to the larger, many-bladdered, luxuriant plants found in sheltered bays, such as Cuan Chill Chiaráin and na Beirtrí Buí, Connemara).

For many people, *F. vesiculosus* represents the most familiar seaweed shape on account of its inclusion in the biology curricula, with line drawings of its morphology being found in most biology textbooks. Frequently, it is mispelled in these texts as **'vesiculosis'**.

(Sue Hiscock)

Fig. 14 ***Fucus vesiculosus*. Sheltered form with many bladders.**

(M.D.Guiry)

Fig. 15 ***Fucus vesiculosus* with numerous small air bladders on a sheltered shore.**

Older, larger specimens of *F. vesiculosus* have smaller more numerous bladders (see Fig.15 above) but, as mentioned earlier, bladders may be absent on plants in very wave-exposed areas. Under certain ecological conditions fucoid species other than *F. vesiculosus* form elongated bladders and these are normally either *F. ceranoides* or *F. ceranoides* x *vesiculosus* hybrids.

Harvesting and commercial use

Given the huge natural resource of *F. vesiculosus* in Ireland only a tiny fraction of the overall biomass is used today. What modest amount of *Fucus* used is either hand cut or collected as drift mostly for local fertiliser use. Aside from this use, *F. vesiculosus* is also used along with *F. serratus* as an active ingredient in bodycare products as well as in health supplements, such as kelp tablets. Many current organic seaweed shampoos, shower gels and body creams contain a small amount of *F. vesiculosus* extract (often less than 3%) as one of their active ingredients.

When used in hot seawater baths or steamed, fucoids release polysaccharides such as alginic acid and iodine as well as other minerals which are said to be beneficial to skin, to lower high blood pressure and to ease arthritis and rheumatic pains.

For a high vitamin C content the wrack is best harvested in Autumn, and in the Summer for a high vitamin A content. In Europe, dried plants are steeped as a tea which is credited with slimming effects, and are also used to impart a sweet taste to foods with which they are steamed or boiled.

Various wracks, including *Pelvetia canaliculata*, were once widely used as cattle feed. At present, a small amount of *F. vesiculosus* is included as a "by-catch" of *Ascophyllum nodosum* in the formulation of seaweed meal used as a mineral and vitamin supplement in livestock feed. Reported benefits of the prolonged use of such seaweed meal are increased milk quality from cows, increased yolk content in chicken eggs and increased wool production from sheep. It has also been used as a source of liquid seaweed extract for soil fertilisers and conditioners. Its manurial properties were much valued in coastal areas and large quantities were widely used on the land. This practice continues in coastal areas today, albeit on a much smaller scale, with local gardeners, farmers and organic farms collecting driftweed consisting of kelps (mostly *Laminaria*) and wracks, (mostly *Fucus* spp. and *Ascophyllum*), for manure.

Nutritional analysis

A nutritional analysis is given below (Table 5).

Table 5. Nutritional analysis of *Fucus vesiculosus*.

Protein	5-10%
Fat	0.5 - 2%
Carbohydrates	62%
Vitamin C	100-700 ppm
Beta-Carotene	present
Zinc	14-80 ppm
Phosphorus	20 ppm
Alginic Acid	18-22%
Fucoidan	16-20%

Fucus serratus

Common names

English: Serrated wrack, Saw wrack, Toothed wrack.

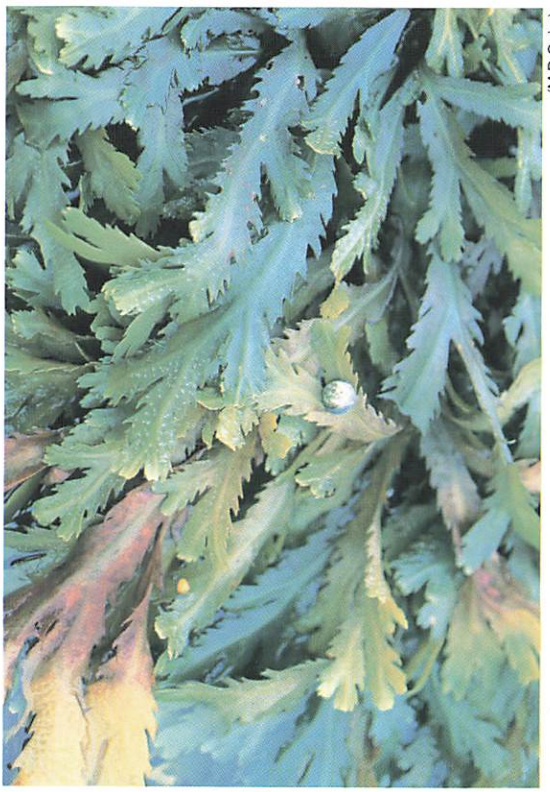
Gaeilge: Míoránach, Dulamán, Múrach dhubh.

Distribution

Fucus serratus is a common seaweed of the middle to lower shores present from Northern Norway to Northern Spain. It is mostly found growing on rock below *Fucus vesiculosus* in the lower-middle to low intertidal zone. At its upper limit on the shore it is sometimes mixed with *F. vesiculosus* and *Ascophyllum nodosum,* and its lower limit merges with the kelps, normally *L. digitata* or *L. saccharina,* at the low water of neap tides. On gentle sloping semi-exposed shores it is not unusual to find abundant beds of *F. serratus* in excess of 30 m width down the shore. *F. serratus* is often found on exposed shores but is absent from very exposed shores. Its pliable fronds are well suited to withstanding the impact of breaking waves seemingly by yielding to them. Generally, *F. serratus* tends to be covered for half the tidal cycle.

Description

F. serratus (Fig.16) is an olive-yellow-brown colour drying to greenish black. It grows up to 60 cm in length. It has a smooth, thin, flat, irregularly branched frond with a prominent mid-rib, the frond edges being characteristically serrated or toothed, like a saw. The frond tips are bluntly rounded and generally forked. In autumn and winter they bear compressed, pointed, fruiting bodies up to 5 cm long also with serrated edges. There are no bladders. At various times of the year it can be similar to both *F. vesiculosus* and *F. spiralis* when those species are devoid of bladders and reproductive receptacles, but *F. serratus* does not often hybridise with *F. vesiculosus;* occasionally chimeras (species growing in close proximity with mixed tissues) are found.



(M.D.Guiry)

Fig.16 ***Fucus serratus***

Harvesting and commercial uses

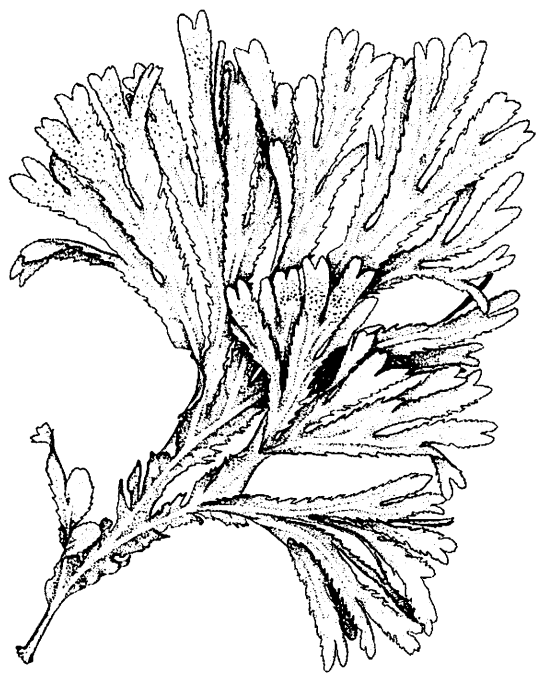
A small amount of hand harvesting of *F. serratus* takes place in Ireland mainly for uses in seaweed baths, bodycare products, and in composting manures. Manures made from the species are especially popular in the Channel Islands, where it is said to be very common, for growing potatoes and tomatoes. In Ireland, some fucoids are processed into seaweed meal and used as raw material for liquid seaweed extracts. Seaweed body-care products are also made from seaweed meal derived from *F. serratus* and *F. vesiculosus*. In France, frozen plants of *F. serratus* and the kelp *Laminaria digitata* are ground into paste for processing into clear gels for the body-care industry and for use in body wraps in thalassotherapy centres. This cold process is designed to maintain complete vitamin integrity of the seaweeds that would otherwise be damaged by the normal extraction processes which involve heat or alkaline solutions. At present, France appears to be the only place where this type of preparation is widely prepared and used.

Applications for seaweed-based creams and gels are numerous, including bath and shower gels, massage creams, barrier creams for hands, soaps, algal bath salts, poultices for relief of rheumatism, cellulite removal, deodorant sticks, sun-screen creams, face masks, hair-setting gels, slimming creams, shaving foams, shampoos and conditioners. The main problem with using algal pastes as raw materials in cosmetics is that of end-product preservation. Preservatives and anti-fungal agents are used to prevent colour deterioration and growth of any unwanted bacteria or fungi on the product.

An undetermined amount of fresh locally-gathered fucoids are used as coolant/packaging for transporting oysters and other shellfish, and small amounts have been used in presentation displays at supermarket fish counters.

Chemical analysis

F. serratus contains high levels of many minerals and trace elements, namely iodine, bromine, phosphorus, manganese, zinc, titanium, molybdeneum, cobalt, potassium and calcium. For a general nutritional analysis see *F. vesiculosus*, to which this species is very similar in constituents.



