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Assessment of the Effects of Commercial Seaweed Harvesting on Intertidal and Subtidal Ecology in Northern Ireland

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Assessment of the Effects of Commercial Seaweed Harvesting on Intertidal and Subtidal Ecology in Northern Ireland

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Executive Summary

1. Marine plants have been utilised by man for hundreds of years, collected traditionally for food, medicines and fertilisers. Seaweeds now play a wide and varied role in modern life as they are increasingly being exploited as a food resource and a source of industrial and pharmaceutical chemicals. Seaweeds as primary producers provide the foundation for aquatic food webs and habitat for marine flora and fauna. Management on an ecological basis is essential to ensure that a balance is achieved between the importance of seaweeds in marine ecosystems and their exploitation by humans.

2. This report documents the current status of the seaweed industry in Northern Ireland, and evaluates the potential effects of seaweed harvesting on designated features and priority habitats and species, and on coastal processes. This was achieved by carrying out personal and telephone interviews with individuals involved in and associated with the industry, and by reviewing published and grey literature on seaweed harvesting worldwide.

3. At present, three commercial seaweed harvesting companies have been identified in Northern Ireland, although small scale collection is also seasonally customary. Twelve species of seaweed are commercially harvested as fresh vegetation or drift, beach-cast seaweed. Collection is at present carried out largely by non mechanical means: harvesters use boats for shore access, vehicles for the transportation of the harvest, and diving and cutting equipment. Seaweeds are marketed for consumption as sea vegetables, beauty and health products and land fertilisers.

4. The international seaweed industry value exceeds US $6 billion annually, which is an important driving factor for the NI seaweed industry. Other major driving factors are the increasing interest and use of seaweeds in the health and wild food market, and use of natural products. Northern Ireland seaweed companies are driven by prospects of financial gain, employment and establishing a business. Grant aid for business set-up and development are available from several sources (InvestNI and European funding), however to date no grant aid specific to the seaweed industry is available and the industry is therefore in direct competition with a large number of proposals for other activities.

5. There is very little published information on the distribution and biomass of commercial seaweeds in Northern Ireland; a list of data sources is given. Recent work on macroalgal biomass on the shores of Strangford Lough is detailed in the report. Standing crop wet mass of *Ascophyllum nodosum* is estimated at 119,000 tonnes. The lack of biomass and distribution data for Northern Ireland needs to be addressed to enable management strategies of the resource to be prepared.

6. The effects of seaweed harvesting have been comprehensively detailed in this report. The negative effects that seaweed harvesting activities have on areas of conservation importance, protected and priority habitats and species include disturbance to birds and wildlife, disruption to food webs, damage to substrata, habitat destruction, trampling, localised biodiversity changes, and changes in particle size distribution in sediments. Direct harvesting impacts of selected species are discussed in depth. The scale of harvesting (small, artisanal and commercial) and the impacts of each scale are discussed.

7. All ecosystems are controlled and organised by a set of key plant, animal and abiotic processes that engineer and structure the landscape or substrate. Macroalgal beds influence coastal processes, for example they provide food and shelter for many marine organisms, alter biogeochemical cycles in the coastal zone, and dissipate wave energy and turbulence, so protecting the shore from erosion. Beach-cast seaweed is an important source of energy for coastal food webs and its removal for harvesting or cleaning can adversely affect some aspects of coastal and nearshore environment. Impacts can be site-dependent, and therefore trials are recommended before harvesting is undertaken. Research on the effects of harvesting attached seaweed reinforces the argument that large-scale harvesting should be restricted, and substantial areas should be left unharvested.

8. The current legal status of seaweed harvesting appears to be entangled in myth of traditional and perceived rights to harvest. The right to harvest seaweed from the shore line varies from area to area.

9. Several management methods are used in the seaweed industry world-wide (Australia, Canada, New Zealand, and South Africa), however at present there is no effective management of seaweed harvesting in Northern Ireland or the rest of the British Isles. Management of marine resources including seaweeds is important to ensure sustainable use and reduce damage to associated communities. We propose a voluntary code of practice, which makes recommendations on permits, reporting and monitoring, no-take zones, harvesting rotation, species-specific harvesting techniques and environmental protection measures.

10. From this research it is apparent that further work is required on the effects of seaweed harvesting and more specifically on Northern Irish habitats, species and coastal processes. We have made recommendations for further research on the effects of commercial harvesting using different harvesting methods; the physical impact of harvesting; the role of no harvest zones; the current distribution and biomass of macroalgal including the

priority species *Ascophyllum nodosum*; the role beach cast seaweed has on coastal ecosystems and coastal processes and the effect beach cleaning and commercial collection have on these roles.

1. Background to the global seaweed industry

1.1. Introduction

Algae are fascinating in their diversity, beauty and utility (Harlin & Darley, 1988)

Seaweed is a rather ill-defined term for a diverse group of organisms which plays an important role in the marine ecosystem. These primary producers contribute to an estimated 40 percent of the planet's photosynthetic productivity, and provide a foundation for aquatic food webs and habitats for many of consumers and associated marine flora and fauna (Harvey, 1849; Chapman & Chapman, 1980; Andersen, 1992; Radmer, 1996). Marine plants have been utilised by man for hundreds of years and are increasingly being exploited as a food resource and a source of industrial and pharmaceutical chemicals (Chapman & Chapman, 1980). Although the seaweed industry and its products have a wide and varied role to play in modern living, the world seaweed industry remains relatively unknown and poorly understood (Lee & Momdjian, 1997). Equally, knowledge of the industry in Northern Ireland and its effects on the marine environment is extremely limited.

The traditional collection of seaweeds for use as foodstuffs, medicines and fertilisers has occurred throughout the world and over a long period of time, with records of collection in Japan dating back to the fourth century (McHugh, 1987). In the past the resource was exploited locally by coastal populations, in a subsistence manner, and although unfortunately in many areas seaweed has become associated with times of hardship and famine, its use has continued also during ample times.

In far eastern countries, seaweeds are, and continue to be, a large component of the human diet. The demand has recently reached a level that natural supplies cannot meet and culturing techniques have been extensively investigated and developed (McHugh, 1987).

1.2. Seaweed uses

Seaweed extractives

Substances present in the cell walls of brown seaweeds and red seaweeds can be extracted and their properties have been extensively exploited. Products derived from seaweed thalli have become common in modern food products. Phycocolloids, such as carageenans and alginates extracted from seaweeds are used in food but not for their nutritional value, rather to give viscosity and stability to aqueous products and to emulsify mixtures of fatty and aqueous materials.

Fertiliser

Seaweeds have been used as fertilisers and soil improvers in Europe for centuries. This practice has been concentrated around coastal regions because of the prohibitive cost of transport of this slippery, bulky, and wet material. There are numerous reports based both on scientific research and anecdotal evidence that suggest that seaweeds are highly beneficial to plant growth. Seaweeds when used as fertilisers contribute many mineral nutrients, trace metals and plant hormones. Reports from users of the products from a Northern Irish company suggest that the benefits of using seaweeds as soil conditioner include acting as an anti-fungicide. Reports from golf course managers indicate that the amount of fungicides required to maintain the condition of their greens decreased three fold when seaweed was used as a fertiliser (Declan McMeel, pers. comm.).

Sea vegetables and supplements

The term "sea vegetables" describes seaweed that is used in the food industry. This sector appears to have gained momentum in recent years due to the healthier outlook that individuals have on their lifestyle. There are two main companies that are involved in the sea vegetable market. Both of these companies package their products and market them at various outlets.

Biomedical/biochemistry

Biomedical and pharmaceutical companies are continually searching for useful substances in their quest for innovative drugs. In recent years there has been increasing interest in natural products synthesised by seaweeds and the potential for using these in pharmaceutical products. The species *Corallina officinalis* is also collected for medical purposes in Europe and further afield. The fronds are dried and converted to hydroxyapatite and used as bone forming material (Tyler-Walters, 2003). One such avenue of research that is currently being explored is the antiviral properties of various algae.

Cosmetics

The use of seaweeds in cosmetics has been long established. Seaweeds have also been used in baths. This practice is believed to provide relief to stress, muscle pain and various other aches that are associated with the general wear and tear on the human body (Guiry, 2005).

1.3. Background to the European and Irish seaweed industry

The coastline of the British Isles harbours a large array of seaweed. In excess of 500 species of seaweeds have been identified on the Irish coastline, a small number of which are exploited for commercial gain (Guiry, 2005). Three distinct periods have been identified in the seaweed industry in Europe. The first stage was the collection and utilisation of seaweeds for soda, the second stage was their use for the manufacturing of iodine and the third was the harvesting for the alginate industry (Chapman & Chapman, 1980). The seaweed industry in Ireland has followed the European industry through several stages, with periods of success and periods of demise.

Historically, seaweed is documented to have been collected on a large scale for agricultural purposes (McHugh, 2003). From at least the 18th century, cast or drift seaweed was collected from beaches in Ireland as a result of the spread of information on improvements in agricultural methods. The cast material was sufficiently valuable that access for carts was made to particularly good shores for the accumulation of drift weed. Carts or creels would be taken to the drift line and loaded by hand with the cast seaweed which would then be transported inland for use as manure on the fields. Drift weed was gathered using drag ropes and rakes to pull it from the swash zone and then loaded and transported in the same way. The rights to collect the wrack were apportioned by landowners to their tenants. The biomass of macroalgae collected is not known. In northern France (Brittany), the Curator of La Museé des Goumanniers (The museum of the seaweed-collectors) described to D. Birkett that for generations, all accessible cast weed was collected from the beaches for agricultural use until well into the 1950s. Seaweeds were also collected for the production of soil (lazy beds) by mixing sand with seaweeds in barren areas to grow crops (Aran Islands, Ireland) (Guiry, 2005). The stipes of *Laminaria* were collected first as cast material and later as cut material and were dried on the shore prior to being sent for alginate extraction. In addition to drift seaweed, free-living calcareous seaweed, or maërl, was collected from the shore or by dredging from sub-tidal banks. Initially this material was used locally as agricultural manure and as an addition to the diet of poultry. Edible seaweeds, *Palmaria palmata* (Dulse) and *Chondrus crispus* (Carrageen moss) have also been historically used in the diet and as health remedies of Irish coastal populations (Guiry, 2005).

The Seaweed Industry in Ireland and Europe grew as seaweeds began to be utilised for their chemical properties. In Ireland the development of a commercial seaweed industry essentially revolutionised the economy of the north and west coasts, with an established industrial production and a potential export item (McErlean et al., 2002). During the 18th and early 19th century *Ascophyllum nodosum* and *Fucus vesiculosus* were harvested and burnt to produce "kelp" (the commercial term for burnt ashes of seaweed) which was used for soda, sodium and potassium salts, an important component in manufacturing processes of the glass and linen industries. Documentation from Strangford Lough reported the influence the industry had on the local economy, providing employment for up to 300 people and producing profits reaching £1000 per annum (McErlean et al., 2002). Several management practices were used during this period, including rotational cropping and the introduction of substrate (boulders) in areas which did not support natural seaweed flora and therefore extending the biomass available (McErlean et al., 2002; Dring, 1992). Competitive import markets and changes in taxes caused the industry to decline substantially until the 19th century when harvesters replaced intertidal *Ascophyllum* with subtidal *Laminaria* as a source of iodine.

The demand for iodine for the prevention of the deficiency disease goitre and for use in the photography industry maintained the seaweed industry in many parts of Ireland (Childs, 2005). Although records show that a number of iodine factories were built on the Irish coast during the 19th century, closure followed later in the century. Nevertheless, production continued in Scotland and kelp from Ireland continued to be harvested and exported until around the 1940's when the industry collapsed due to competition from other sources (Childs, 2005). The commercial collection of *Laminaria* for iodine failed to develop on any large scale in Northern Ireland and Strangford Lough (McErlean et al., 2002).

The third stage of the seaweed industry was the use of seaweed for alginates, extracted from the cell-walls of brown algae (Phaeophyceae), which continues today on a lesser level on the west coast of Ireland (Guiry, 2005). Alginates are gelatinous materials extracted from seaweeds and used in food, textile, printing, paper, welding rods, pharmaceutical products and medical dressings for their thickening, gelling, stabilising and film forming properties (McHugh, 1987). Alginates are currently valued between US$ 2.5 to 7 per pound according to the product use (McHugh, 1987). The collection of seaweed along the west coast for seaweed meal, and its subsequent use for animal feed and alginate extraction, successfully employed large numbers of people in the past, and although employing a lesser number at present, one company (Arramara Teoranta) continues to employ some 267 harvesters and 32 people full time in their factory and offices (Childs, 2005; Dhonncha, 2000). In Northern Ireland there was past interest in harvesting *Ascophyllum nodosum* from Strangford Lough for alginates, and a trial harvest was carried out before an injunction was obtained by the National Trust (Boaden & Dring, 1980). At present no company in Northern Ireland harvests or processes seaweed for alginate extraction.