(Sue Hiscock)

Fig. 17 ***Fucus serratus***

Ascophyllum nodosum

Common names

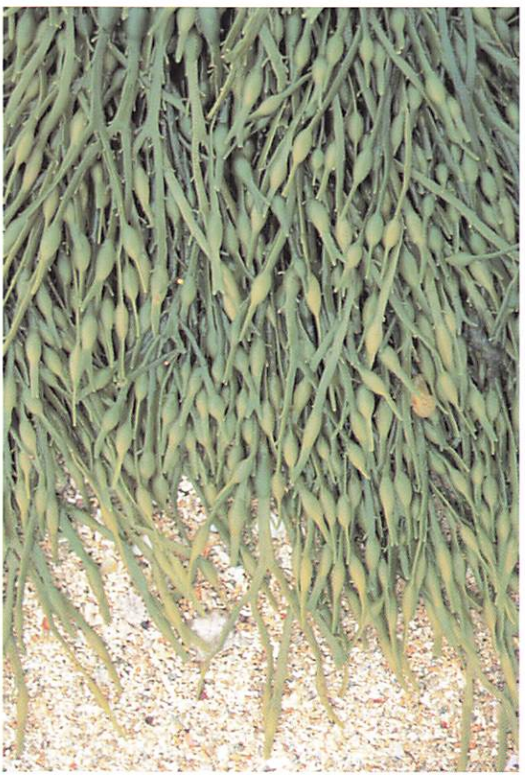
English: Knotted Wrack, 'Asco', Rockweed, Yellow weed, Sea whistle, Yellow tang.

Gaeilge: Feamainn bhuí, Feamainn bhuí bhoilgíneach,

Distribution

Ascophyllum nodosum is a very common wrack of the middle-shore in Europe and the Atlantic coast of North America. It is sometimes found as a co-dominant with *Fucus vesiculosus* in sheltered areas, but not in as diverse a range of habitats. Due to the considerable bulk of adult *A. nodosum* it requires a substantial substratum for firm anchorage and will not grow on mud or small stones. Generally, it is found growing on rocks, larger stones, piers and other solid objects of attachment in estuaries and semi-sheltered bays. In certain Donegal bays, the deliberate placement of rocks as substratum for seaweed attachment takes place in otherwise bare sand or mudflat areas yielding good crops of this species and other wracks.

A. nodosum is most abundant in sheltered places, such as Cuan Chill Chiaráin and Cuan na Beirtrí Buí in Connemara, where it forms dense, luxuriant, tangled beds hanging from the uneven rock substratum by their points of attachment. When submerged, the plant floats buoyed by its air bladders, so that it stands up vertically often just reaching the surface, where it can restrict passage for small craft. At high tide, these beds provide shelter and food for many small fish and other marine organisms. Despite being associated with more sheltered areas, *A. nodosum* can be found in small niches on surprisingly exposed sections of coast, particularly on gently sloping rock platforms, which cut down on wave exposure.



(M.D.Guiry)

Fig. 18 ***Ascophyllum nodosum*** **on coral sand**

Description

A. nodosum (Fig. 18) is an olive green to yellow seaweed, turning greenish black when dried. It generally grows up to 2 metres in length (after three to five years) and has long, tough, leathery, elastic, slender, strap-like, irregularly-branched fronds (with no midrib) growing from a crowded, disc-shaped holdfast.

The basal disc supports numerous basal fronds, often numbering >50. Spaced at intervals along the middle of the main fronds and sometimes occupying their full width are the characteristic long, egg-shaped bladders, which contain gas. The number of bladders present gives an indication of the age of the plant after allowing for 2 years' initial growth. One bladder is generally formed each year. When submerged by the tide, these bladders float the fronds up towards the light maximising the photosynthetic potential of the seaweed. Bright yellow plants of *A. nodosum* are particularly associated with Connemara, where the local name, An Fheamainn Bhuí, translates as "the yellow weed".

The reproductive fruiting bodies grow out laterally from the sides of the fronds, usually in pairs, from November to May. These reproductive receptacles are yellow in male plants and green in female plants, stalked, and similar in size and colour to raisins or sultanas. When they fall off at the end of the season their point of attachment is usually colonised by the common epiphytic red seaweed *Polysiphonia lanosa,* which develops small purple-red tufts of fine branches. At this time large piles of discarded receptacles are a prominent feature of the shore accumulating at the high tide mark and in rock pools.

Sustainable harvesting techniques

Ascophyllum nodosum grows apically; in other words, the tips are actively growing with the plant progressively becoming older towards its base. As mentioned earlier, the growth cycle takes between 3-5 years depending on the area. The adoption of sustainable harvesting practices for exploitation of this resource since the start of large-scale exploitation of *A. nodosum* by Arramara Teoranta in the 1960's has successfully maintained and even enhanced the natural resources of *A. nodosum.* Sustainable harvesting means allowing regeneration of the resource between harvests, to this end a number of guidelines have been adopted over the years by hand harvesters supplying to Arramara Teoranta:

- When cutting *A. nodosum* at least 15-25cm (one or two hand's length), of the base of the plant are left attached to the shore. This practice of leaving a generous stump serves to speed up the regeneration process greatly. If the whole plant is ripped off the shore the resulting space is quickly colonised by opportunistic seaweed species such as *Fucus spiralis,* delaying the re-colonisation of *A. nodosom* at that site.

- Following harvesting as described above, *A. nodosum* takes between 3-5 years to regenerate with the rate of regeneration being determined by the availability of nutrients. Accordingly, sustainable harvesting practice requires that between 3-5 years is allowed to pass before the next cut of weed is taken from the same area. Such fallow -ing of harvested areas helps prevent overexploitation of the resource.

- Even within a previously fallowed area designated to be harvested, many harvesters do not harvest the weed cover in its entirety, leaving pockets of undisturbed plants. Apparently, this helps minimize the displacement of fish and animals that live among and beneath the canopy of *Ascophyllum* beds.

It has been found that regular harvesting of *A. nodosum* gives greater production.

Fig. 19 Hand harvesting of *Ascophyllum nodosum* with knife during low tide.

Harvesting and commercial uses

Ascophyllum nodosum is the most important species of seaweed collected in Ireland and has been used for the past 40 years. During this period annual harvested tonnages (by Arramara Teoranta) have averaged over 30,000 tonnes, but have been as much as 65,000 t. The weed is mainly for use as the raw material for seaweed meal. Harvesting takes place all year round by several hundred mostly part-time seaweed harvesters on the bi-monthly Spring tide cycles. Weed cutting is still carried out by hand (Fig. 19) using a short sickle-like blade. The cut seaweed is gathered into clumps and encircled with rope to hold it together, to form a climín (literally a bundle). Climíní are then either transported by water (towed behind curraghs), or by road to the drying and milling facilities operated by Arramara Teoranta in Kilkieran, Connemara and near Dungloe in Co. Donegal. Preliminary trials with a mechanical cutter have taken place recently.

Harvested *A. nodosum* is used mainly in the production of seaweed meal which is exported for the extraction of alginates (see below). However, horticulturists, market gardeners, organic farmers and fruit growers are increasingly using both dried seaweed meal and liquid extracts in soil conditioning and crop spray applications. *A. nodosum* is the main ingredient in the production of popular liquid seaweed extracts like Maxicrop which is widely used for horticultural and agricultural applications; for example, in gardens, glass-house crops and orchards.

Seaweed-based manures are valued for their proven record of beneficial effects on plant growth and health attributed to their concentrations of important trace elements. The regular application of seaweed manure or spray is said to have the following benefits:

- the promotion of seed germination and growth,
- increases resistance to frost damage and drought,
- increases resistance to fungal and insect pests,
- fruit trees produce larger and more abundant crops of apples, oranges, bananas, tomatoes, pineapples, grapes, strawberries, peaches, etc.
- crops of potatoes, carrots, Brussels sprouts, beetroot also show increased yields.

Nutrition analysis

Ascophyllum nodosum contains high levels of nutrients and vitamins and trace elements, for example, barium, nickel, vanadium, selenium, cobalt, chromium, molybdenum and copper. A nutritional analysis is given below (Table 6).

Table 6. Nutritional analysis of *Ascophylum nodosum*.

Protein	5-12%
Fat	2-4%
Carbohydrates	42-64%
Mannitol	4.2%
Alginic Acid	26%
Laminaran	10%
Vitamin C	500-1650 ppm
Beta-Carotene	35-80 ppm
Vitamin B1	1-5 ppm
Vitamin B2	5-10 ppm
Vitamin B3	10-30 ppm
Vitamin B6	0.1-0.5 ppm
Vitamin B12	0.8-3 ppb
Vitamin E	260-450 ppm
Vitamin H	0.1-0.4 ppm
Vitamin K3	10 ppm
Calcium	1-3%
Iodine	700-1200 ppm
Iron	101-176 ppm
Magnesium	0.5-0.9%
Manganese	10-15 ppm
Sodium	3-4%
Zinc	70-240 ppm

Uses of alginates

In the absence of an Irish alginate manufacturing facility, Irish-produced seaweed meal has for 40 years been exported by Arramara Teoranta to Scotland for secondary processing to alginates, mainly for food applications. Alginates are natural polymers with a great range of commercial uses as low-cost thickeners.

Alginates, (E400-405) are commonly used as emulsifying, suspension, binding and stabilising agents in hundreds of foodstuffs including ice cream, tomato sauces, pet-food, fruit drinks, instant soups, jellies, instant champagne, salad dressings, spreadable mar-

garines, and many other products. Alginates are also used as a binder in the restructuring of food, for example in crabsticks and reconstructed meat. Their suspension, gelling and stabilising properties also have a diverse range of industrial applications, such as in the manufacture of paints, insecticides, water softeners, car polishes, ink-print binders for textiles and paper, seed capsules, for clarifying beer and many more uses.

Alginates are also widely used by the pharmaceutical and body-care industry as an ingredient in the manufacture of a great range of products. These include gastroesophageal reflux preparations, toothpaste, impression material (Zelex, a common dental gel containing alginates sets in 4.5 minutes), as a base for dental creams, jellies, hair sprays and hair products. Alginates have been shown to fix and remove radioactive strontium and other metal pollutants from the body by binding with them after which they are excreted from the body in the faeces.

(M.D.Guiry)

Fig. 20 Freshly harvested, wet *Ascophyllum nodosum* being loaded into a hopper at Arramara Teoranta's Kilkieran factory in Co. Galway, for processing into seaweed meal. Primary processing into seaweed meal consists of washing, mincing, kiln drying and sieving into different grades of meal. The resultant seaweed meal is either used as soil conditioner/ fertiliser, animal fodder supplement, liquid seaweed extract or transported to Scotland for alginate production.

Calcium alginate dressings are used in external and internal wound dressings to control bleeding. They are unique in that the gauze-like dressings can be left in the body where they gradually dissolve and are carried away by body fluids. On surface wounds, they can be dissolved with a sodium chloride solution avoiding painful disturbance of the surface scab of wounds, caused by pulling off traditional dressings. Another medical application, pioneered in Norway, involves making alginate beads and gels with encapsulation properties needed for a variety of applications such as slow-release tablet coatings. These tablets release desired levels of medication such as insulin into the intestine having passed through the stomach resisting digestion, within a protective alginate gel coating.

Pelvetia canaliculata

Common names

English: Channelled wrack, Cow tang.

Gaeilge: Dubhlamán (W. Clare), Caisíneach (Aran and Connemara).

Distribution

Pelvetia canaliculata is a very common small brown wrack in the upper shore zones and splash zones of the Eastern Atlantic from Iceland to Portugal.

Description

P. canaliculata is the smallest of the wracks. It is immediately recognisable by its position at the highest points of the intertidal shore. It attaches to rocky surfaces by a discoid holdfast and does not grow larger than 15 cm in length. Normally, it is olive brown in colour but it can often appear yellow or a much darker brown or green-brown. The narrow fronds are dichotomously branched with swollen, granular fruiting bodies at their tips. The partially inrolled, downward-facing, channelled fronds help to retain moisture. Additionally, its small size and surface area reduces the loss of moisture through evaporation. *P. canaliculata* can thus withstand long periods of exposure, which accounts for its dominance high on the shore.

(M.D.Guiry)

Fig. 21 ***Pelvetia canaliculata*** **in the upper shore zone**

Harvesting and commercial uses

Unlike the well-documented use of other wracks, such as *A. nodosum* and *Fucus* spp. as fodder supplements added to pig and cattle feed, the use of *P. canaliculata* for the same purpose is less well known. Drift seaweed was commonly used as fodder in the most barren western areas. This was a practice born more of desperation than desire, as drift seaweed is not an ideal food for animals, being more suited to a small part of a mixed diet. Given the low digestibility of seaweeds their main value lies in their high mineral, trace element and vitamin content, hence their suitability as fodder supplements. Farm animals mainly sheep adjacent to the shore frequently grazed on intertidal wracks, in particular *P. canaliculata* given its accessibility high on the shore. Several wracks including *P. canaliculata* were known in Connemara, as Muirín na muc in the 1930's and 1940's, suggesting that they were used as pig food.

P. canaliculata is the most edible of the wracks and is consumed occasionally as a sea-vegetable condiment on salads.

Nutritional analysis

P. canaliculata is particularly rich in selenium and vitamin C and contains many other trace elements. It is very similar in constituents to *F. vesiculosus* (Table 5).

Fig. 22 ***Pelvetia canaliculata***

THE RED SEAWEEDS OR RHODOPHYTA

Introduction

Some 275 species of red algae are found in Ireland most of which are quite rare and particular to certain habitats or geographical regions. There is a considerable range of colours in the various so-called red seaweeds from red or bright pink to a dark purplish-brown, to almost black. The range of colours are a result of the presence of two extra pigments, phycoerythrin (red) and phycocyanin (blue), which mask the green chlorophyll and other photosynthetic pigments. Further modification of colour can take place as red seaweeds are often bleached to a light brown or yellow in bright sunlight and can thus be confused with brown algae.

Any seaweeds growing on open rock on the seashore must be well adapted to tolerate strong wave action, drying out from sun and wind, extremes of air temperature and occasional soaking in rainwater that lowers the salinity. Red seaweeds tend to be small and delicate and are most sensitive to light, so they have a tendency to occupy the lower shore and subtidal or are found shaded by, or growing on wracks and kelp.

The most delicate species grow in the subtidal where wave action is much reduced, where fluctuations in temperature and salinity are minimal and where no danger of drying out exists. Less delicate red seaweeds are also found in the relative darkness of deep rock pools in the mid-shore. An exception to most red seaweeds are the hardy species of *Porphyra,* some of which are found high in the intertidal and can tolerate several days of drying out during neap tides, when the tide is insufficiently high to cover the plants.

Among the commercially important Irish red seaweeds are several species of calcareous algae known as 'maërl', which have a hard, pinkish-purple coral-like appearance. Deposits of dead maërl (bleached white), are washed up in Mannin Bay and Carraroe (Co. Galway) and a few other areas to form spectacular 'coral strands'.

Many types of red seaweed such as *Palmaria palmata* and *Polysiphonia lanosa* are found growing on the stipes (stalks) of kelp and wracks where they are described as being epiphytic. Some red seaweeds such as Carrageen moss (*Chondrus crispus* and *Mastocarpus stellatus*) are tough enough to withstand drying out when the rocks on which they live are exposed by the falling tide.

The search for therapeutic molecules from algae continues in pharmaceutical and biotechnological research and the numerous species of red seaweeds in particular have been identified as having considerable potential in these areas. Already, certain species of red algae have been used in the development of anti-coagulant compounds, while research on the anti-viral properties of other species continues.

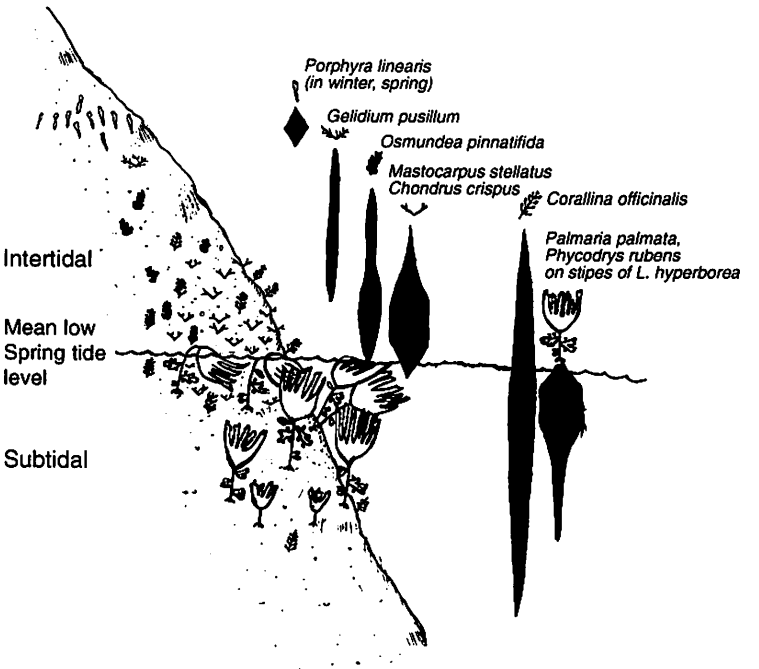


Fig. 23 The vertical zonation of red seaweeds at a typical rocky site of moderate wave exposure in Ireland. The kite diagrams show the abundance of different species at vertical intervals. The wider the band, the greater the abundance of a particular species at that level on the shore. (Jim Morrissey)

Palmaria palmata

Common names

English: Dillisk, Dulse, Shell dulse, Seagrass (Co's Kerry and Clare only).

Gaeilge: Duileasc (name given to larger plant), Creathnach (name given to smaller plant growing on mussel shells).

Distribution

Palmaria palmata is a common cold-water species of the middle to lower shore in many parts of Europe, and the North Atlantic coasts of America. In Europe, it reaches its southern limit in Northern Portugal and the Azores. In Ireland, *P. palmata* is common on all coasts where there is suitable rock, or on the stipes of *L. hyperborea* plants. There is some anecdotal evidence of larger plants being commonly found on the South and North-Eastern coasts of Ireland.

Description

P. palmata (Fig. 24) has a reddish-brown to dull dark red colour. It appears tough almost leathery, with flat fronds of 10-50 cm length, arising directly from a disc holdfast. In the lower intertidal it is found in clumps fringing rock pools or hanging from rocks shaded under wracks. It is also found occasionally as an epiphyte growing on *Fucus serratus*. In the subtidal it is found in abundance growing on the rough-textured stipes of the large brown kelp *Laminaria hyperborea,* along with other red seaweeds. The shape of the frond can vary considerably between an irregular fan-shape or a single frond with lateral marginal leaflets.