1.4. Current status of the seaweed industry

Commercial harvesting of seaweed has been recorded in some 35 countries, distributed in both the Northern and the Southern hemisphere (McHugh, 2003). Recent research carried out by the Food and Agriculture Organisation (FAO) has estimated that an annual quantity of 7.5-8 million tonnes of wet seaweed is collected and used by the industry, which is derived from two sources, naturally growing seaweed or cultivated (farmed) seaweeds (McHugh, 2003). A large number of seaweed species are utilised worldwide, however a lesser number are used in Europe, Ireland and Northern Ireland. The genera (Europe) and species (Ireland) of seaweed harvested are listed in table 1. The Northern Irish seaweed industry has been investigated during this report and is discussed in section 3.

Table 1: Species of macroalgae reported to have been harvested in Ireland currently or recently.

Macroalgal species harvested in Ireland abstracted from Morrissey et al., (2001)	**Macroalgal genera harvested in Europe** abstracted from Briand, (1991)
Green algae	**Green algae**
Ulva spp.	*Ulva*
Enteromorpha (Ulva) spp.	*Enteromorpha (Ulva)*
Codium fragile	
Brown algae	**Brown algae**
Ascophyllum nodosum	*Ascophyllum*
Pelvetia canaliculata	
Fucus vesiculosus	*Fucus*
Fucus serratus	
Himanthalia elongata	
Laminaria digitata	*Laminaria*
Laminaria hyperborea	
Laminaria saccharina	
Alaria esculenta	
Red algae	**Red algae**
Mastocarpus stellatus	*Mastocarpus*
Chondrus crispus	*Chondrus*
Palmaria palmata	*Palmaria*
Porphyra spp.	*Porphyra*
Asparagopsis armata	*Gracilaria*
Maërl spp *(Phymatolithon calcareum Lithothamnion corallioides)*	*Phymatolithon Lithothamnion*
	Furcellaria
	Pterocladia
	Gelidium

2. Methods

To investigate the seaweed industry in Northern Ireland and determine the species currently harvested, the scale of such harvests and the methods used, telephone and personal surveys were conducted. Our initial contact list was derived from attendees of the C-Mar (Portaferry) Seaweed Workshops, and consultations with Gus Heath of Dolphin Sea Vegetables and Dr. Stefan Kraan of the Irish Seaweed Centre in Galway. A questionnaire was constructed (Appendix 1) about harvesting practices, collecting guidelines, seaweed products, markets, grant aid available and attained, and the level of consent gained to harvest. Interviews with individuals known to participate in seaweed harvesting, currently or previously were conducted by telephone and by personal visits over the duration of the contract. The information was compiled, and is discussed in a later section of the report.

The biomass of seaweeds within Strangford Lough was estimated using several baseline surveys and the construction of a series of environmental models. More detailed methodology is available from the following reports, Dring (1975), Savidge & Dring (1996) and Birkett (2004).

To establish the main biotope of each of the intertidal species of commercial interest (see table 7), The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC (Connor, 2004), was consulted. Using the biotope code applicable to each species, we referred to the Translation Table Version 97.06 - Version 04.05.. This method allowed us to consult the Northern Ireland Littoral Survey to establish where potential areas of commercial interest may lie.

To investigate the current seaweed harvesting management practices in the British Isles and further afield, contact was made with governmental and non governmental organisations by electronic mail and telephone (copies of communications are being held by QUB). Information on current and past commercial seaweed harvesting (the level, species harvested and harvesting methods) and management measures was requested from the various Environment Agencies within each jurisdiction of the UK.

3. The seaweed industry in Northern Ireland

This study of the current status of the seaweed industry in Northern Ireland has identified three established commercial companies. Currently, the harvesting of seaweed is relatively small, but it is, nevertheless, a potential growth industry, as niche markets in sea vegetables, beauty products, neutraceuticals and land fertilisers with high value products are developed.

Telephone and personal surveys were conducted with individuals associated with and involved in the seaweed industry in Northern Ireland, and these have provided detailed information on the current harvesting practices and the seaweed industry as a whole (a copy of the questionnaire is available in Appendix 1).

The main commercial organisations that are currently in operation in Northern Ireland are;

Redacted - excepted under Regulation 12 (5) (f) (iii) of the Environmental Information Regulations 2004.

These three companies currently employ only a small number of people. Five people are employed full-time harvesting, processing and marketing seaweed in Northern Ireland, with another five being involved on a part-time seasonal basis or secondary level.

During the consultation process, reports were obtained of several small cottage industries which gather seaweed for personal use and on a commercial scale, to supply local wholesalers and seasonal markets such as the Lammas Fair in Ballycastle. The full extent of these industries is difficult to assess due to their small scale, seasonality and the furtiveness of individuals involved. In recent years the numbers of harvesters have declined substantially, and this has also been recorded in the industries in the Republic of Ireland (Kelly et al., 2001). For these reasons and due to limited resources, the cottage industries (artisanal harvesting) have not been included in this section of the report, which has focused principally on commercial seaweed industries.

3.1. Species harvested

At present, only a limited number of seaweed species are of commercial interest. Twelve species, as listed in table 3 are currently harvested from the Northern Ireland coast in a commercial manner. However it is difficult to assess the scale of harvesting as the companies concerned were reluctant to give details of the amount of seaweed they removed.

Seaweed species are harvested in two states, fresh vegetation from attached plants and drift seaweeds from plants detached as a result of natural events such as wave action and grazing. Two seaweed companies harvest fresh attached vegetation, for use as sea vegetables (table 3) and health products, and one company uses beach-cast drift seaweed for soil fertilisers.

A range of seaweed commodities are produced in Northern Ireland, from sea vegetables (Dulse, *Palmaria palmata* priced around £0.85 per 17g), soap (£2.50) skincare (£15.99-£20.99), health products (Phycoplex £19.99) and soil improver and fertilisers (£1000 per tonne) (Gus Heath, pers. comm.; Declan McMeel pers. comm.). The companies presently operating in Northern Ireland are attempting to develop a "niche market" for their products.

Of the sea vegetables exploited in Northern Ireland (see table 2), *Palmaria palmata* (Dulse) is currently harvested to the greatest level, due to its high market demand in this country. In general the natural stocks of these species are thought to be sufficient to meet the current demand. However there has been concern about the ability of local stocks of *Palmaria palmata* to permit the development of this industry. In response to the possibility of stocks becoming a limiting factor, research has been conducted by Queen's University of Belfast in association with interested workers in the seaweed industry on the potential of establishing *Palmaria* farms. Trials of farms of these seaweed farms will be conducted throughout 2005 (Gus Heath, pers. comm.).

Table 2: Main species used as Sea Vegetables in Northern Ireland

Scientific name	**Common name**
Alaria esculenta	Atlantic wakame
Enteromorpha spp.	Green Sea Veg
Laminaria saccharina	Sweet Kombu, Kombu Royale
Laminaria spp.	Kombu
Palmaria palmata	Dulse
Porphyra spp	Nori

Table 3: A list of the macroalgal species commercially harvested in Northern Ireland, compiled from interviews.

Phylum	Species harvested in Northern Ireland	Species Harvested (Common Name)	State Harvested
Green algae	*Ulva* spp.	Sea lettuce	Attached
Brown algae	*Alaria*	Tangle, Wakame	Attached
	Fucus vesiculosus (Possibly *F. serratus)*	Bladder wrack (serrated wrack)	Attached
	Himanthalia elongata	Thongweed, buttonweed, sea spaghetti	Attached
	Laminaria digitata	Oarweed, kombu	Drift
	Laminaria hyperborea	Oarweed	Drift
	Laminaria saccharina	Seabelt, sweet kombu	Drift and attached
	Alaria esculenta	Dabberlocks	Attached
Red algae	*Mastocarpus stellatus*	Carrageen moss, Irish moss	Attached
	Chondrus crispus	Carrageen moss, Irish moss	Attached
	Palmaria palmata	Dulse	Attached
	Porphyra spp.	Laver, sloke, nori	Attached
	Corallina officinalis		Attached
	There have been reports of *Dumontia* harvesting during 2000/2001		Attached

The research conducted for this report has shown that no company in Northern Ireland at present harvests or processes seaweed for alginate extraction. This would involve a dramatic increase in the amount of seaweeds harvested in Northern Ireland. To meet the demands of an alginate industry, mechanical harvesting of seaweeds along the NI coast would become a necessity. Also, at present there are no facilities in NI for processing seaweed for this use, so that all seaweed would have to be exported to Scotland or other EU countries for processing. The use of seaweed resources for biomedical and biochemistry uses are at present, unexplored in Northern Ireland.

Recently there has been an application to harvest seaweed from the County Down coastline for cosmetics and health purposes (seaweed baths). A report on the resource, the potential effects of harvesting on designated habitats and species and a plan for harvesting for this purpose has been produced for the Environment and Heritage Service (Birkett, 2004).

In Northern Ireland, one company produces high quality fertilisers from seaweed. As is usual for seaweed that is destined for soil conditioners, the raw material for this company is the driftweed that is cast on to the foreshore. Although the drift is composed of several different species, the targeted species are members of the genus *Laminaria*. During meetings held with workers in this sector of the seaweed industry it emerged that there was an inherent lack of trust in, and awareness of the abilities of seaweed fertilisers to provide results comparable or superior to those with using artificial fertilisers. This has contributed to a slow uptake of the products produced and may possibly become a limiting factor in the development of this industry.

3.2. Harvesting methods used

The harvesting methods used for attached and drift seaweeds are substantially different, and will therefore be discussed separately.

At present, attached seaweeds are gathered using hand harvesting practices. The equipment employed is limited. One company uses diving apparatus, hand picking, knives and sacks for collection, while another company uses boats for shore access and knives or hands for cropping plants.

The amount of the targeted plant removed is dependent on two main factors, the species selected and the company's or harvester's cutting practice. The common procedure for the majority of targeted species is to harvest the total biomass of each plant; the thallus is removed either by hand grabbing or cut using a cutting implement. Exceptions to this practice are the harvesting practices used with *Alaria*, *Laminaria* and *Himanthalia,* in which the plant is cut above the holdfast to enable regeneration.

One harvesting company professes to use a species-specific harvesting practice for the following species.

- *Alaria* is cut above the receptacles taking only the frond of the plant,
- *Laminaria* is cut 5 cm above the stipe, and
- *Himanthalia* cut above the button holdfast.

This practice has followed research by this one company and their aim is to harvest in a sustainable manner. However, the extent to which these methods are used in practice and the approach of other companies is not currently known.

It is important to consider the harvesting practices that are used over a long time scale to manage the seaweed resource. For example, there is historical evidence that sound management strategies were being implemented for *Ascophyllum* harvesting in Strangford Lough in the 18th century. The foreshore was divided using low stone walls to define seaweed rights and to regulate three-year rotational cutting cycles (McErlean et al., 2004). It has been difficult to clarify the harvesting management practices currently undertaken in Northern Ireland and it appears that if any harvesting strategy is employed it will vary significantly between companies.

Drift seaweed is harvested from shorelines where the material is cast onto the shore. Unfortunately the company involved in this method of harvesting did not wish to contribute to the report, and therefore the specific harvesting methods employed cannot be detailed in the report.

Following collection, the processing of harvested seaweeds varies according to the desired end product, but commonly involves washing, usually with freshwater, sorting, drying (using in-house drying apparatus, or outside drying in suitable weather) and final packaging.

3.3. Harvesting sites

From consultation with harvesters, three broad harvesting areas have been identified. These are Strangford Lough, the Antrim coast and the Down coast, although harvesting for personal use and for cottage industries may occur over a much wider area. The selection of sites by harvesters is primarily dependent on the biomass of the targeted species, the location of the company, access to the site and the ability to gain permission for the selected harvesting area. Permission is a potentially major problem with current harvesting practices, as the legal issues are not always clear to harvesters, and locating wrack right holders and land owners can be a lengthy and difficult process.

Of the companies currently harvesting, one has acquired permission from a local county council to harvest at a specific coastal site, another claims to have rights of a selected shoreline although they did not specify who permission was granted from and another company did not discuss permission to harvest, although did refer to contact being made with the Crown Estate.

Discussions with harvesters have confirmed that the legal issues associated with seaweed collection are clearly not apparent, not understood, or are somewhat overlooked by those partaking in the activity.

Specific information on harvesting sites used by each company is essential to ensure required permission to harvest has been granted from the landowner or lease holder, to determine if sites lie within a designated area, and therefore are notifiable to the Environment and Heritage Service (see figure 12), and to enable monitoring proposals to be carried out in the future to ensure the harvesting regime is sustainable and impacts on priority species and habitats can be identified.