(M.D.Guiry)

Fig. 24 The broad form of *Palmaria palmata*

Harvesting and commercial uses

Carrageen moss (*Chondrus crispus* and *Mastocarpus stellatus*) and *Palmaria palmata* are by far the two most popular sea-vegetables used in Ireland, but other species such as *Alaria esculenta, Laminaria saccharina* and *Himanthalia elongata* are becoming popular. *P. palmata* is harvested all year round, but especially between Spring and Autumn when the vitamin content is said to be high. Sustainable harvesting techniques for *P. palmata* involve picking off the main mass of fronds, ensuring that the lower part of the plant and holdfast are left attached in order to facilitate quicker regeneration. Given favourable weather conditions and low Spring tides it is even possible to wade out at low water to pick clumps of epiphytic *P. palmata* growing on kelp stipes. *P. palmata* (Dillisk or Dulse), is a popular sea-vegetable on both sides of the Northern Atlantic famed for its rich, salty, nut-like taste and unique mouth feel. Dillisk is often eaten dried and whole as a sea-vegetable, but equally it can be added in flaked form to soups, breads and cakes for flavour, or as a relish with potatoes.

(M.D.Guiry)

Fig. 25 Smaller form of *P. palmata* known as 'Creathnach', growing on juvenile mussels.

In parts of the north and west of Ireland, there is a preference for eating a smaller type of *P. palmata* found growing on small mussels, known as Creathnach, or Shell dulse. In this case, the whole plant is torn off frequently accompanied by the small mussel shells. *P. palmata* is particularly popular in Northern Ireland, where it is known as dulse and is widely available as a bar snack, and in grocery stores.

Improved health awareness in recent years has resulted in a resurgence of interest and overall use of sea-vegetables, which is reflected in the growing number of Irish health-food shops that stock ranges of sea-vegetable products. While many of these products come from Asia, where a massive seaweed industry exists, there are a number of small Irish sea-vegetable companies supplying to both the domestic market and abroad.

Fig. 26 **Line drawing of *Palmaria palmata* growing epiphytic on stipe of the kelp *Laminaria hyperborea*.**

Dwindling numbers of committed harvesters, combined with the growth in popularity of sea-vegetables have led on occasion to an increase in demand for *P. palmata* beyond the current supply.

The recent shortfalls in supply of wild *P. palmata* have stimulated interest in cultivation of this and other species to meet the demands of an expanding market. Preliminary aquaculture trials of both *P. palmata* and *A. esculenta* in Co. Galway have shown that these species can be grown on long lines in more sheltered areas than their natural habitat. As a perennial seaweed, *P. palmata* is particularly suited to cultivation on ropes floating in the sea. Once a standing crop is established on ropes it can be harvested at intervals without having to reseed. Following harvesting, new blade growth emerges from the edges of cut surfaces and the crop regenerates by itself until the next harvest. It is likely that such commercial seaweed farming operations will develop in Ireland over the next few years.

Currently, harvesters are fetching between IR£500-800 per fresh tonne of hand-picked *P. palmata,* depending on quality.

Apart from sea-vegetable use, *P. palmata* has been used in the preparation of anti-perspirant products for the bodycare industry, while research is proceeding into potential medical applications based on the beneficial properties of *P. palmata* extracts.

Nutritional analysis

P. palmata contains high levels of protein, vitamin A and iron. It also contains several other vitamins, minerals and many trace elements. A nutritional analysis is given below (Table 7).

Table 7. Nutritional analysis of *Palmaria palmata*.

Protein	12-21%
Fat	0.7-3%
Carbohydrates	46-50%
Vitamin C	150-280 ppm
Beta-Carotene	663 i.u.
Vitamin B1	7 ppm
Vitamin B2	2-5 ppm
Vitamin B3	2-19 ppm
Vitamin B6	9 ppm
Vitamin B12	6.6 ppb
Vitamin E	1.71 ppm
Calcium	2000-8000 ppm
Iodine	150-550 ppm
Iron	56-350 ppm
Magnesium	0.2-0.5%
Manganese	10-155 ppm
Sodium	0.8-3%
Zinc	3 ppm

Porphyra Species

Common names

English: Nori, Laver, Purple laver, Sloke, Black butter, Purple sea-vegetable.

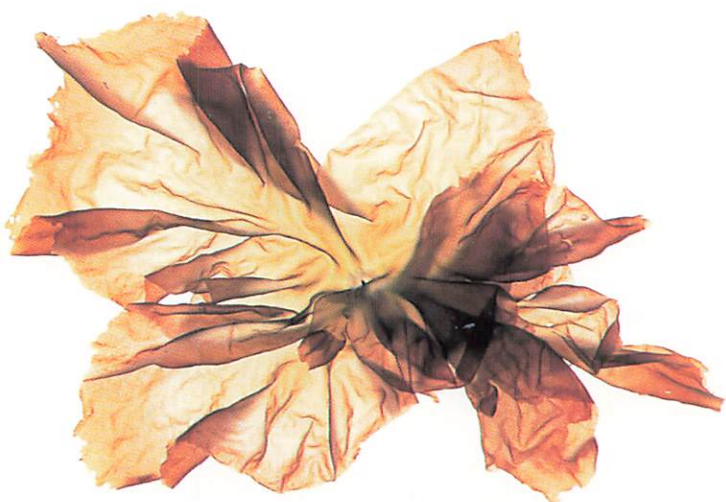
Gaeilge: Sleabhcán, Sleabhac, Sladaí

Distribution

Porphyra species are found on all European coasts from the high to the mid-intertidal, typically growing on rough-surfaced rocks, mussels and concrete breakwaters as well as on other seaweed species in wave-exposed places. In general *Porphyra* spp. can tolerate very high wave-exposure but are also found on more sheltered coasts often growing on rocks buried in sand. There are some 115 species of *Porphyra* world-wide but the main commercial species are *Porphyra umbilicalis, P. tenera, P. dioica, P. linearis, P. haitanesis* and *P. yezoensis*. In Ireland between 6-8 species of *Porphyra* plants have been identified to date, of which *P. linearis*, a winter annual, is said to be superior in taste. Unfortunately the available biomass of this species is low.

Description

When viewed at low tide flat against steep rock faces, piers and slipways, dried *Porphyra* may resemble strips of black plastic refuse sacks melted or stuck onto rocks. The green-rose-purple colour of the thin fronds is only apparent under the water when the plant frond unfurls. Generally, plants grow up to 20-30 cm long. In their earlier stages they may be coloured green becoming brownish purple, then light chocolate before turning black when ready to harvest. *Porphyra* is generally a winter crop that flourishes in temperatures between 4-9°C, although certain species can appear throughout the summer.



(M.D.Guiry)

Fig. 27 ***Porphyra umbilicalis***

Harvesting and commercial uses

Hand harvesting of *Porphyra* spp. for use as a sea-vegetable takes place from Spring to Summer on a small scale at various locations in the West Coast of Ireland. The major problem with harvesting *Porphyra* from the wild is the small amount of naturally occurring plants in any particular area and the low biomass of individual plants. Existing harvestable quantities are insufficient to sustain the harvesting necessary for a commercial nori manufacturing operation in Ireland. In addition, none of the species available are entirely suitable. In Asia, well-established large-scale aquaculture operations provide the large biomass of *P. yezoensis* required as raw material for the profitable Nori industry. In Ireland, aquaculture trials to develop farming and husbandry techniques for the production of large quantities of *Porphyra* species have yet to commence.

In Asia farmed *Porphyra yezoensis* is dried and fashioned into nori sheets for sale as a food and as a condiment. Nori is the world's most popular sea-vegetable being superior in its vitamin, trace element and protein content to all terrestrial vegetables. Japanese railway station buffets, hotels and restaurants serve nori as 'sushi'. Sushi is prepared by placing boiled rice and strips of vegetable, meat or fish on a sheet of nori, which is then rolled up and cut into slices. Nori is also flaked and used in biscuits and snack-food manufacture. Closer to home, *Porphyra* is popular in South Wales as 'laver bread' with the industry centred in Swansea. In making laverbread, boiled *Porphyra dioca, P. purpurea* and other species of *Porphyra* are boiled, sprinkled with oats and fried in bacon fat or butter. Recipes for *Porphyra* also exist around the Irish Coast where it is mainly boiled and used in more or less the same way.

Nutritional analysis

Porphyra species like all seaweeds are subject to seasonal variation in content but are generally very high in protein, vitamins and minerals. A nutritional analysis is given below.

Table 8. Nutritional analysis of *Porphyra umbilicalis*.

Protein	15-37%
Fat	0.12-2.48%
Carbohydrates	50-76%
Vitamin C	130-1110 ppm
Beta-Carotene	266-384 ppm
Vitamin B1	3-6 ppm
Vitamin B2	10-29 ppm
Vitamin B3	50-98 ppm
Vitamin B6	112 ppm
Vitamin B12	10-20 ppm
Vitamin E	5 i.u.
Calcium	2000-8000 ppm
Iodine	150-550 ppm
Iron	56-350 ppm
Magnesium	0.2-0.5%
Manganese	7-83 ppm
Sodium	0.5-3.2%
Zinc	41 ppm

Chondrus crispus (and *Mastocarpus stellatus*)

Common names

English: Carrageen moss, Carrageen, Carragheen, Irish moss, Mousse d'Irlande, Jelly moss.

Gaeilge: Carraigín, Cosáinín carraige, (*Mastocarpus stellatus* is also known as Clúimhín Chait).