4. The factors that drive seaweed harvesting,

The total value of the international seaweed industry exceeds US$ 5.5-6 billion annually, of which the Irish and Northern Irish industries contribute only a very small percentage (McHugh, 2003; Guiry, 1994). The value of the industry worldwide is one main driving factor for the development of the industry in Northern Ireland. Use of seaweeds in the health food and wild food market for example is becoming increasingly popular in the British Isles, and the products are relatively expensive (£3-4 for 50g dry weight). Many products are derived from imported material, although the same species exist on many local British Isles shores, which may be a current or future driving factor for the establishment of local seaweed industries (Milliken & Bridgewater, 2001)

The seaweed industry in Northern Ireland is driven in effect by financial gain, through the supply of seaweed products (sea vegetables, beauty and health products, and seaweed fertilisers) to niche markets. The industry has a potential to provide employment in rural areas (although less than ten individuals are currently employed), and to establish a market, which through product development has the potential to grow supplying both the local and international markets. Marketing research for seaweed products in Northern Ireland is an area which needs to be further developed. Neglecting marketing can cause fundamental problems, as is evident in the Scottish seaweed industry (David Donnan, pers. comm.). As the problems in the industry are identified (see table 4), and slowly addressed the industry may have immense prospects.

Table 4: A list of the problems affecting the Irish Seaweed Industry identified by the Irish Marine Institute as adapted from Guiry (1994).

The problems identified in the Irish seaweed industry as adapted from Guiry (1994)
High failure rate of seaweed-based industries
In harvesting, a lack of mechanisation
Increasing affluence
High fuel costs for drying
Fluctuations in demand for certain seaweed products
Lack of research and development
Poor marketing and packaging
A shortage of entrepreneurs

Grant aid is available for business start ups and development (InvestNI), and the development of rural and tourism businesses (Leader+ and NRRTI), however no specific grant aid for the seaweed industry is currently in existence and therefore seaweed applications are in direct competition with a host of different applications (Robert Wilkes, pers. comm.). Strong competition and often very stringent criteria can make it difficult to establish businesses. However, there are several sources which can be explored and network systems which can assist in several stages in developing a business.

Invest Northern Ireland, formed in 2002 incorporated several organisations (the Industrial Development Board (IDB), the Local Enterprise Development Unit (LEDU), and the Industrial Research and Technology Unit (IRTU)) to become the primary economic development organisation in Northern Ireland designed to promote and develop the economy. Invest NI supports businesses through start up and development grants and programmes. The organisation also provides expert advice, information and business training which are potential support to the seaweed industry (InvestNI, 2005; Ciara Malone, pers. comm.). However, from the consultation process with seaweed companies in Northern Ireland, there is currently no financial support being given to current seaweed businesses.

European Union support programmes have been set up to assist small and medium enterprises (SMEs) by providing grants, loans and advice. Several programme categories exist with a variation of funding types; one includes structural funds which have been designed to develop least favoured regions, and regions facing difficulties. The Leader+ programme is an example of this funding type, although being European funding, it is managed at a national level (European Commission, 2003). In Northern Ireland the Leader+ programme's objective is to increase the economic and employment contribution small businesses make to the rural economy (DARD, 2001), and therefore it is an important funding source, which has potential use in developing seaweed harvesting businesses. This pathway has previously been pursued by a seaweed harvesting company; however the project did not proceed due to several factors (Andrew McAlister, pers. comm.). Other programmes are designed for research and education, which may be other avenues which could be pursued to further develop the industry and its products.

Also derived from European Union funding is the £15 million Natural Resource Rural Tourism (NRRT) Initiative, which is an element of the PEACE II programme, created to help the economy in rural areas in Northern Ireland through the development of tourism (Rural Development Programme, 2005). This was a potential source of funding, and has received applications by those wishing to partake in seaweed harvesting; however the programme is no longer accepting applications (Ruth Blair, pers. comm.).

The situation is similar to the Irish seaweed industry, which also has no specific funding although it has established the Seaweed Industry Centre (ISC) and the Irish Seaweed Industry Organisation (ISIO) which have assisted the Irish seaweed industry through research and support. Seaweed development officers were appointed through the Bord Iascaigh Mhara (BIM Irish Sea Fisheries Board) and the Marine Institute, yet one has subsequently been redeployed to another area (Robert Wilkes, pers. comm.).

Analysis of the world and Australian seaweed industries was carried out by Lee & Momdjian (1997) who identified and outlined several market factors affecting the industry's growth, which are largely applicable to the Northern Irish industry and therefore are listed as follows:

Strategic driving market factors

- Improved understanding of the international and local (Northern Irish) market growth and demand.
- Critical analysis of management alternatives for seaweed based upon overseas experience.
- Development of a seaweed management plan which is attuned with current Fisheries management.
- Recognition of seaweed as a new and emerging industry which warrants support from Government and research organisations.
- Specific product development and applications of seaweed for food.
- Consumer and industry awareness of the uses of seaweed.

Constraining market factors

- Lack of knowledge of the opportunity to utilise local (Northern Irish) seaweed as a resource.
- Lack of data on sustainability and ecological impacts of utilisation of the seaweed resource.
- Lack of quantitative data for the local seaweed resource
- Competitive marketing strategies of international groups.
- Small size of the industry, and lack of industry investment.

5. Distribution of the resource

5.1. Distribution of the intertidal resource

Distributional data for intertidal seaweed species are available from the maps included in the DSc thesis of M.J. Lynn (1937), for which most of the shore survey work was undertaken between 1928 and 1935. More than 100 different species (including subspecies and forms) of macroalgae were recorded during the survey, which covered the entire shoreline of Northern Ireland (Table 5). Not all the species and sub-species listed in the thesis are recognised today and many have undergone taxonomic revision, so the list itself must be utilised with caution.

The Northern Ireland Littoral Survey (NILS) recorded the presence/absence of some of the intertidal fucoid species and descriptive estimate of shore cover during stage one of the survey. Stage two of the survey provided more detailed information, with the presence/absence of more than 250 species of macroalgae being recorded on the shores of Northern Ireland (Wilkinson et al., 1988). However, NILS was a conservation orientated study and therefore these data have not been analysed with respect to the distribution of seaweeds of commercial interest (Wilkinson, et al., 1988).

On the northern part of the County Down coast, some data are available for the biomass and distribution of *Ascophyllum* (Dring, 1975) summarised in Table 6a. Within Strangford Lough, as part of a study of the productivity of a semi-enclosed coastal embayment for the Natural Environment Research Council (Final report, NERC grant GR3/9072 (Savidge & Dring,1996)), a comprehensive survey of macroalgal distribution, population density and biomass was undertaken (Table 6b). On the southern coast of County Down an estimate of the biomass of the mid to lower shore fucoids has been made (Birkett, 2004) and is summarized in Table 6c.

There is very little published information available on the distribution of seaweeds of commercial interest in Northern Ireland and this lack of data needs to be addressed in order to prepare management strategies for the resource. On the shores of Northern Ireland it is probable that wherever there is a sufficiently stable substrate (rock, boulder, cobble, pebble, and gravel) there could be a significant macroalgal population containing species of commercial interest. Detailed biotope distribution maps indicate areas of habitat suitable for the growth of certain species of macroalgae but are an inadequate management tool for species that are not a characteristic of a biotope.

5.2. Distribution of the subtidal resource

Between 1972 and 1985, a diving team from the Botany and Zoology Department of the Ulster Museum conducted a survey of the sublittoral environment of Northern Ireland. During the course of the survey 201 sites were studied with between 1 and 12 dives at each site. About 100 additional sites were surveyed by the Ulster Museum between 1973 and 1980. Prominent species were recorded (as foliaceous brown / red; encrusting red; green) and provision was made on the record cards for abundance estimates to be noted (Erwin et al., 1986). Over 150 species of macroalgae were identified from samples that were collected. The sublittoral survey enabled the publication of Northern Irish distribution maps for many seaweed species; however the data set unfortunately did not contain detailed biomass data (Erwin et al., 1986).

As part of the study of the productivity of a semi-enclosed coastal embayment (Savidge & Dring, 1996), the distribution (presence/absence) of kelp within Strangford Lough was established. Biomass estimates were also constructed from data in the literature (Table 6b).

It is probable that species of kelp (Laminariales) are present on all parts of the Northern Ireland coast where there is a rock or boulder substrate between MLWS and 10 m. In some locations where water clarity permits, kelps may be found to a depth of 20 m (such as off Rathlin Island); elsewhere they may be limited to only 2-3 m by turbid conditions. The distribution of other species of commercial interest, has to date not been the subject of any major study thus remains relatively unknown.

5.3. Biomass or population density of the resource

To date only a limited amount of research has been carried out on biomass of seaweed resources in Northern Ireland, these data are presented in tables 6a, b and c. It is important to note that the biomass data provided applies only to the time of the study, and therefore the biomass may have since changed. For example, recent population studies on *Ascophyllum nodosum* have indicated that biomass has declined over the last 25 years, which has led to the species being selected as a Northern Ireland priority species (see table 15). Macroalgal biomass information is important for both conservation and resource management reasons, and as outlined in our recommendations (section 12) further research is required.

Table 5: Data sources for possible estimates of macroalgal species distribution and biomass estimates for the coasts of Northern Ireland.

Coastal Area	Intertidal vs subtidal	Distributional data (presence/absence)	Biomass	Population Density	Cover
Derry	Intertidal	58 transects, Lynn (1937), Wilkinson *et al* 1988	No data	No data	No data
	Subtidal	Erwin *et al* .,1986	No data	No data	No data
North Antrim (eastwards to Torr Head)	Intertidal	222 transects, Lynn (1937), Wilkinson *et al*., 1988	No data	No data	No data
	Subtidal	Erwin *et al* .,1986	No data	No data	No data
East Antrim (inc. north Belfast Lough)	Intertidal	275 transects, Lynn (1937),Wilkinson *et al*., 1988	No data	No data	No data
	Subtidal	Erwin *et al* .,1986	No data	No data	No data
North Down (inc. south Belfast Lough)	Intertidal	256 transects, Lynn (1937),Wilkinson *et al*.,1988	Dring (1975) (*Ascophyllum*)	No data	No data
	Subtidal	Erwin *et al* .,1986	No data	No data	No data
North Down (Strangford Lough)	Intertidal	252 transects, Lynn (1937), Wilkinson *et al*.,1988	Dring (1975) (*Ascophyllum*), Savidge & Dring,(1996) (fucoids)	Savidge & Dring,(1996) (fucoids)	Savidge & Dring,(1996)
	Subtidal	Erwin *et al* .,1985	Savidge & Dring,(1996) (Laminarians)	No data	No data
South Down (inc. north Carlingford Lough)	Intertidal	154 transects, Lynn (1937), Wilkinson *et al*.,1988	Birkett (2004) (fucoids)	No data	Savidge & Dring,(1996) (fucoids)
	Subtidal	Erwin *et al* .,1986	No data	No data	No data

Table 6a: Biomass estimates for *Ascophyllum nodosum* (Dring, 1975). Total standing crop was determined from the following data; (Rossglass, n=24; Ballyquintin n= 13) mean: 11.96 ± 0.88 Kg m^{-2} on "abundant" sites: (Ballyquintin n=8) mean: 7.59 ± 1.36 Kg m^{-2} on "common" sites (Dring, 1975). The annual biomass increment is determined from internode mass measurements.

Species and coastal region	Area of habitat (hectares)	Total standing crop (tonnes wet mass)	Annual biomass increment (tonnes wet mass)
Millisle to Portavogie	55.82	6,600	932.0
Millin Bay to Ballyquintin Point	26.57	2,820	396.2
Ballyquintin Point to Ballyhenry Island (east shore of the Narrows, including Angus Rock)	48.89	5,480	773.2
Yellow Rocks to Kircubbin	32.59	3,910	554.0
Mahee Island to Killyleagh (including all islands connected by bridges or causeways to the mainland)	96.33	11,210	1,585.7
Killyleagh to Chapel Island	55.58	5,530	774.0
Larger islands in western Lough (30 with *A. nodosum*)	145.59	16,970	2,400.4
Smaller islands and rocks in the rest of the Lough (15 with *A. nodosum*)	55.86	6,660	942.9
Chapel Island to Killard Point (west shore of the Narrows)	56.23	5,490	768.0
Killard Point to Ballyhornan (including Gunns Island)	25.18	2,860	403.7
Total	601.64	67,530	9,530

Table 6b: Biomass estimates for macroalgae species in Strangford Lough (Savidge & Dring, 1996). The total standing crop (biomass) is based on biomass samples (5 per spp.) from over 100 transects around Strangford Lough.

Species	Total standing crop (tonnes wet mass)
Intertidal species	
Pelvetia caniculata	804
Fucus spiralis	1,434
Ascophyllum nodosum	118,609
Fucus vesiculosus	31,896
Fucus serratus	46,187
Laminaria digitata	-
Laminaria saccharina	-
Ephemeral spp.	-
Subtidal species	
Laminaria digitata	50,080
Laminaria saccharina	202,314
Laminaria hyperborea	170,722
Saccorhiza polyschides	7.28

Table 6c: Biomass estimates of intertidal brown algae on the shores of South Down (Birkett, 2004). The total standing crop is based on estimates of percentage cover and biomass samples.

Species	Area of habitat (hectares)	Total standing crop (tonnes wet mass)
Mixed fucoids	320 h of habitat below mean sea level	5,650
Ascophyllum nodosum	Species habitat areas not measured	2,675
Fucus vesiculosus		1,585
Fucus serratus		1,390

Table 7: Seaweed species harvested, showing biotopes involved, with the scale and distribution of harvesting. Areas harvested, refers to the areas where commercial harvesting takes place (see table 9 for the definition of commercial harvesting). + indicates current harvesting.

Species name	Main Biotope Complex	Commercial harvesting	Small scale	Personal use	Areas harvested
Ulva spp.	LR.FLR.Eph		+	+	Co. Antrim
Ascophyllum nodosum	LR.LLR.F.Asc.FS		+ Proposed		Proposed on the south Down coast
Fucus vesiculosus	LR.LLR.F.Fves		+	+	Co. Antrim
Fucus serratus	LR.LLR.F.Fserr		+	+	Co. Antrim
Himanthalia elongata	LR.HLR.FR.Him		+	+	Co. Antrim
Laminaria saccharina	SS.SMp.KSwSS.LsacR		Past +	+	Co. Antrim – attached weed Co. Down – cast weed
Laminaria digitata	IR.MIR.KR.Ldig	Past	+ Beach cast		Co. Down – cast weed
Laminaria hyperborea	IR.MIR.KR.Lhyp	Past	+ Beach Cast		Co. Down – cast weed
Alaria esculenta	IR.HIR.KFaR.Ala		+	+	Co. Antrim
Mastocarpus stellatus	LR.HLR.FR.Mas			+	Co. Down – Ards Peninsula, (reported)
Chondrus crispus	LR.HLR.FR.Mas			+	Co. Down – Ards Peninsula, (reported)
Palmaria palmata	LR.HLR.FR.Pal IR.MIR.KR (Epiphytic on Laminaria stipes)	+	+	+	Co. Antrim Co. Down - Strangford Narrows; Outer Ards
Porphyra spp.	LR.FLR.Eph.Ent.Por		+	+	Co. Antrim
Osmundea pinnatifida	LR.HLR.FR.Osm			+	
Corallina officinalis	LR.HLR.FR.Coff		+	Past	

Table 8: Littoral Biotope locations in Northern Ireland, extracted from the Northern Ireland Littoral Survey (NILS) report produced by Wilkinson et al., (1988).

Main Biotope Complex	Sites Found in Northern Ireland
LR.FLR.Eph	Ardglass Bay (Rock); Bloody Bridge; Carnlough Bay; Seacourt; Whitebay Point.
LR.LLR.F.Asc.FS	Ardglass Bay (Rock);Audleys Castle Rocks; Ballygalley Head; Ballygalley Head; Ballyhenry Bay; Ballymacormick Point; Ballyquintin Point; Black Neb; Carnfunnock Bay; Carrstown Point; Cave House Shore; Chapel Island Causeway; Coney Island Bay Boulders; Craigleway; Cushendun North; Cushendun South; Doon Bay; Down Rock; Drummond Island; Garron Point; Green Island; Greencastle Rocks; Herring Bay Boulders; Isle O'Valla; Kearney; Kilclief; Layd Church; Limestone Rock; Mahee IslandlMid Island Bay; Mill Quarter Bay; Murlough Bay; North of Killowen; Pawle Island; Port Vinegar; Portdoo; Portgorm A; Portmore (Loughan); Red Arch; Ringboy Boulders; Robin's Rock; Selk Rock; Turnley's Port; Wallaces Rocks; Whitechurch; Yellow Rocks.
LR.LLR.F.Fves	Ardglass Bay (Rock); Barr Hall Bay; Dalriada Point; Herring Bay; Horse Island; Killough Harbour (Outer); Launches Little; Mill Bay site D; Wallaces Rocks.
LR.LLR.F.Fserr	Dundrum Inner Bay (North) site E; Herring Bay; Horse Island; Kircubbin Point; Launches Little; Mill Bay site D; South Island
LR.HLR.FR.Him	Black Head; Carrick-na-ford; Dunimeny Castle; East Lighthouse Platform; Larry Bane Bay; Marie Isla; Port-na-Tober Headland; Seacourt; Stackamore site AStraidkilly Point; The Dutchman
LR.HLR.FR.Mas	Culloden Hotel; Lough Shore Park; Swinely Point; The Gobbins
LR.FLR.Eph.Ent.Por	Black Rock; Carnfunnock Bay; Halfway House Ballygawley; Rinagree Point; Ruebane Point; South of Nicholson's Point; White Lady East
LR.HLR.FR.Coff	Kinbane Head; Kinrea; Portandoon site A; Portmoon; The Burnfoot site A; The Burnfoot site B

6. The effects of seaweed harvesting on the coastal, intertidal and near-shore ecosystems of Northern Ireland

6.1. Introduction

There are large numbers of research reports that have a bearing on the effects of harvesting seaweeds. Much of the research undertaken in recent years has not been published in the scientific literature, having been prepared on behalf of the companies harvesting the seaweeds or by Government Departments responsible for the ecological status of the harvesting area, mostly in countries that harvest seaweeds from the wild (rather than through aquaculture) on a large scale (Norway, Chile, France, Canada, USA).

Seaweed harvesting can occur at a number of different scales. These are described in Table 9 (opposite).

Table 9: Scales at which macroalgal harvesting can occur.

Harvesting scale	Description (notes on amounts harvested are as wet mass)
Small **(no regulations)**	• for personal or family use • collection of possibly a wide variety of species, at different times of the year; usually for culinary, cosmetic or medicinal purposes • small quantities, variable with species, usually several grams to 1 kg per species per day • intertidal and shallow subtidal; by hand • drift material may be collected for use in the garden; an arbitrary value of 100 kg per household per week with a maximum of 1,000 kg per household per year
Artisanal **(wrack rights required)**	• for extended family use, family (small) business (farming, seaweed baths, specialist food supply, cosmetic production) • collection of a restricted range of species, spread throughout the year, usually for culinary, cosmetic or medicinal purposes • small to medium quantities, variable with species, usually several tens of kg per species per day but not collecting more than an arbitrary 25% of the biomass of any species within a patch or 100 m^2 area of its habitat and not harvesting that patch again until species re-growth has taken place • intertidal and shallow subtidal; by hand (some species may be collected by diving) • drift material may be collected for agricultural use; an arbitrary value of 1-2 tons per business per week with a maximum of 100 tons per year
Commercial **(wrack rights required)**	• for business use, chemical industry, pharmaceutical industry, agricultural industry • collection of a limited number of commercially valuable species • large to very large quantities, hundreds to thousands of tons daily per business; arbitrarily more than 5% of the standing biomass per kilometre of coast; internationally cropping limits to the harvest are based on macroalgal growth rates and harvesting areas are controlled • intertidal and subtidal habitats; smaller species are collected by hand but where possible other species are collected by machinery of various kinds, including dredges, suction dredges, "scoubidou" and specifically engineered harvesting machines • drift material collection by bulldozer and lorry transport for large scale composting, may be seasonal, very large tonnages

The effects of harvesting may be direct or indirect. Available reports can be grouped as follows:

Biological aspects

Effects on the target species
- Growth rates
- Canopy removal experiments
- Clearance experiments
- Recovery from harvesting

Effects on other species
- Population dynamics of species associated with the target species
- Recovery of the major species to pre-harvesting levels
- Coastal ecosystems

Economic aspects
- Cost comparisons of harvesting methods
- Benefits to local communities

However, there is an extraordinary lack of information on the wider consequences of seaweed harvesting. Most reports and reviews in which seaweed harvesting is discussed mention that:

- very little information about the effects of harvesting on other species of flora and fauna is available
- there is almost no information about the consequences of primary producer biomass removal on food webs
- this type of research project is required in order to determine the long-term consequences of seaweed harvesting
- this information is required for ecological management

There have been no long term monitoring programmes of the effects of intertidal seaweed harvesting from the shores of the UK. A number of literature reviews provide useful summaries of what information is available and extracts of these reviews are incorporated below. There are a number of concerns with respect to the potential impact of seaweed harvesting. Within designated areas (as well as elsewhere on the shore) these can be summarised as disturbance to birds, disruption of food webs and damage to substrates and species attached to or within the substrate. The different categories of designation are addressed separately but the precautions and mitigations proposed apply to non-designated shores as well.

6.2. Potential effects of harvesting selected species on ecosystems

The ecological effects of seaweed harvesting are similar to those of natural disturbances; both remove all or portions of populations, providing space or other resources that initiate succession. Natural disturbances vary in severity, extent, and frequency (Foster & Barilotti, 1990). The ecological impact of macroalgal harvesting depends on the frequency, intensity and percentage removal of the harvest as well as the characteristics of the life history of the organisms harvested and the phenological attributes of the community. The magnitude of harvesting depends on the harvesting strategies, and should be in accordance with the biological characteristics of the target species to allow sufficient time for recovery (Vasquez, 1995) of the ecosystem. Some of the potential ecological effects of harvesting species that are currently being exploited in Northern Ireland (as established by this report) and some that have the potential to be exploited are outlined below.

Alaria esculenta

Alaria grows from the base of the frond and not the tip of the plant. The removal of the complete plant from the rocky substratum will delay the recovery for a period of years (Morrissey, 2001). Good harvesting practice should be observed by harvesting above the sporophylls of the plant thus allowing sufficient plant material to reproduce. Due to the lack of detailed research into the recovery rates of *Alaria* after harvesting, evidence from other kelp species can be used to infer that a period of 3-4 years should be allowed for recovery of the stock. It is also worth noting that in canopy clearance experiments, *Alaria* may appear early in the succession (Tyler-Walters, 2003).

Ascophyllum nodosum

Dring and Boaden (1980) have provided us with a rare assessment into the ecological effects of seaweed harvesting in Northern Ireland. They have reported that the effect of harvesting *Ascophyllum nodosum* persisted over the 2½ year period of their study. This study arose from an unsanctioned harvesting activity that subsequently was halted. The results of this study shed light on the ecological effects of harvesting *Ascophyllum*. In the cut area:

1. Growth rate of *Ascophyllum* had increased but shore cover was still less.
2. Cover by green algae and *Fucus vesiculosus* had increased.
3. *Patella* density had increased and mean size decreased.
4. Microalgal cover of boulders had increased.
5. Sediment median diameter had increased.

6. *Halichondria*, *Hymeniacidon* and to a lesser extent *Balanus crenatus* had decreased.

7. Under boulder fauna remained impoverished by approximately 50%.

Even with small scale cutting it is clear that there had been a noticeable ecological change (Boaden & Dring, 1980).

The history of *Ascophyllum* harvesting dates back to great antiquity. There have been a number of studies undertaken to establish the most effective way of maintaining a harvestable crop (e.g. Baardseth, 1955; and Keser *et al*., 1981). Through the observations of these studies and of other individuals examining the recovery of *Ascophyllum* after harvesting it has being reported that if lengths of 10-20cm of *A. nodosum* are left uncut the plants can recover and re-harvest is possible in 3-6 years (Guiry, 1997). This provides the possibility of a sustainable harvest; however, it does not shed light on what the effects of repeated harvesting activity on the associated ecosystems. What is clear is that under no circumstances should "clearance harvesting" be allowed to take place in Northern Ireland. While this species is highly fecund, its recruitment to areas where it has been cleared is extremely slow with reports of re-colonisation times in excess of 8-10 years (Hill & White, 2004). It is suggested that a combination of climatic or environmental conditions is needed for effective re-colonisation. Recovery of the population to original abundance and biomass is therefore, likely to take a very long time (Hill & White, 2004).

Fucus species
Over harvesting could occur on easily accessible shores if harvesting of *Fucus* increased significantly. Provided the plant is not removed entirely, the algae can regenerate from the remaining stem. Recovery would be high due to the high fecundity of the species and its widespread distribution and capacity for dispersal. *Fucus vesiculosus* recruits readily to cleared areas of the shore although full recovery may take 1-3 years (White, 2003).

Himanthalia elongata
Himanthalia elongata rapidly recruits to cleared areas of the shore, so provided not too much of the shore is harvested the species would be able to recover relatively quickly (White, 2003).

Laminaria spp.
Discussed in section 6.4.