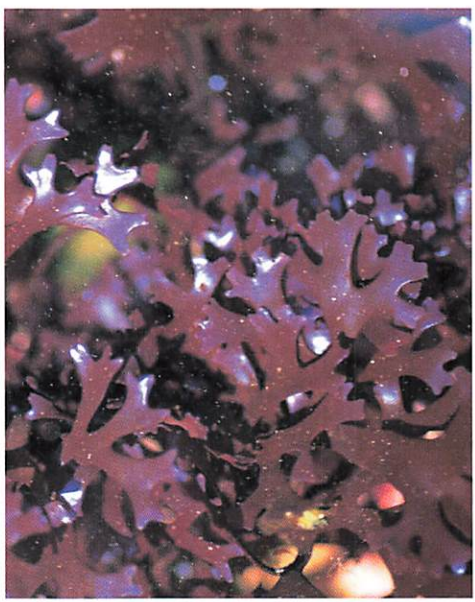
Distribution

Carrageen Moss is a generic term for *Chondrus crispus* and *Mastocarpus stellatus*. They are both very common red seaweeds found on both sides of the Atlantic, from Iceland south to Spain and Portugal. Generally both species are found in the mid-low shore on poorly drained rock surfaces and in rock-pools.

Description

C. crispus (Fig. 28, right) is a low bushy plant rarely exceeding 15 cm in height, with a variety of forms and colours, from dark red, brown-red, purplish green, and brownish yellow to whitish-yellow when bleached by sunlight.

(M.D.Guiry)



(M.D.Guiry)

Fig. 28 ***Mastocarpus stellatus*** **(left) and** ***Chondrus crispus*** **(right) collected as Carrageen Moss or Irish Moss. Note the iridescence on the branch tips of submerged** ***Chondrus crispus*****; this is common on healthy plants.**

Plants are normally 7-15 cm tall, with tough, flat fronds that divide regularly and often form a broad fan-shape tapering down to a narrow base and small disc-shaped holdfast. Underwater, the branch tips often have a violet iridescence that disappears when the plant is not submerged (Fig. 28, right).

The appearance of *C. crispus* depends largely on the wave exposure of the shore where it is found. In more sheltered estuarine shores, the stipes (stalks) are short and the plant bushy with small divisions at the ends, whilst on wave-exposed shores the stipe is longer and the plant narrower with sparser branching.

C. crispus may be readily distinguished from *M. stellatus* (Fig. 28) by the fact that its frond margins do not become inrolled into a channel, and also the latter tends to have numerous small fruiting bodies on stalks emerging from the frond surface. But both species are harvested as Carrageen moss and used for the same purposes.

Harvesting and commercial uses

In terms of harvested tonnage Carrageen moss is still the most important and well-known Irish sea-vegetable. *C. crispus* and *M.stellatus* have long been hand picked in the mid-and lower intertidal from late Spring to early Autumn, dried and/or bleached for sale in Ireland and abroad as 'Carrageen moss' or 'Irish moss'. Sustainable practices that have evolved for harvesting Carrageen involve pulling only the bushy top half of the frond off leaving holdfast and base undamaged. Harvesting of Carrageen by Irish pickers has generally been sustainable with individual pickers developing an intuitive feel for the annual cycles of their local stock. Careful harvesting early in the season (late Spring), can lead to good regeneration of harvested beds and a possible second harvest by the end of the season. Given favourable conditions collectors can harvest up to 150 kg of wet weed per Spring tide.

The gelling properties for which Carrageen moss is famous, demonstrated most memmorably in the mousse-like blancmange, are due to the presence of the hydrocolloid carrageenan. These polysaccharides have largely replaced agars as low-cost food ingredients valued for their thickening, suspension, preservative and fat and milk-protein stabilization properties. Food applications for carrageenans (E 407) are many, including canned foods, desert mousses, salad dressings, bakery fillings, ice cream, instant deserts and canned pet-foods. Industrial applications for purified extracts of carrageenans are equally diverse. They are used in the brewing industry for clarifying beer, wines and honeys, although less commonly than previously. Traditionally, carrageenans were used in the soap industry, for leather curing, and in the manufacture of paper and linen (for these last two uses it provided a soft finish to which print will adhere). They are also used for the even distribution of antibiotics through ice for the preservation of fish on fishing boats.

Many people, without knowing it, use or consume carrageenans as well as other hidden seaweed extracts on a daily basis, whether in foodstuffs, toothpastes, or in various lotions and creams. For example, carrageenan gel is also used mixed with gums as the gradual release agent in perfumed air fresheners for toilets, cars, etc.

Carrageen also has a large number of medical applications, some of which date from the 1830's. It is still used to make traditional medicinal teas and cough medicines, to com-

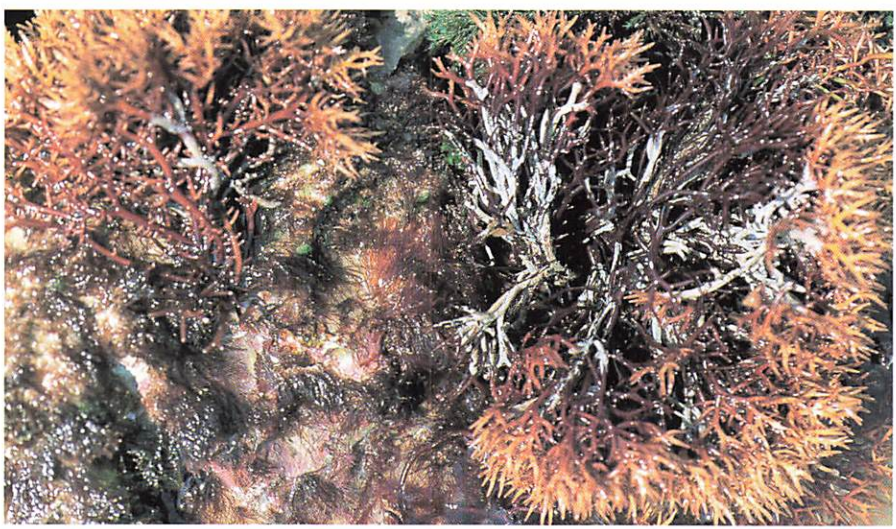
bat colds, bronchitis, and chronic coughs. It is said to be particularly useful for dislodging mucus and has anti-viral properties. Carrageenan is also used as a suspension agent and stabiliser in other drugs, lotions and medicinal creams. Other medical applications are as an anticoagulant in blood products and for the treatment of bowel problems such as diarrhoea, constipation and dysentery. It is also used to make internal poultices for the control of stomach ulcers.

Nutritional analysis

Chondrus crispus contains high levels of vitamin A, vitamin B12 and high iodine. It also contains protein, sugar, starch, fat, vitamin B1, iron, sodium, phosphorus, magnesium, copper, calcium, and many other trace elements. A nutritional analysis is given below (Table 9).

Table 9. Nutritional analysis of *Chondrus crispus*

Protein	11-18%
Fat	1-3%
Carbohydrates	55-66%
Vitamin C	10-30 ppm
Vitamin B12	0.6-4 ppm
Calcium	0.9-1.3%
Iodine	200-300 ppm
Iron	170-210 ppm
Magnesium	6700-8351
Manganese	2-28 ppm
Sodium	2-2.6%
Potassium	3.4%



(M.D.Guiry)

Fig. 29 ***Chondrus crispus***

Asparagopsis armata

Common names

English: Harpoon Weed.

Gaeilge: Feamainn mhuirgha.

Distribution

Asparagopsis armata was introduced to Europe from the Southern Hemisphere, probably from Australia. It was first recorded in Europe in 1925 at Cherbourg and at Biarritz, before arriving in Ireland at Galway in 1939, where it is now well established in open sandy pools of the lower intertidal and subtidal. Gametophytes are found grown epiphytically, mainly on *Ulva* spp. To date, *A. armata* has been commonly recorded in the following areas of the Irish coast: Carnsore Pt, (Co. Wexford); Magharees Lagoon, (Co. Kerry), and from Finavarra, (Co. Clare) north to Clare Island (Co. Mayo). An alternate phase, the tetrasporophyte juvenile plants appear as small red tufts epiphytically on *Corallina officinalis*. These plants are more widely distributed on Western and Southern Coasts of Ireland.

Description

The *A. armata* tetrasporophyte is a bushy, many branched, filamentous seaweed, occurring in dense cotton-wool-like tufts to 15 mm in diameter (Fig. 31). Its natural pale red-purple colour quickly degenerates when removed from the water becoming distinctly orange. It occurs all year round, but is most obvious from October to March. The male and female gametophytes (Fig. 32) occur from June up to September (occasionally over-wintering). These plants are bushy, with a cylindrical axis up to 1 mm wide and 200 mm long, arising from bare, creeping stolons. They are irregularly branched, with four rows of branchlets. It has simple, short, branchlets alternating with longer ones with four rows

(Stefan Kraan)

Fig. 30 **Cultivated *Asparagopsis armata* on ropes.**

of simple filamentous ramuli. Lower branchlets are unbranched, long, and tapered, with harpoon-like barbs. Key characteristics are the harpoon-like hooks and bushy habit. It has an association with *Ulva* species but may also be found free-floating. Both phases readily reproduce vegetatively with ease. Drift specimens of the gametophyte readily attach to other algae by barbed branchlets and produce new shoots. This opportunistic species appears not to be eaten by herbivores and has a rapid growth rate.