Chondrus crispus
Harvesting of *C. crispus* has taken place in Atlantic Canada and Ireland. In particular, intensive harvesting of this species has occurred in Atlantic Canada. Here, studies have indicated that there are short term effects of harvesting, and long term effects due to successional re-harvesting of this species. Prior to 1980, the seaweed beds of Prince Edward Island were dominated by *C. crispus* and the species was heavily exploited. Recently, there has been a marked increase in abundance of another red seaweed, *Furcellaria lumbricalis*, which was avoided by the commercial harvest, and an associated decline in abundance of *Chondrus crispus* (Rayment, & Pizzola, 2004). Frond size-class structure changes in the harvest intensity; as intensity increases the mean frond size decreases in the population. A thorough assessment of *Chondrus* reproductive capacity for intensely harvested areas of Prince Edward Island demonstrated significantly less reproductive structures per unit area of bed in an intensively harvested bed vs. a non-harvested bed (Sharp & Pringle, 1990)

Furcellaria lumbricalis
Furcellaria lumbricalis grows very slowly compared to other red algae and takes a long time to reach maturity. It has been reported that in Wales, *Furcellaria lumbricalis* typically takes 5 years to attain fertility. This would mean that, following perturbation, recovery to a mature reproductive community would take at least 5 years. Over-exploitation of *Furcellaria lumbricalis* has resulted in severe depletion of stocks. In Canada on the shores of the Gulf of St Lawrence the harvest is sustainable as dredging and raking are prohibited and only storm cast plants may be gathered. In view of the potential impact that harvesting may have on the population, intolerance is assessed as high, however, no commercial harvest as yet occurs in Britain or Ireland (Rayment, 2005).

Porphyra spp.
Unfortunately there appear to be no studies of the impacts that harvesting this species may have on the ecology of the intertidal environment of sites in the British Isles. However, a study conducted in South Africa by Griffin et al. (1999) indicates that harvesting of populations of *Porphyra* species can have an effect on amphipod and gastropod populations. When the initial dense *Porphyra* strands were reduced by natural population changes or harvesting, both amphipods and isopods, previously present in high numbers, were nearly always absent. Several species of gastropods were less frequent in treatment as opposed to control sites, which may indicate a response to harvesting (Griffin et al. 1999).

Ulva spp
Ulva species are generally considered to be an opportunistic species, with an '*r*-type' strategy for

survival. The *r*-strategists have a high growth rate and high reproductive rate. For instance, the thalli of *Ulva,* which arise from spores and zygotes, grow within a few weeks into thalli that reproduce again, and the majority of the cell contents are converted into reproductive cells. The species is also capable of dispersal over a considerable distance. These biological adaptations suggest that *U. intestinalis* is likely to have a considerable ability for recovery within a year thus the long term effects of harvesting on *Ulva* populations may be minor. Unfortunately, there do not appear to be many studies of the short term effects of clearing *Ulva* species from the environment (Budd & Pizzola, 2004).

In the evaluation of the ecological impact of marine plant harvesting one question that requires addressing is whether it affects the long-term stability of the community. Foster & Barilotti (1990) suggested a mechanism for classifying the harvesting operation, combining the extent of plant removal and the major form of recruitment (table 10). This table has been extracted in its entirety and is shown over leaf.

Table 10: Types, procedures, and ecological effects of harvesting natural seaweed populations as adapted from Foster & Barilotti (1990).

Harvest type
I. Entire plants removed: repopulation by spores, other propagules, or juveniles remaining after harvest or immigrating into harvested area. II. Vegetative and reproductive structures removed: re-growth from basal attachment structures and as in Type I. III. Vegetative canopies removed: repopulation from re-growth and reproduction of partially harvested plants, and as in Type I. IV. Beach Cast Plants Removed: effects on repopulation processes minor to none?
Harvest procedures
a. Method: general – hand, mechanical, etc.; specific -How used? How much of a plant removed? What parts, sizes, etc. of plants removed? b. Extent: patchiness of harvest, area affected and biomass removed locally (in beds) and in entire region of harvest. c. Frequency: how often harvested? d. Season: when harvested?
Ecological effects of harvest
a. On harvested population: changes in recruitment, survivorship, and stability. b. On community (effects from removal of associated species, removal of food, alteration of habitat): changes in population sizes and distribution of associated species. c. On ecosystem (effects of reduced organic input to associated communities): changes in affected populations.

6.3. Assessment of the potential impact of harvesting low-shore intertidal fucoids in Northern Ireland
The following passage is an edited extract from "Sustainable Small Scale Harvesting of Intertidal Fucoids on the South Down Coast". Report prepared for Soak Seaweed Baths (Birkett, 2004).

Relatively little data has been published on the long-term effects of seaweed harvesting on the ecosystems of coastal waters. A major research project has recently been undertaken at N.U.I Galway on the impact of both hand and mechanical harvesting of *Ascophyllum nodosum* at two sites on the west coast of Ireland. This study recorded the changes that occurred to previously un-cropped shores as a consequence of both mechanical and traditional cutting methods. The local tradition in the study area is to cut floating fronds by hand from a small boat, leaving about 30% cover and about 20 cm length of each plant. In both the hand and mechanical cropping areas, all (most) plants were harvested. Kelly et al., (2001) reported from their preliminary study that there was no overall impact on the biodiversity of the harvested sites, however harvesting did have an impact on a small number of species, and the percentage *Ascophyllum* cover of the sites was claimed to be nearing recovery after 11-17 months. Over this time, there was an increase in the proportion of *Fucus vesiculosus* at the harvested sites, as this species was not cropped. There was no effect on other species of macroalgae, nor was there any impact on the fish population or other large mobile epifaunal species (Kelly et al., 2001). A similar increase in the proportion of *Fucus vesiculosus* in the intertidal macroalgal cover was reported after the harvesting of *Ascophyllum nodosum* [at Rathcunningham] (Boaden & Dring, 1980). However, at the Rathcunningham site (within Strangford Lough) the target species was also *Ascophyllum* and all plants were cut to within 10-15 cm of the base. This site yielded a crop of nearly 22 T wet mass from 100 m of shoreline approximately 60 m wide. In the area of the shore where cutting had occurred, the subsequent growth (2½ years) of the terminal portions of *Ascophyllum* was 40% greater than for the area where plants were not cut, but no biomass data is given. However, significant differences were recorded between cut and un-cut areas in the population structure of *Patella vulgata* and the colour morph proportions of the population of *Littorina obtusata*. In their quantitative study, Boaden and Dring (1980) concluded that the effects of harvesting *Ascophyllum* had persisted over a 2½ year period, and they predicted that an 80% recovery of the entire *Ascophyllum* community structure may occur within 4 years. Although the harvested site was not subsequently monitored after the study, a visit to the site in 1999 observed differences between the cut and uncut areas in algal communities and limpet numbers (Christine Maggs, pers. comm.).

6.4. Assessment of the potential impact of harvesting kelp species
The following brief discussion of the effects of harvesting on kelp biotopes (section 6.4. a & b) has been extensively abstracted from the work of Martin Wilkinson (1995) "Information review on the impact of kelp harvesting" and is reproduced as an extract from: "Infralittoral Reef Biotopes with Kelp Species" (Birkett et al., 1998).

Case studies of the effects of kelp harvesting in UK and European waters
The impact information comes from two sources: the removal of kelp for scientific experiments, and from observations made on harvested grounds in Norway and Brittany. The observations and data need to be considered in two different ways, the effect of harvesting on the resource itself and the effect of kelp harvesting on the complete kelp forest ecosystem. Not surprisingly most published work concerns the resource rather than the entire ecosystem. The international scientific community recognises the difficulty of determining both the short-term impacts of kelp harvesting and the long-term consequences to the coastal environment. Around the coasts of Brittany 75-80,000 t of seaweed are collected each year and yet there is no data on the effects of this biomass loss from coastal ecosystems (Dauvin, 1997).

a. Experimental canopy removal and clearance experiments

i. Early experiments - effects on the kelp population
Scotland The earliest manipulative experiments on a kelp forest were carried out in 1936 on the west coast of Scotland by Kitching (1941). He removed canopy plants of *L. hyperborea* with shears and one year later a new canopy of dense plants, 1 m high, had formed. The old holdfasts of the cut plants had gone, showing that they would not survive, along with their own distinctive fauna. The new holdfasts were described as very tight and clean of epibiota. This early experiment shows a standard pattern of response - the forest has considerable potential to regenerate but, when it does so, the age and size structure and plant morphology may be altered with consequent effects on the rest of the ecosystem.

Isle of Man Kain (1975) carried out clearance experiments in the Isle of Man which showed that although the *L. hyperborea* forest could regenerate, there might be a temporary domination by other species, notably *Sacchorhiza polyschides*. Concrete blocks at 0.8 and 4.4 m below ELWS were cleared of attached algae. Different blocks were cleared in different years and at different times of the year so that the recolonisation patterns could be related to length of recovery period and responses to seasonal differences in recovery. Blocks at the shallow level cleared in August were re-colonised by *L. hyperborea* but, if cleared in November, February or June, there was initial replacement by *S. polyschides*, *Desmarestia aculeata* and *Alaria esculenta* (in different years). Whatever the replacing species, *S. polyschides* became dominant by the August following clearance of the blocks. However, *L. hyperborea* had always replaced the *S. polyschides* after 2 years and, the biomass of *L. hyperborea* on the blocks was equal to that measured in control areas after 3 years. Colonisation of the blocks at 4.4 m was more variable and it took longer for the *L. hyperborea* to re-establish. On the control blocks at this depth, *S. polyschides* and *D. aculeata* flourished if the block did not hold any plants of *L. hyperborea*. Where blocks at a depth of 1.3 m. were continually cleared at intervals, kelp dominance was lost and the blocks were populated by 41 different species of algae, with reds having maximum biomass in the winter, browns in the spring and greens in the late summer. When sterilised stones were placed in the experimental area they were not colonised by *L. hyperborea* except when the canopy plants were reproductive, although on cleaned but *not* sterilised blocks, new sporophytes grew at all seasons (presumably from microscopic sporophytes or from fertilisation of gametophytes).

ii. Kelp growth rates after clearance

Isle of Man In further work with cleared areas in the Isle of Man, Kain (1976) investigated the growth rates of remaining kelp plants. At 0.8 m depth, growth was rapid after canopy removal, indicating the role of the canopy in limiting the light available for the growth of other strata of kelps in the forest. 1-3 year old plants in the cleared areas became larger than those in control areas as a consequence. However, after 3 years the biomass and frond area index of the experimental area was restored. At 4.4 m depth, recolonisation was haphazard and the growth rates of the plants were lower. The manipulative experiments of Jones & Kain (1967) in which the local population of *Echinus esculentus* was removed showed the potential of urchins to inhibit the regeneration of a kelp biotope after harvesting (see section IV.B.*3*.). iii. Epiphyte growth after canopy removal Harkin (1981) examined the effect of kelp canopy removal on the algal epiphytes of the kelp stipes. There was a rapid increase of red algal biomass in the first summer but brown algae were able to grow better in the first winter. This re-established the previous mixture of red and brown epiphytes. Two years after the removal of the canopy, the biomass of epiphytes had returned to a level similar to that measured before the canopy removal allowed an explosion of growth.

iv. Conclusions

These experiments suggest that some semblance of a kelp forest, in terms of macroalgal biomass and of subsidiary algal species, may be regained within 3 years of canopy removal. However, the size of kelp plants and the age structure of the population in the re-grown forest is different from the untouched forest. Furthermore, the experiments do not directly mimic the effect of kelp harvesting. For example, Harkin's experiments deliberately left intact stipes that a kelp harvesting dredge would have removed. New stipes would not have developed the normal epiphyte flora so quickly. While this work might superficially suggest that 3-4 years is a suitable interval between harvesting to allow regrowth of the macroalgae, a much better picture of the effects of harvesting can be obtained by examining harvested grounds in Norway and Brittany.

b. *Laminaria hyperborea* harvesting

i. Introduction

The stipes of kelp plants cast ashore after storms have been collected commercially for many years as part of a mixed coastal economy in France, Ireland, Scotland and Norway. More recently, methods of dredging *L. hyperborea* on a commercially viable scale have led to this kelp being harvested under strict regulatory conditions in Norway and in Brittany (Arzel, 1996), and harvesting trials were carried out in Scottish waters in 1991 (H.T. Powell, pers. comm.). The commercial harvesting of *L. hyperborea* in French coastal waters was proposed only in 1995-6, as the local industry had previously concentrated on the collection of *L. digitata* (Arzel, 1996) and consequently, no impact assessments of harvesting have yet been published.