(M.D.Guiry)

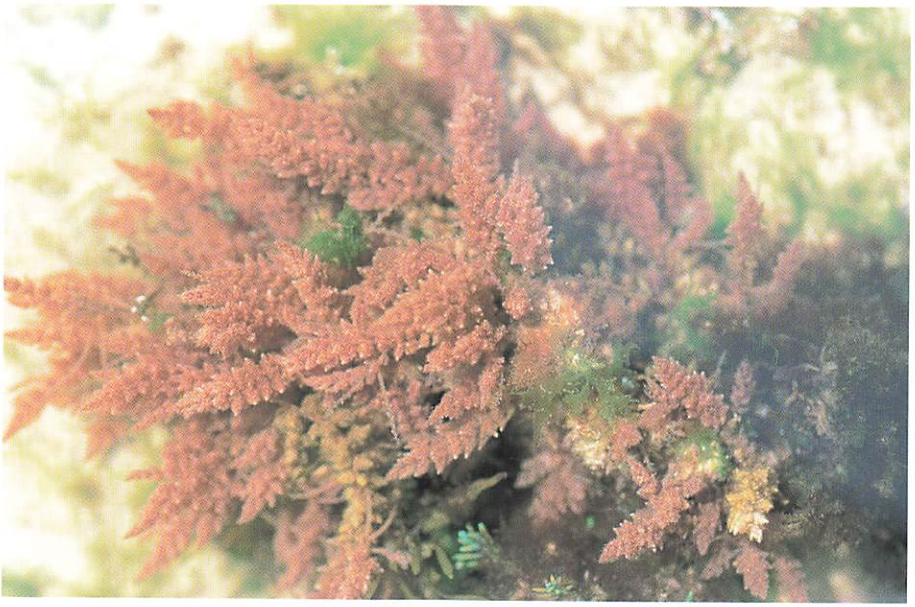
Fig. 31 Tetrasporophyte of *Asparagopsis armata*

Harvesting and commercial uses

No harvesting from wild populations of *A. armata* has been carried out in Ireland to date. *A. armata* is a species that has only recently been identified as having commercial value. Current interest from European cosmetic firms in extracts from this species has led to it being cultured on longlines in Connemara (Fig.30). Extracts from the red weed are used as an active ingredient in cosmetic preparations. At present, this is the only commercial-scale, seaweed aquaculture operation in Ireland. However, there would seem to be potential to expand aquaculture efforts of this species as well as certain popular species of sea-vegetables.

Nutritional analysis

None available at present, but the species is not, and should not be eaten. It contains bromophenols that may be hazardous if inhaled and plants should not be kept in poorly ventilated areas. Ideally, gloves should be worn when handling plants on ropes.



(M.D.Guiry)

Fig. 32 Gametophytes of *Asparagopsis armata* or Harpoon Weed

Maërl spp.
(Phymatolithon calcareum, Lithothamnion corallioides)

Common names

English: Maërl is the collective name for the detached coralline algae also known as rhodoliths.

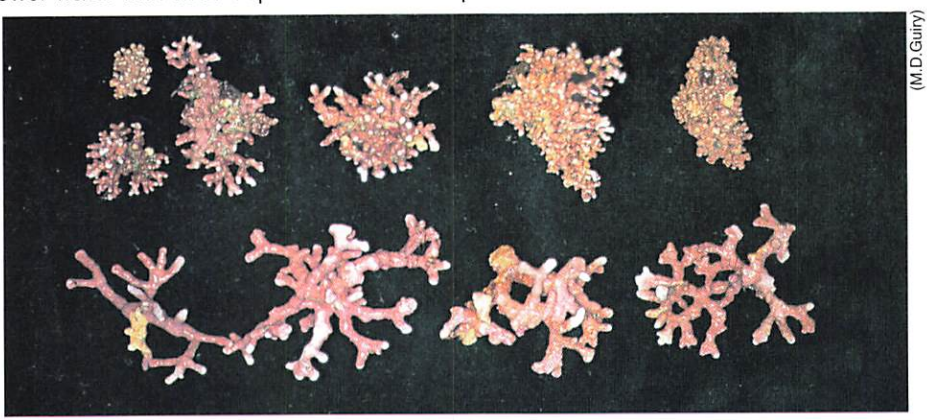
Gaeilge: Griúan, is a common name for all stony pinkish seaweeds

Distribution

Maërl is a generic name given to the unattached calcareous red seaweeds found in Europe from Norway south to the Mediterranean. These subtidal red seaweeds extend down to a depth determined by the clarity of the water. In clear water off the Aran Islands maërl has been recorded down to 32 m but more commonly is found down to 10-15 m depth in relatively turbid coastal waters. The main Irish maërl deposits are in Galway Bay, Mannin Bay, Bantry Bay, Kenmare River, and Roaringwater Bay. Significant maërl beds are present off Falmouth in SW England, Iceland, Norway, Scotland, and Brittany, France.

Description

Slow-growing maërl species are calcareous red seaweeds meaning they are coated with hard calcareous deposits, mainly of calcium and magnesium carbonates. Plants are between 2-10 cm in diameter with irregular branching giving them a branched coral-like appearance. Live *L. corallioides* plants (Fig. 33) are a reddish-pink colour whereas *P. calcareum* plants may have more of a steel-blue hue. When dried both species turn a blue-grey with shore-cast plants bleaching to a pale cream or brilliant white colour. This resemblance in colour to true coral when bleached, combined with similarities in their branched shape accounts for the common misidentification of dead maërl beach deposits as coral strands. Reef-building animal corals do not occur on Irish shores. Maërl plants lie unattached at the bottom of the sea forming extensive banks in certain areas, the upper layers of which are alive. There is a tendency for live maërl to exist in shallower water with dead deposits found in deeper water.

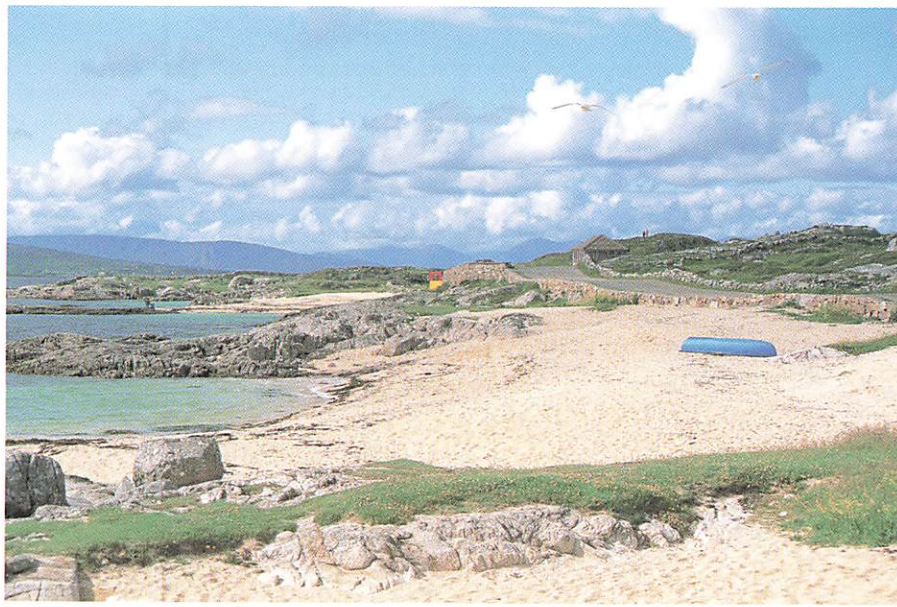


(M.D.Guiry)

Fig. 33 **Two forms of the maërl species *Lithothamnion corallioides***

Harvesting and commercial uses

In France, maërl deposits off Brittany lie in banks up to 15 metres thick while maërl beds in Ireland are less substantial, generally ranging from 2-200 cm in depth. Celtic Sea Minerals, based in Co. Cork are licenced to harvest maërl at a single site near Castletownbere in Bantry Bay. They use a suction pump dredger for harvesting purposes and the processed product is used as a functional ingredient in foods, dietary supplements, personal care applications as well as in horticultural and agricultural applications.



(M.D.Guiry)

Fig. 34 Coral strand at Carraroe, Co. Galway formed by cast-up, bleached maërl,

Spectacular coral strands at Ballyconneely, Carraroe (Fig. 34) and Mannin Bay in Co. Galway consisting of cast-up bleached maërl particles represent an important tourist amenity attracting many visitors to these areas.

In both agriculture and horticulture, the use of maërl as a magnesium source in animal fodder and as a combined soil conditioner and mineral supplement for acid soil has received a boost from the growth of organic farming practices. Calcified seaweed powders have also seen use in the area of thalassotherapy where they have been used to formulate pastes for relief of arthritic pains. Finely-milled food-grade maërl is also used in the food ingredients industry as a calcium supplement for addition to a wide range of processed dairy products and other foodstuffs. Given its high pH it is also used for the treatment of acidic drinking waters and in other water filters.

Conservation issues involving maërl concern themselves with its slow growth rate and recovery rate after disturbance, as well as its provision of habitat for small bottom-

dwelling creatures. Intense exploitation of maërl off France since the 1970's has caused a significant reduction in stocks. In Ireland some bays with prominent maërl beds are being afforded protection through current marine SAC* designation.

Mineral analysis

Being calcareous algae, maërl primarily contain high levels of calcium and magnesium but also contain many trace elements and minerals. A mineral analysis is given below (Table 10).

Table 10. Mineral analysis of maërl species.

Calcium	34%
Magnesium	2.4%
Sulphur	0.45%
Iron	25 ppm
Manganese	125 ppm
Boron	16 ppm
Sodium	310 ppm
Iodine	160 ppm
Arsenic	<1 ppm
Flourine	200 ppm
Molybdenum	39 ppm
Chromium	13 ppm
Copper	10 ppm
Zinc	37 ppm
Mercury	<50 ppb
Aluminium	<5 ppb
Nickel	<30 ppm
Lead	460 ppb
Cobalt	6 ppm
Selenium	1 ppm
Cadmium	0.2 ppm

Mineral analysis courtesy of Celtic Sea Minerals Ltd

* Special Areas of Conservation

THE GREEN SEAWEEDS (CHLOROPHYTA)

Introduction

Of the three algal divisions, green seaweeds show the least variation in colour usually being a bright grass-green colour. They owe this green colour to the presence of the photosynthetic pigment chlorophyll, which is not masked by other coloured pigments as in the red and brown algae. The presence of chlorophyll, similar to terrestrial plants, enables them to flourish in the higher shore and in places such as estuarine mudflats and sandbanks. In tropical regions with clearer water (less particulate matter in the water), green algae may occur at depths down to 250 m. In Ireland there are about 80 species of green seaweed.