ii. Early assessments of impact

Norway The earliest assessment of the effect of kelp dredging in Norway was that of Svendsen (1972). He studied kelp beds at depths of 4 to 10 m over periods of up to 3 years after harvesting. These areas were quickly overgrown with new plants of *L. hyperborea*. Within 1 year the population was dense and well-developed. Although he regarded the beds as completely regenerated after 3-4 years in terms of *Laminaria* biomass, the individual plants were only half the height (about 1 m) of the former mature plants (about 2 m tall). The re-grown biomass was made up by the greater density of smaller plants. From an industrial point of view, the stipes of these new plants were of better quality for alginate extraction because they were less contaminated by epiphytes. From an ecological point of view, even after 3 years, the disturbed biotope was species-poor in comparison to an undisturbed habitat. As in the manipulative experiments described earlier, the forest may regenerate sufficiently after 3-4 years to be harvestable again but it is certainly different in structure, both as regards the kelp plants and the subsidiary flora and fauna. A system of rotation of harvested areas was introduced by the Norwegian government to ensure that each area of kelp forest was harvested only once in 4 years to allow for re-growth of the *Laminaria* plants. It has since been recommended that this time scale be extended to 7-10 years to allow for the partial recovery of populations of non-kelp species.

iii. More recent impact studies of harvesting on kelp populations

Norway Sivertsen (1991) has compared the re-growth of kelp in areas trawled 1 - 5 years previously with areas freshly trawled and control areas. Large canopy-forming plants were absent until the fourth year after harvesting, but the structure of the kelp population was beginning to stabilise with little change in plant density between years 4 and 5. The age structure of the re-grown areas showed downwardly skewed age distributions in comparison to control areas. At 4 years after harvesting, kelp plants had only reached 2/3 of full before-harvesting canopy height in the re-grown areas. Sivertsen suggested that harvesting should occur at 6 or 7 year intervals to match the natural growth and recruitment cycles in the kelp population. In addition, the post-harvesting growth data showed that the re-establishment of kelp in harvested areas was primarily dependent on the growth of viable individuals remaining after harvesting. Climax kelp communities, dominated by canopy individuals, provide poor conditions (e.g. light) for new recruitment of sporophytes to the population, so presumably the new sporophytes that grow into the population were present prior to harvesting but were small enough to escape damage. The harvesting dredge used in Norway is designed to leave behind the small kelp plants, only collecting those of canopy height (H.T. Powell, pers. comm.).

A further interesting observation in Sivertsen's report is the temporary post-harvesting replacement (for one year only) of the *L. hyperborea* dominated forest with a population of *S. polyschides* as in the clearance experiments by Kain (1975).

iv. The impact of harvesting on associated flora and fauna

Norway In a separate survey that was primarily directed at the effects of kelp harvesting on other common organisms in the kelp biotopes (Rinde *et al.*, 1992), the forest structure seemed to recover to something approaching normal after 3-4 years, but with persistent differences from an undisturbed forest. Rinde *et al.* (1992) argue that the forest may be re-harvestable after 4 years but that it does not provide the same physical environment for the other organisms which it shelters. They concentrated on the species thought to be most closely linked to the kelp and considered epiphytes, holdfast fauna and bottom fauna and flora separately. Their report contains a wealth of detail of the species present and the numbers within different animal groups.

The epiphyte community developed in complexity with the increased age of the host stipe. The plants in control areas, at about 10 years old, have a much richer and more extensive epiflora than the younger, replacement plants found in previously harvested areas. The development of a diverse epiflora was deemed to be a desirable feature of kelp biotopes because the physical structure of the epiphytes provides a habitat niche for species of amphipods, isopods, gastropods and small fish.

The epifaunal species present on the kelp stipes were not as diverse as the epiflora, usually consisting of several species of crust-forming bryozoans. Other animals were found only on the older plants; shrubby erect bryozoans and the sponge *Halichondria sp*. on 10-year-old plants, and tunicates on the 6 years post-harvest population. The full development of the epiphyte community of plants and animals seems to need much longer than the advised 4-year interval between trawling.

The holdfast fauna is richer in both species and numbers of individuals for 10-year-old plants from the control area than for younger plants from previously harvested areas. A physically obvious difference between the younger and older plants was the development of large numbers of the large tubeworm, *Filograna*, which forms a visually obvious feature only on the holdfasts of the older plants. As the kelp plants become older the area and the volume occupied by the holdfast increase, with an apparently related increase in the numbers of individual animals, and also in both the biomass and biodiversity of the holdfast fauna. Various larger species were found associated with the holdfasts: shrimps, lobsters, *Hyas* sp., *Cancer* sp., hermit crabs, *Echinus esculentus* and *Strongylocentrotus droebachiensis*. These species were absent from recently dredged areas and well established populations appeared only in the undisturbed kelp forest, suggesting that full biological restoration after harvesting may take at least 10 years.

Benthic macrofauna and macroflora were more diverse in the control area (51 species) than the recently dredged area (21 species). The dredged areas tended to have growth of other kelps on the bottom, e.g. *Alaria esculenta*, and also *Desmarestia* spp., while the bottom between the young *L. hyperborea* plants was uniformly covered with coralline algae after 3 years. In the control areas, there was a more diverse bottom community. The coralline algae were still a significant part of the bottom cover but were joined by species of cnidarians, bryozoans and sponges.

v. The impact of harvesting on other species and beyond the kelp beds

There may be consequences for kelp ecosystem components other than those directly associated with the kelp, including fish and lobsters, but these have not yet been investigated in Europe. Sivertsen (1991) suspected that kelp harvesting could have been the cause of dune erosion from adjacent areas. The removal of the kelps reduced the drag caused by the kelp beds, which had had a wave-damping effect. Higher energy waves reaching the adjacent sandy shores and their dune hinterland resulted in increased rates of sediment removal. In the United States, beds of artificial kelp have been used to prevent sand erosion from beaches. Thrush (1986) refers to the importance of accumulations of laminarial detritus on the seabed of Lough Hyne, County Cork. The POM (particulate organic matter) had a significant input to the energy web of the benthic macrofauna of soft bottoms. The export of both POM and DOM (dissolved organic matter) would be significantly affected by kelp harvesting but the effects of this reduction have not been investigated.

Harvesting of *Laminaria digitata*

This information has largely been abstracted from Arzel (1996).

Brittany Around the coasts of Brittany there is a long tradition of seaweed collection. Several species of seaweeds have been harvested on a commercial scale, large or small, since the 1950s and form the basis of a series of flourishing industries. The collection of *L. digitata* around the coasts of Brittany has provided the French alginate industry with feedstock for the production of emulsifiants. The plants are collected from small boats using a device called a "scoubidou". The scoubidou is a curved iron hook which is suspended from a hydraulic arm mounted on the boat. The scoubidou is lowered into the *L. digitata* bed and rotated. The blades of the seaweed are wound around the rotating scoubidou and the hydraulic arm pulls them out of the sea (McHugh, 2003). The hook is then winched inboard and whole plants of *L. digitata* are ripped from the substratum, including blades, stipes and some holdfasts.

There is no literature available on the effects of this method of harvesting on the biodiversity and population structures of the kelp bed species. *L. digitata* plants rapidly re-colonise any gaps in the upper infralittoral which result from storm damage and are assumed to respond in a similar way to areas cleared by harvesting. The areas licensed for harvesting represent only a small proportion of the total habitat of *L. digitata* around Brittany, but the substratum area which is effectively cleared each year is not recorded, just the wet mass of the harvest. The complaints of local fishermen that crustacean catches are locally reduced in harvested areas have been dismissed as an example of the historical animosity between fishermen and seaweed harvesters (Dauvin, 1997).

6.5. Areas of conservation concern in Northern Ireland (Designated Sites)

The effects of seaweed harvesting on protected areas of the shore in Northern Ireland are of particular concern. However, as there is no information on the origins of the POM (Particulate Organic Matter) that supports the coastal faunal food webs, all areas could be impacted by seaweed harvesting, not just those which are already designated. POM is a term used to describe the mixture of particles that are available within the water column to the multitudes of marine invertebrates (and some vertebrate species) that obtain their food by water filtration. POM consists of the photosynthesising primary producers (phytoplankton – flagellates, diatoms, etc.) as well as the zooplankton (such as copepods, ctenophores and the larval stages of most marine invertebrates). However, the bulk of the POM is of detrital origin. In coastal waters the majority of the POM is formed from the fragmentation of decomposing macroalgae (Thrush, 1986).

The following forms of designation for the purposes of nature conservation can be found on the shores of Northern Ireland:

- Marine Special Areas of Conservation (SACs) - Habitats Directive 92/43/EEC
- Areas of Special Scientific Interest (ASSIs) - Nature Conservation and Amenity Lands (Northern Ireland) Order 1985; The Environment (Northern Ireland) Order 2002
- Special Protection Areas (SPAs) - EC Directive 79/409 on the Conservation of Wild Birds
- Ramsar sites (Wetland of International Importance), The Convention on Wetlands of International Importance (1976)
- Marine Nature Reserves (MNRs) - Nature Conservation and Amenity Lands (Northern Ireland) Order 1985; The Environment (Northern Ireland) Order 2002
- National Nature Reserves (NNRs) - Amenity Lands Act (Northern Ireland) 1965
- Areas of Outstanding Natural Beauty (AONBs) - Nature Conservation and Amenity Lands Order (Northern Ireland) 1985.

6.6. The effects of seaweed harvesting on: Northern Ireland Marine Habitats (features of SACs) and Species listed in Annex I and II of the Habitats Directive (92/EEC) and Priority marine habitats (U.K and Northern Ireland)

The following tables (11 and 12) list the marine species and habitats identified as priority UK and NI habitats or habitats and species which are listed in the Habitats Directive. An indication is given of the potential for the impact of harvesting of macroalgae on each listing and mitigating practices that might be applied are suggested. The tables incorporate information summarised from websites of DoE NI, JNCC, MNCR, Habitas, and MarLin etc.

In the intertidal habitats there is the potential for the disturbance of feeding, breeding or roosting wildfowl and waders. Access to the shore on foot and without dogs reduces disturbance effects on birds. Harvesting activity should be limited in these areas during the late winter and spring when feeding disturbance in particular can be deleterious to the migrant bird populations. Excessive trampling of the intertidal and coastal fringe either on foot or by the use of vehicles or sledges may result in habitat destruction. The use of mechanical methods of harvesting either intertidally or subtidally may also result in habitat destruction.
The loss of primary producer biomass may disrupt food webs either locally (small scale harvesting) or near-shore (large scale harvesting) as a consequence of the removal of the seaweeds as a habitat, as a direct food source or as an energy source within the detrital food web.

If the annex II species (table 12) are present in a harvesting area, cropping should be shifted to a part of the area where human activity will not disturb the animals. ***Small scale harvesting*** for personal use is likely to have no impact, ***artisanal scale harvesting*** of a species should be based on a minimal impact cropping method and harvesting cycle appropriate to each species and ***commercial scale harvesting*** will require resource management, for which much more knowledge of the effects of biomass removal on this habitat and the ecosystems and species within it will be needed; mechanical harvesting should not be considered until such information is available.

Table 11: Potential impact of macroalgal harvesting and suggested mitigating practices for Northern Ireland Annex I habitats and Annex II species, marine.

Annex I Habitats (marine)	Notes – Potential impact of macroalgal harvesting and suggested mitigating practices (potential effects in bold type)
Large shallow inlets and bays	Potential for harvesting a wide range of species from hard substrate intertidal and subtidal areas on all scales and both by hand or using mechanised methods **disturbance to wildlife; food web disruption** *small scale harvesting* for personal use is likely to have no significant impact *artisanal scale harvesting* of a species should be based on a minimal impact cropping method and harvesting cycle appropriate to each species *commercial scale harvesting* will require resource management, for which much more knowledge of the effects of biomass removal on this habitat and the ecosystems and species within it will be needed; mechanical harvesting should not be considered until such information is available
Reefs	Potential for harvesting, especially kelps and their epiphytes on all scales and both by hand or using mechanised methods **habitat destruction; food web disruption** *small scale harvesting* for personal use is likely to have no impact *artisanal scale harvesting* of a species should be based on a minimal impact cropping method and harvesting cycle appropriate to each species *commercial scale harvesting* will require resource management, for which much more knowledge of the effects of biomass removal on this habitat and the ecosystems and species within it will be needed; mechanical harvesting should not be considered until such information is available
Mudflats and sandflats not covered by seawater at low tide	Not usually considered applicable for seaweed harvesting; but some areas described as mudflats incorporate mixed sediment areas of boulders or cobbles which can form luxuriant patches of macroalgal habitat and cropping of these patches may have consequences **disturbance to wildlife especially birds, habitat destruction; food web disruption** *small scale harvesting* for personal use is likely to have no impact other than possible wildlife disturbance *artisanal scale harvesting* of a species should be based on a minimal impact cropping method and harvesting cycle appropriate to each species and the habitat *commercial scale harvesting* will require resource management, for which much more knowledge of the effects of biomass removal on this habitat and the ecosystems and species within it will be needed; mechanical harvesting should not be considered until such information is available
Estuaries	There is the potential for harvesting from hard substrate areas in marine portions of the intertidal area **disturbance to wildlife especially birds, habitat destruction; food web disruption** *small scale harvesting* for personal use is likely to have no impact other than possible wildlife disturbance artisanal scale harvesting of a species should be based on a minimal impact cropping method and harvesting cycle appropriate to each species *commercial scale harvesting* will require resource management, for which much more knowledge of the effects of biomass removal on this habitat and the ecosystems and species within it will be needed; mechanical harvesting should not be considered until such information is available
Sandbanks that are slightly covered by seawater all the time	Not usually considered as a habitat supporting seaweed but this feature incorporates near-shore maërl beds in some areas of the coast; harvesting from maërl beds (dead or alive) is by dredging and has similar effects to aggregate removal **habitat destruction; food web disruption** *small scale harvesting* for personal use is likely to have no impact *artisanal scale harvesting* should be based on a minimal impact collection method such as snorkel diving with a bucket and limited to areas of dead material *commercial scale harvesting* will remove the habitat and should not be considered on or adjacent to live maërl meds

Table 12: Potential impacts of macroalgal harvesting and suggested mitigating practices for Northern Ireland Annex II species, marine.