Certain green seaweeds especially *Ulva* and *Enteromorpha* spp, are associated with macroalgal blooms during the Summer that have caused considerable problems to local authorities in France, Southern UK and in Belfast, Cork and Dublin in Ireland. In these areas, localised coastal eutrophication from sewage input stimulates rapid growth of *Ulva* and to a lesser extent *Enteromorpha,* which are then cast up on beaches producing large piles of decomposing weed. Mechanical removal of these by municipal authorities is required, particularly in tourist areas to clear beaches of these unsightly drifts which can cause offensive smells.

The green seaweeds show less distinct zonation on the shore than other seaweeds. *Enteromorpha* species are common at all shore levels, while *Ulva* species extend from the mid-shore right down to the subtidal. Overall, one can say that the green seaweeds have a greater aptitude for life in shallow waters (but can be found in deep waters also), while brown algae preferably occur at depths down to 15 metres and red algae have the greatest propensity of the three for living in deeper waters.

Ulva rigida

Common names

English: Sea lettuce.

Gaeilge: Glasán (generically applied to any *Ulva*)

Distribution

Ulva rigida is found worldwide in sheltered to moderately exposed situations on rocks, submerged structures, and in pools and shallow waters near low watermark. Along with other species of the genus, it thrives in brackish water with organic enrichment. It is found commonly on all Irish coasts but is particularly common on sheltered or moderately exposed shores.

(M.D.Guiry)

Fig. 35 ***Ulva rigida***

Description

Ulva is a large genus of marine and brackish water green algae. It is edible and plants are often known as Sea lettuce. The thallus is flat and blade-like and is composed of two layers of cells. There is no differentiation into tissues; all the cells of the plant are more or less similar except for the basal cells, which are elongated to form attachment rhizoids. The two most common *Ulva* species in Irish waters are probably *U. rigida* and *U. lactuca.*

The thin wafting fronds of *U. rigida* (Fig. 35), and other species of *Ulva,* when waterborne, resembles lettuce leaves, hence the name 'Sea-lettuce'. Plants are generally pale green when young, bright green when mature, and dark green when old.

U. rigida may be up to 45 cm long with a perennial holdfast. The fronds are often as broad as they are long, are of irregular shape, very thin, membranous, and growing in bunches. *Ulva* is easily torn loose from substratum accumulating in large drifting mass-

es or cast up on the beach. It is likely that between 5-7 species of *Ulva* occur in Irish waters but further studies are required.

While *Ulva* has a theoretical life history in which gametophytes and sporophytes alternate in a cycle, most populations reproduce by asexual zoospores, often released in a lunar or semi-lunar cycle.

Harvesting and commercial uses

Ulva is another sea vegetable used in the preparation of sea-vegetable salads. Drifting plants can be harvested if fresh but care should be exercised in using plants from harbours and industrialised areas. Fresh plants are rather coarse and tough in texture and should be dried and chopped. As well as a main constituent of sea vegetable salads *Ulva* is also used in soups and cooked with other vegetables, fish and meat dishes. It can be used fresh or washed in seawater and dried. Currently in Ireland, only one or two sea-vegetable processors are using dried *Ulva* as part of a dried sea-vegetable mix sold in 50g packages. Young tender plants are harvested in Spring for taste and early Summer for high vitamin C content.

As mentioned above, blooms of *Ulva* can be a nuisance in nutrient-enriched areas close to sewage outfalls. Cork Harbour, Dublin Bay and Belfast Lough all have populations of *Ulva* that often grow rapidly in the Summer covering large areas of mudflats. These so-called green tides are especially troublesome when they start to decompose as the unpleasant odours that result can negatively impact on the amenity value of beaches and require clearing up by the local authorities. In Brazil, coastal farmers use manure made from gathered *Ulva* species mixed with other seaweeds. In Dublin, seaweed from Dollymount and Sandymount strands is either sent for composting or to landfill by the local authority depending on the degree of tainting.

Nutritional analysis

U. rigida contains high levels of iron, Vit. B12, manganese and magnesium. A nutritional analysis is given below (Table 11).

Table 11. Nutritional analysis of *Ulva rigida*.

Protein	15-25%
Fat	0.6-1%
Carbohydrates	42-46%
Magnesium	2.8%
Vitamin A	4286
Vitamin C	100-200 ppm
Vitamin B3	98 ppm
Vitamin B12	6ppm
Calcium	7300
Iodine	240 ppm
Iron	870-1370 ppm
Manganese	347 ppm
Sodium	1.1%
Potassium	0.7%

Enteromorpha intestinalis and *Enteromorpha compressa*

Common names

English: Sea Grass

Gaeilge: Glasán, Líneáil Ghorm.

Distribution

The genus *Enteromorpha* is extremely common. Anyone who has slipped on green seaweed on boat slipways has already encountered it. Plants consist of very similar green seaweeds on all shore levels, found in bright green mats around the whole of the Irish coast, Europe and North America. *Enteromorpha* is present on a wide variety of substrata including rocks, estuary mudbanks, muddy sandflats, slipways, harbour walls and in sheltered pools. It is commonly found in brackish areas, near freshwater inflows and in the splash zone above the high water mark. Rapid growth occurs in Winter and Spring so that it forms a thick green carpet by early Summer. Lengths often break off and float in intertidal pools or in the sea where they are inevitably cast up onto shores by the tide.

Description

Two similar species are widely distributed in Ireland, *Enteromorpha compressa* (Fig. 36), and *E. intestinalis*. Both are mid to bright green with a maximum length of 15-30 cm. *E. compressa* fronds are usually flattened and less than 5 mm broad with a branched appearance. It is very common on all shores. *E. intestinalis* is more common in brackish sheltered waters and is often inflated like a large intestine.

(M.D.Guiry)

Fig. 36 ***Enteromorpha compressa*** **on 'coral' sand (cast-up maërl particles).**

The fronds of *E. intestinalis* are normally broader than those of *E. compressa* but are nipped in at irregular intervals along their length and swell with gas during growth. *E. intestinalis* is remarkably tolerant of low salinities and is often found growing in freshwater. Both species are used for the same applications.

The flat limestone terraces of the South West coasts of all three Aran Islands, particularly where freshwater seeps out along cracks, are covered with spectacular large carpets of *Enteromorpha* that bleach white during the Summer months.

Harvesting and commercial uses

Despite the abundant resources of this seaweed around the Irish coast there has been little use of *Enteromorpha* in Ireland beyond some small-scale drying as a sea-vegetable, and use as fertiliser when mixed in with total drift. However, given that in Asia *Enteromorpha* is farmed on netting and widely sold as Green nori, there is potential for its commercial exploitation as a sea-vegetable in Ireland and for the export market to Europe. There is some usage currently in France.

Enteromorpha is eaten raw as a salad in many parts of the world. It is also sun dried, toasted or roasted, and crumbled into a fine flakes or powder to be used in cooking in the same manner as any herb. In Brazil, both *Enteromorpha* and *Ulva* species are used as manure by coastal farmers.

Like *Ulva*, its mass appearance can be a consequence of coastal eutrophication, especially in the vicinity of seaside towns. It is regarded as a nuisance when large drifts appear and decompose on tourist beaches, requiring action by local authorities to remove it. As a consequence of these unsightly drifts in proximity to towns, outfalls, etc., *Enteromorpha* abundance is often used as an indicator of eutrophication, and pollution. This assumption is not necessarily correct as *Enteromorpha* spp. grow equally well in areas of clean water with strong currents, which may have a similar effect of supplying large amounts of nutrients.

Nutritional analysis

Enteromorpha species have a high content of magnesium, sodium and iron along with many other trace elements and vitamins. A nutritional analysis is given below (Table 12).

Table 12. Nutritional analysis of *Enteromorpha* spp.

Protein	10-18%
Fat	0.5-1.7%
Carbohydrates	48%
Vitamin C	40-122 ppm
Calcium	8200-9400 ppm
Iodine	70 ppm
Iron	152 ppm
Magnesium	2.6-2.8%
Manganese	1-12 ppm
Sodium	7.3-8.4%
Potassium	0.7%

Codium fragile

Common names

English: Fleece, Sponge seaweed, Sponge-weed, Green sea velvet, Sponge tang.

Gaeilge: Spúinse.

Distribution

Codium fragile is relatively common in upper and mid-shore rock pools of sheltered areas of rocky coasts of Europe and the Southern coasts of North America, as well as Australia. Two subspecies of *C. fragile* have been introduced, perhaps by shipping, into Ireland: subspecies *atlanticum* before 1800 and subspecies *tomentosum* before 1930. A number of these subspecies have been introduced, probably from Japan, all around the world. In some places it has proved to be a pest, fouling shellfish beds and harbours but no such problems have thus far been recorded in Ireland.

Description

C. fragile plants (Fig. 37) are deep green in colour and up to 45 cm in length. There are numerous thin branches dividing dichotomous with a distinctive waterlogged spongy texture and felt-like appearance.