Annex II Species (marine)	Notes (potential effects in bold)
Halichoerus grypus **(Grey Seal)**	There are no known direct impacts on the species as a result of seaweed harvesting although access to harvesting areas may result in disturbance in the intertidal and large scale kelp harvesting may remove fishing areas **disturbance to resting animals; food web disruption**
Phoca vitulina **(Common or harbour seal)**	There are no known direct impacts on the species as a result of seaweed harvesting although access to harvesting areas may result in disturbance in the intertidal and large scale kelp harvesting may remove fishing areas **disturbance to resting animals; food web disruption**
Lutra lutra **(Otter)**	There are no known direct impacts on the species as a result of seaweed harvesting although access to harvesting areas may result in disturbance in the intertidal and large scale kelp or fucoid harvesting may remove fishing areas **disturbance to resting animals; food web disruption**

Table 13: Northern Ireland Annex I habitats and Annex II species, marine, which have *no* potential for impact by macroalgal harvesting.

Habitats (marine)	**Notes**
Lagoons	Not a habitat of the target species
Sandbanks that are slightly covered by seawater all the time	Not a habitat of the target species
Submerged or partly submerged sea caves	Not a habitat of the target species
Submarine structures made by leaking gases	Not a habitat of the target species
Species (marine)	**Notes**
Phocoena phocoena (Harbour porpoise)	Not normally present in potential seaweed harvesting areas
Tursiops truncates (Bottlenose Dolphin)	Not normally present in potential seaweed harvesting areas
Caretta caretta (Loggerhead turtle)	Not normally present in potential seaweed harvesting areas
Petromyzon marinus (Lamprey)	Not normally present in potential seaweed harvesting areas
Acipenser sturio (Sturgeon)	Not normally present in potential seaweed harvesting areas
Alosa spp. (Shad)	Not normally present in potential seaweed harvesting areas
Small scale cropping of seaweeds will have no impact on the food webs supporting the above marine species. **The effects of large scale harvesting on the near shore food webs that support these species in Northern Europe are *not known***	

Table 14: UK and NI priority marine habitats in which commercial or potentially commercial macroalgal species are found in Northern Ireland, with notes on the potential impact of macroalgal harvesting and suggested mitigating strategies.

Priority habitat, marine	Notes – Potential impact of macroalgal harvesting and suggested mitigating practices (potential effects in bold type)
Sheltered muddy gravels	On stable shores (both intertidal and subtidal) the target species may grow luxuriously if occasional larger pebbles or cobbles (for attachment) are present overlying the substrate. Removal of the macroalgal cover could result in changes to the localized biodiversity (Kelly *et al*, 2001) and possibly to the particle size distribution of the adjacent sediment (Boaden & Dring, 1980). **Disturbance to wildlife, habitat destruction; food web disruption** *Small scale harvesting* for personal use is likely to have no impact. *Artisanal scale harvesting* of a species should be based on a minimal impact cropping method and harvesting cycle appropriate to each species. Restricting the cropping to a maximum of 25% of the coverage of the target species, by hand, with the cutters accessing the site on foot and with an interval between visits of several years would have negligible effect on the habitat. *Commercial scale harvesting* will require resource management, for which much more knowledge of the effects of biomass removal on this habitat and the ecosystems and species within it will be needed; mechanical harvesting should not be permitted until such information is available. Mechanised harvesting methods are not appropriate as substrate disturbance will result in increased sediment mobility and reduced water clarity. There is potential for the disturbance of feeding or roosting wildfowl and wading birds on all scales. Access to the shore on foot and without dogs reduces any disturbance. Harvesting activity should be limited in these areas during the late winter and spring when feeding disturbance in particular can be deleterious especially to the migrant bird populations.
***Sabellaria alveolata* reefs**	The reefs of sandy tubes built by this species can be susceptible to the effects of trampling. Where these reefs are present on the lower intertidal, they may become colonised by target species and so be a source of macroalgal material. **Habitat destruction, food web disruption** *Small scale harvesting* for personal use is likely to have no impact. *Artisanal scale harvesting* should be discouraged to avoid trampling effects. *Commercial scale harvesting* will require resource management, for which much more knowledge of the effects of biomass removal on this habitat is required; mechanical harvesting should not be permitted from this habitat.
Sub-littoral and littoral chalk sites	See notes for "sheltered muddy gravels" above due to the soft nature of chalk, this habitat is not normally considered to be a major habitat for macroalgae, however on the Antrim coast the chalk rocks have been modified and are unusually hard, numerous species of macroalgae may be present. **Disturbance to wildlife, food web disruption**
Littoral or sub-littoral limestone pavement	See notes for "sheltered muddy gravels" above; the precautions which are applied generally to harvesting macroalgae should apply in this habitat as the physical structure is not likely to be damaged by harvesting activities. **Disturbance to wildlife, food web disruption.**

Table 14 continued.

Priority habitat, marine	Notes – Potential impact of macroalgal harvesting and suggested mitigating practices (potential effects in bold type)
Tidal rapids	These features are notable for the high diversity of intertidal species that inhabit them and also for the presence of species more commonly associated with the shallow sub-tidal. They are susceptible to human activities such as bait collection and the turning of boulders but, infrequent access on foot and limited cutting within any given patch of a target species will have a negligible effect on the habitat. **Habitat destruction; food web disruption.** *Small scale harvesting* for personal use is likely to have no impact. *Artisanal scale harvesting* of a species should be based on a minimal impact cropping method and a harvesting cycle appropriate to each species. *Commercial scale harvesting* will require resource management, for which much more knowledge of the effects of biomass removal on this habitat and the ecosystems and species within it will be needed; mechanical harvesting should not be considered until such information is available and there should be no motorised access across this habitat.

Table 15: UK and NI priority marine habitats in Northern Ireland which have *no* potential for direct impact by harvesting of macroalgae (with explanatory notes)

Priority habitat, marine (Note: potential effects in bold type)	Comments
Coastal and floodplain grazing marsh	not a habitat of target species; for some species within the habitat **- food web disruption**
Maritime cliffs and slopes	not a habitat of target species: for some species associated with the habitat - **food web disruption**
Coastal sand dunes	not a habitat of target species; cast weed often acts as a primary barrier against which blown sand will accumulate and as a rooting medium for primary colonising species - **food web disruption**
Coastal vegetated shingle	not a habitat of target species; the decomposition of cast weed may act as a growth medium and fertilizer for shingle vegetation - **food web disruption**
Mudflats	where target species are present in this habitat, it is due to the presence of gravel or larger stones and shells which form an attachment point for the algae. See "Sheltered muddy gravels" above - **disturbance to wildlife, habitat destruction; food web disruption**
Coastal saltmarsh	not a habitat of target species**;** although not a seaweed, the harvesting of *Salicornia europaea* from this habitat may introduce similar problems to those posed by macroalgal harvesting **- disturbance to wildlife, habitat destruction; food web disruption**

On some stretches of the Northern Ireland coast, there is the probability that portions of the above habitats may need to be crossed in order to access the intertidal for the purposes of harvesting macroalgae. Specific precautions may be required to be publicised with regard to the avoidance of trampling of vegetation, disturbance of breeding birds and damage to the structure of the habitat.

small scale harvesting *for personal use is likely to have no impact; where such a possibility exists any impact should be no more than that of normal recreational walking of the area*

artisanal scale harvesting - *any impact should be no more than that of normal recreational walking of the area; no motorised transport should be permitted on the shore or coastal vegetation or features*

commercial scale harvesting - *no motorised transport should be permitted on the shore or coastal vegetation or features; mechanical harvesting should not be considered in areas where access and transportation would be across these habitats.*

Maerl beds	not harvested and should not be dredged - **habitat destruction; food web disruption**
Mud habitats in deep water	not a habitat of target species **- food web disruption**
Saline lagoons	not a habitat of target species
Seagrass beds	not a significant habitat of target species **- disturbance to wildlife, habitat destruction; food web disruption food web disruption**
***Modiolus modiolus* (horse mussel) beds**	not a habitat of target species **- food web disruption**
***Sabellaria spinulosa* reefs**	not a habitat of target species - **food web disruption**
Sub-littoral sands and gravels	not a habitat of target species **- food web disruption**

6.7. Priority Species associated with commercial or potentially commercial macroalgal species in Northern Ireland.

Table 16: Lists of Northern Ireland subtidal and intertidal Priority Species and Species of Conservation Concern which are or are reliant on these environments for feeding at some time in the year (This list has been modified from the EHS web site and within the taxon groupings species are not listed in taxonomic order, but in alphabetic order).

Notes:

- Species names in blue are primary producers
- Species names in bold type are **filter feeders reliant on POM** (particulate organic matter)
- Species names in red feed on the POM feeders, directly or at higher trophic levels
- Code letters listed under "Potential impact of seaweed harvesting"
    - D disturbance (to feeding, breeding, roosting)
    - T trampling (may destroy species or structure of habitat)
    - R removal (harvested, removed with macroalgae, collected as ancillary harvest)
    - HD habitat destruction (removal of shade, structure, host)
    - FW food web disruption (removal of supporting biomass, supply of POM, supply of POM feeders, supply of higher trophic levels)

Priority species	Species of conservation concern	habitat	Potential impacts of seaweed harvesting (for codes see above)				
Porifera							
	Axinella dissimilis	subtidal, bedrock, exposed coasts					FW
	Biemna variantia	subtidal, rock & mixed sediments					FW
Clathria barleei	*Clathria barleei*	subtidal, rock & stones					FW
Eurypon coronula	*Eurypon coronula*	subtidal, rock & stones					FW
Hymerhabdia typica	*Hymerhabdia typical*	subtidal, rock & stone					FW
Iophon ingalli (hyndmani)	*Iophon ingalli (hyndmani)*	subtidal, epifaunal, sheltered areas					FW
Microciona elliptichela	*Microciona elliptichela*	subtidal, rock					FW
Mycale (contarenii)	*Mycale (contarenii)*	intertidal & subtidal, rock, boulders	D	T			FW
	Mycale lingua	subtidal, rock					FW
	Mycale ovulum	no data					FW
Mycale similaris	*Mycale similaris*	no data					FW
	Myxilla cf. rosacea	subtidal, rock, kelp beds		T			FW
	Phakellia rugosa	subtidal, rock					FW
	Plocamiancora arndti	subtidal, rock					FW
Spanioplon armaturum	*Spanioplon armaturum*	subtidal, exposed to sheltered rock & epifaunal					FW
	Spongionella pulchella	subtidal, rock					FW
	Stelleta grubii	no data					FW
	Stryphnus ponderosus	subtidal, rock overhangs					FW
Cnidaria							
	Alcyonium hibernicum	subtidal, sheltered rock, no algae					FW
Anemonactis mazeli	*Anemonactis mazeli*	subtidal, sand & mud					FW
Arachnanthus sarsi	*Arachnanthus sarsi*	subtidal, sand & shelly mud, in "parchment" tube					FW
	Aureliania heterocera	low intertidal & subtidal, base buried in sand, gravel, maërl				HD	FW
Caryophyllia inornata	*Caryophyllia inornata*	subtidal, vertical & overhanging rock, caves					FW
Diphasia alata	*Diphasia alata*	subtidal, bedrock & stable boulders, strong currents					FW
Diphasia nigra	*Diphasia nigra*	subtidal, bedrock & stable boulders, strong currents					FW
Edwardsia timida	*Edwardsia timida*	intertidal & subtidal, burrows in sheltered sand, moderate current					FW