(M.D.Guiry)

Fig. 37 ***Codium fragile.***

Harvesting and commercial uses
At present, *Codium* is rarely used in Ireland but this situation may change as palates evolve and people experiment with a wider range of sea-vegetables. It is used in Asia mainly as a food when fresh and is also used in a dried state to make tea. It is added to soups whole and chopped when dry into other dishes. Sustainable harvesting or aquaculture of *Codium* for export may have potential in the future if a market were to be identified.

Codium contains high levels of agaropectin, a gel-forming substance. As a result of the acute energy crisis in the 1970's there was a strong impetus for research in the US into the concept of marine seaweed farms as a source of sustainable bio-fuel. At the time *C. fragile* along with *Gracilaria* spp. and *Laminaria saccharina* were cultivated in trials to provide the biomass for the bioconversion process. Since then, natural gas supplies have stabilised so work in this field has continued in the US at a research level rather than with immediate industrial implementation in mind.

Nutritional analysis
Codium contains high levels of iron. It also contains sugar, some starch, and trace elements and is similar in nutrient contents as previously described for *Ulva* and *Enteromorpha* spp.

Bio-remedial applications of Seaweed aquaculture
The regular removal of farmed or natural seaweed biomass from bays would seem an effective way to help reduce the damaging effects caused by the high nutrient loads in Ireland's coastal seas. A basic requirement for seaweed growth, in addition to the fundamental requirement for light, is a readily available source of nutrients. Nutrients are readily available in coastal waters as a consequence of land and municipal runoff and are often strongly concentrated in semi-enclosed water bodies to the extent that harmful eutrophication can occur, impacting negatively on aquaculture and other marine activities in those areas. The unique ability of seaweed to mop up waste nutrients from various sources by converting it to frond growth has favourable implications for these situations with the added advantage that a crop of commercial value is produced. The cultivation and regular harvesting of commercially valuable seaweeds in the eutrophicated neighbourhood of bays and near fishfarms could be effectively used to recycle waste nutrients originating from municipal waste as well as fish excretion and waste feed pellets from fishfarming sites.

The dual benefits of such a system are a cleaner marine environment with an additional seaweed crop of value representing a diversification of aquaculture effort.

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Glossary of terms used in the text

Agar: Commercially valuable phycocolloid extracted from certain red algae (mainly *Gelidium* and *Gracilaria* spp.), widely used in food, and pharmaceutical industry. In particular, agar is used as a gelling agent in jams, jellies and canned food. Also used as a culture medium in microbiology where it is known as agar-agar.

Algae: Diverse assemblage of primitive plant-like organisms ranging from unicellular planktonic species to large benthic seaweeds. All lack true roots, stems and leaves and none produce flowers or seeds.

Algal bloom: Sudden increase in phytoplankton population, normally during the Summer and early Autumn, brought about mainly by abundant supply of nutrients due to favourable environmental conditions and perhaps by heavy anthropogenic inputs of nutrients. In this case, zooplankton (as grazers of phytoplankton), cannot keep up with the sudden increase in phytoplankton population resulting in the formation of an algal bloom. Blooms are becoming more common in Irish coastal waters where they have caused harvesting bans of shellfish in many bays during early Autumn.

Alginate: Commercially valuable phycocolloid extracted from brown seaweeds, a salt of alginic acid. Found in cell walls of brown algae where it gives stiffness in the same way that cellulose does in land plants. Extracted from brown seaweeds such as *Laminaria digitata, L. hyperborea* and *Ascophyllum nodosum* and purified into alginate powders for use in a great number of food, medical, cosmetic and industrial applications.

Algotherapy: Therapy involving seaweeds, usually in the form of seaweed baths, wraps, face masks or paste applications.

Annual: A plant that completes its life cycle in one year or less; for example most plants of *Himanthalia elongata.*

Bioconversion: The conversion of a substance into another substance as a result of biological activity. For example, the production of methane gas from *Laminaria digitata.*

Biomass: The total weight of organisms in a given environment.

Carageenan: Commercially valuable phycoccolloid extracted from red seaweeds such as *Chondrus, Mastocarpus, Eucheuma* and *Kappaphycus.* This polysaccharide is used in many food and industrial applications, including canned pet-food and ice-cream. Because of its lower cost, carrageenan has replaced agar in some foodstuffs.

Cellulose: Type of polysaccharide that acts as the main constituent of plant cell walls.

Chimera: An organism consisting of at least two genetically different kinds of tissue as a result of mutation or grafting, etc. In the case of wracks, two different species can grow together as one entity.

Chlorophyll: This is the fundamental green pigment that carries out virtually all photosynthesis.

Conceptacle: The cavity that contains the reproductive tissue in some wracks.

Coralline: A term referring to some members of the red algae (Rhodophyta), which become encrusted with lime. Examples of coralline algae are the maërl species.

Dichotomous: Branching by repeated divisions into two equal parts.

Distal: Situated farthest from the point of attachment, i.e. the end or tip of the frond.

Dominant: A species that is particularly abundant or more prevalent than others, when importance or prevalence is shared between two or more species, they are called co-dominants.

Ecotype: The product arising as a response of a genotype of an organism to the particular habitat in which it lived.

Epiphyte: A plant that grows attached to another and uses it solely for the purposes of support. Epiphytes are non-parasitic.

Eutrophication: A process by which pollutants cause a body of water to become over-rich in organic and mineral nutrients, so that various organisms grow rapidly and deplete the oxygen supply.

Frond: The blade or main leaf-like part of seaweed. It often bears the reproductive cells, for example, the receptacles at the tips of *Fucus vesiculosus* fronds.

Gametophyte: That part of the life-cycle that gives rise to the sex cells which on forming produce the sporophyte phase.

Genotype: The genetic make-up of an individual.

Habitat: The kind of place in which a plant is found growing.

Herbivores: Grazing animals that solely eat plant material, in this case seaweed, such as periwinkles, sea urchins, abalone and limpets.

Iridescent: Frond surface reflecting light as a blue or green sheen when submerged, very noticeable in submerged *Chondrus crispus*. It may be warning off grazing animals.

Midrib: A continuation of the stipe visible as a prominent line running along the length of the frond in its middle.

Morphology: The shape, general appearance or form of an organism. Within the same seaweed species the morphology can vary considerably depending on the nature of the environment it inhabits. For example, Carrageen moss found in sheltered areas is short, much branched and bushy, while in exposed habitats the same species is longer, narrower and sparsely branched.

Perennial: A plant that continues to live for several years, though parts of it may die back or be shed periodically.

Photosynthesis: The process by which plants convert carbon dioxide and water into food for themselves using the energy of light absorbed by photosynthetic pigments with the release of oxygen.

Phycocolloids: Phycocolloids have the ability to give viscosity, gel strength and stability to aqueous mixtures, solutions and emulsions and are used in the food and pharmaceutical industries, seaweed phycocolloids are polysaccharides.

Polymers: Compounds such as starch or alginate that have large molecules made up of many relatively simple repeated units. Polymers can also be synthetic compounds, such as Perspex.

Polysaccharide: A type of polymer in the form of a large carbohydrate molecule. Polysaccharides are important as storage molecules (such as starch) and as reinforcing materials (cellulose and alginates) in plants and algae. Useful polysaccharides extracted from brown seaweeds are alginate, while agars and carrageenans are extracted from red seaweeds.

Receptacle: The swollen tip of a frond branch carrying the reproductive organs.

Rhizoid: A hair-like structure that functions as a root, penetrating a substance, giving anchorage and absorbing nutrients.

SAC's: Special Area of Conservation, marine and terrestrial conservation areas protected by EU environmental directive.

Scour: Cleaning by rubbing with something rough. In this case the action of waves throwing abrasive particles such as sand against rocks. In colder climates, the attrition of ice floes against rock causes severe ice scour leaving certain levels of the shore bare of seaweed cover.

Spore: Normally a microscopic asexual reproductive body in plants produced by either haploid or diploid generations.

Sporophyte: The stage in the lifecycle during which spores are produced.

Stipe: The stalk or stem-like portion of the seaweed.

Stolon or runner: A long slender stem running along the surface of the ground, whose function is to allow vegetative propagation in an area.

Substratum: A description of the shore or objects on which seaweed are attached, i.e. rock, mussel shells, stones. Unsuitable substratum for attachment of most seaweed would be unstable material such as sand or mud. Not to be confused with 'substrate' which is a chemistry term. Plural is substrata.

Tetrasporophyte: Diploid phase of some algal life cycles that forms an independent plant, e.g., the Falkenbergia-phase of *Asparagopsis*.

Thalassotherapy: Therapy involving the sea, consisting of using seafood, sea air, seawater, algotherapy etc. Well established on the continent where top-class thalassotherapy centres operate largely along the French Atlantic coast. Now becoming popular in Ireland.

Thallus: The whole plant body in seaweeds, which shows no differentiation into holdfast, stipe and frond.

Turbidity: A measure of the suspended matter in water, which causes it to be cloudy and cuts down on the light transmitted through water. Levels of turbidity and water type play an important part in determining the depth to which seaweeds can grow. Light penetration is poor in very turbid waters and hence seaweeds will only be found in shallow waters. In clear waters of low turbidity, such as the Bahamas, certain seaweeds can be found growing to depths in excess of 250 m.

Xylan: Polysaccharide occurring in the cell walls of some algae.

Zonation: The division of an area into zones that experience particular physical conditions. This is particularly clear in the distribution of animals and plants on the rocky seashore, where, for example the sublittoral zone (below low water mark) is followed by the lower shore, middle shore, upper shore and splash zone, each with their characteristic flora and fauna. The brown seaweeds show the most distinct pattern of zonation.

Zoospore: An asexual spore that moves indepentently using flagella (whip-like hairs).

Zygote: The fertilised ovum before developing further.

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