Priority species	Species of conservation concern	habitat	Potential impacts of seaweed harvesting (for codes see above)				
Halecium plumosum	*Halecium plumosum*	subtidal, bedrock, boulders & shells, moderate current					FW
Lytocarpia myriophyllum	*Lytocarpia myriophyllum*	subtidal, sheltered sites, rock, moderate current					FW
	Parazoanthus anguicomis	subtidal, rock, overhangs, organic substrates, epifaunal					FW
Parazoanthus axinellae	*Parazoanthus axinellae*	subtidal, rock and sponges, vertical faces and overhangs					FW
Polyplumaria flabellate	*Polyplumaria flabellate*	subtidal, rock, strong current, scoured by gravel					FW
	Stomphia coccinea	subtidal, on shells or stones in fine sediments.					FW
	Tamarisca tamarisca	subtidal, rocks & shells, strong currents					FW
Virgularia mirabilis	*Virgularia mirabilis*	subtidal, sheltered mud					FW
Annelida (Polychaetes)							
	Harmothoe mackintoshii	intertidal, mixed sediment, below stones		T			FW
	Leucia nivea	no data, family Polynoidae					
Sabellaria alveolata	*Sabellaria alveolata*	lower intertidal, biogenic reef		T		HD	FW
Sabellaria spinulosa	*Sabellaria spinulosa*	shallow subtidal		T			FW
	Spirorbis vitreus	no data					FW
Crustaceans							
Cestopagurus timidus	*Cestopagurus timidus*	intertidal & subtidal, soft sediments, *Zostera* beds					FW
Atelecyclus rotundatus	*Atelecyclus rotundatus*	subtidal sand and gravel			R		FW
	Corystes cassivelaunus	intertidal & subtidal, fine sand					FW
	Homarus gammarus r	subtidal, rock & boulder areas, kelp beds			R	HD	FW
Inachus leptochirus	*Inachus leptochirus*	subtidal, mixed substrates					FW
Munida rugosa	*Munida rugosa rugose*	subtidal, coarse & mixed sediments			R		FW
Palinurus elephas	*Palinurus elephasc*	subtidal, rock & boulder areas			R		FW
Molluscs							
Atrina fragilis	*Atrina fragilis*	subtidal, soft & mixed sediments					FW
Cerastoderma glaucum	*Cerastoderma glaucum*	intertidal & submerged, sand, lagoons			R		FW
Chlamys varia	*Chlamys varia*	intertidal & subtidal, rochy and mixed sediment s			R		FW
	Crenella decussate	subtidal, soft & mixed sediments					FW
Cumanotus beaumonti	*Cumanotus beaumonti*	subtidal, motile					FW
	Cuthona concinna	subtidal, motile					FW
	Embletonia pulchra	intertidal & subtidal, on hydroids				HD	FW
Erato volute	*Erato volute*	intertidal & subtidal, rock and mixed sediments					FW

Priority species	Species of conservation concern	habitat	Potential impacts of seaweed harvesting (for codes see above)				
Eubranchus doriae	*Eubranchus doriae*	subtidal, motile					FW
	Hero Formosa	subtidal, motile					FW
	Hydrobia acuta	intertidal and lagoon, mud					
	Hydrobia ventrosa	intertidal, saltmarsh					
Modiolus modiolus	*Modiolus modiolus*	sheltered subtidal, biogenic reef			R		FW
Ostrea edulis	*Ostrea edulis*	sheltered subtidal, mixed substrates			R		FW
Palio dubia	*Palio dubia*	intertidal & subtidal, under rocks					FW
	Pecten maximus	subtidal, sand & mixed sediment areas			R		FW
	Philinoglossa helgolandica	subtidal, sediments, interstitial					FW
	Stiliger bellula	no data					
	Thecacera pennigera	subtidal, motile					FW
Tonicella marmoreal	*Tonicella marmorea*	intertidal & subtidal, rock and mixed substrates				HD	
Bryozoans							
	Bugula turbinate	intertidal & subtidal, under stones, on rocks		T			FW
Pentapora foliacea	*Pentapora foliacea*	subtidal, sand-scoured rock & boulders		T			FW
Echinoderms							
	Amphiura securigera	subtidal, coarse gravel					FW
Anseropoda placenta	*Anseropoda placenta*	subtidal, muddy sand & gravel					FW
	Asterina phylactica	intertidal pools, subtidal, rocky areas high water movement				HD	FW
Astropecten irregularis	*Astropecten irregularis*	subtidal, clean sand & mud					FW
Labidoplax media	*Labidoplax media*	subtidal, very sheltered soft mud					FW
Leptasterias mulleri	*Leptasterias mulleri*	subtidal, rocky areas including kelp beds				HD	FW
Leptosynapta bergensis	*Leptosynapta bergensis*	subtidal, muddy sand					FW
	Luidia sarsi	subtidal, muddy sediments					FW
Ocnus planci	*Ocnus planci*	subtidal, epifaunal					FW
Paracucumaria hyndmani	*Paracucumaria hyndmani*	subtidal, muddy sediments					FW
	Porania pulvillus	subtidal, rock, boulders, wrecks				HD	FW
Solaster endeca	*Solaster endeca*	subtidal, boulders & muddy gravel					FW
Thyonidium drummondi	*Thyonidium drummondi*	subtidal, mixed & muddy sediments					FW
Enteropneusta							
Glossobalanus sarniensis	*Glossobalanus sarniensis*	subtidal, fine mud					FW

Priority species	Species of conservation concern	habitat	Potential impacts of seaweed harvesting (for codes see above)				
Tunicates							
	Archidistoma aggregatum	subtidal, sand scoured sites, strong current					**FW**
	Boltenia echinata	subtidal, sheltered silty sites					**FW**
Pyura microcosmus	***Pyura microcosmus***	subtidal, shells and rocks, sheltered					**FW**
	Synoicum incrustatum	subtidal, vertical rock, strong currents, sand scour					**FW**
Fish							
Alosa alosa	***Alosa alosa***	shallow coastal, spawns in rivers					**FW**
Alosa fallax fallax	***Alosa fallax fallax***	shallow coastal, spawns in rivers					**FW**
Cetorhinus maximus	***Cetorhinus maximus***	free range, visiting					**FW**
Commercial marine fish	***Commercial marine fish***	no summary					**FW**
Deep-water fish species	***Deep-water fish species***	no summary					**FW**
	Galeorhinus galeus	free-range					**FW**
Osmerus eperlanus	***Osmerus eperlanus***	coastal waters					**FW**
Raja batis	***Raja batis***	coastal waters, have a local area					**FW**
	Raja radiate	no summary					**FW**
	Salmo salar	North Atlantic, then spawns in rivers					**FW**
	Salmo trutta	fresh water but can become sea living					**FW**
	Squalus acanthus	free range, shallow coastal waters					**FW**
Reptiles							
Marine turtles	***Marine turtles***	free range, visiting	**D**				
Birds							
	Alca torda	breeds on seacliffs, nearshore feeding	**D**				**FW**
	Anas acuta	intertidal feeding	**D**				**FW**
	Anas clypeata	intertidal feeding	**D**				**FW**
	Anas crecca	intertidal feeding	**D**				**FW**
	Anas penelope	winter shore feeding	**D**				**FW**
	Anas querquedula	winter shore feeding	**D**				**FW**
	Anas strepera	winter shore feeding	**D**				**FW**
	Anser albifrons flavirostris	winter shore feeding	**D**				**FW**
	Anser anser	winter shore feeding	**D**				**FW**
	Anser brachyrhynchus	winter shore feeding	**D**				**FW**

Priority species	Species of conservation concern	habitat	Potential impacts of seaweed harvesting (for codes see above)				
	Arenaria interpres	intertidal feeding	D				FW
	Aythya fuligula	winter shore feeding	D				FW
	Aythya marila	winter shore feeding	D				FW
Branta bernicla hrota	*Branta bernicla hrota*	winter feeding	D				FW
	Bucephala clangula	winter shore feeding	D				FW
	Calidris alpine	intertidal feeding	D				FW
	Calidris canutus	intertidal feeding	D				FW
	Calidris maritime	intertidal feeding	D				FW
	Cepphus grille	cliff breeding	D				FW
	Charadrius hiaticula	winter shore feeding	D				FW
	Clangula hyemalis	winter shore feeding	D				FW
Crex crex	*Crex crex*	coastal grassland	D				
	Cygnus columbianus	winter shore feeding	D				FW
	Cygnus Cygnus	winter shore feeding	D				FW
	Cygnus olor	intertidal feeding	D				FW
	Falco columbarius	cliff nesting and hunting	D				FW
	Falco peregrinus	cliff nesting and hunting	D				FW
	Fratercula arctica	coastal nesting in burrows	D				FW
	Fulmarus glacialis	cliff nesting & roosting	D				FW
	Gavia arctica	nearshore feeding	D				FW
	Gavia immer	nearshore feeding	D				FW
	Gavia stellata	nearshore feeding	D				FW
	Haematopus ostralegus	intertidal feeding & resting	D				FW
	Hydrobates pelagicus	breeds on rocky islands	D				FW
Larus argentatus	*Larus argentatus*	intertidal feeding, cliff nesting & roosting	D				FW
	Larus canus	intertidal feeding, cliff nesting & roosting	D				FW
	Larus fuscus	intertidal feeding, cliff nesting & roosting	D				FW
	Larus melanocephalus	intertidal feeding	D				FW
	Larus ridibundus	intertidal feeding, cliff nesting & roosting	D				FW
	Limosa lapponica	estuaries & sandy shores	D				FW
Limosa limosa	*Limosa limosa*	winter shore feeding	D				FW

Priority species	Species of conservation concern	habitat	Potential impacts of seaweed harvesting (for codes see above)				
	Melanitta fusca	winter shore feeding	D				FW
Melanitta nigra	*Melanitta nigra*	winter shore feeding	D				FW
	Mergus serrator	winter shore feeding	D				FW
Numenius arquata	*Numenius arquata*	shore feeding, esp. winter	D				FW
	Oceanodroma leucorhoa	breeds on remote grassy islands	D				
	Pandion haliaetus	coastal breeding & hunting	D				FW
	Phalacrocorax aristotelis	breeds & feeds along rocky coasts	D				FW
	Phalacrocorax carbo	breeds & feeds along rocky coasts	D				FW
	Philomachus pugnax	winter shore feeding	D				FW
	Pluvialis apricaria	winter shore feeding	D				FW
	Pluvialis squatarola	winter shore feeding	D				FW
	Puffinus puffinus	breeds on remote grassy headlands and islands	D				FW
Pyrrhocorax pyrrhocorax	*Pyrrhocorax pyrrhocorax*	cliff breeding	D				
	Rissa tridactyla	cliff breeding, coastal feeding	D				FW
	Somateria mollissima	breeds and feeds along coast	D				FW
	Sterna albifrons	coastal breeding and feeding	D				FW
Sterna dougallii	*Sterna dougallii*	coastal breeding and feeding	D				FW
	Sterna hirundo	coastal breeding and feeding	D				FW
	Sterna paradisaea	coastal breeding and feeding	D				FW
	Sterna sandvicensis	coastal breeding and feeding	D				FW
	Sula bassana	cliff breeding	D				FW
	Tadorna tadorna	breeding & winter shore feeding	D				FW
	Tringa erythropus	winter shore feeding	D				FW
Tringa totanus	*Tringa tetanus*	winter shore feeding	D				FW
	Uria aalge	breeding & nearshore feeding	D				FW
Vanellus vanellus	*Vanellus vanellus*	coastal breeding, winter shore feeding	D				FW
Mammals							
Baleen whales	*Baleen whales*	free range, visiting coastal waters	D				
Dolphins	*Dolphins*	free-range, visiting coastal waters	D				FW
Phocoena phocoena	*Phocoena phocoena*	free range, visiting coastal waters	D				FW
Other toothed whales	*Other toothed whales*	free range, visiting coastal waters	D				FW

Priority species	Species of conservation concern	habitat	Potential impacts of seaweed harvesting (for codes see above)				
Phoca vitulina	*Phoca vitulina*	hunting coastal waters, haul out & breed on shore	**D**				**FW**
Lutra lutra	*Lutra lutra*	hunting coastal waters, holts on quiet stretches of shore	**D**				**FW**
MACROALGAE							
Ascophyllum nodosum	*Ascophyllum nodosum*	intertidal		**T**	**R**	**HD**	
Ascophyllum nodosum mackaii	*Ascophyllum nodosum mackaii*	sheltered intertidal gyres		**T**			
Carpomitra costata	*Carpomitra costata*	subtidal, rock					
Desmarestia dresnayi	*Desmarestia dresnayi*	subtidal, rock		**T**			
Ahnfeltiopsis ***sp***	*Ahnfeltiopsis* ***sp***	subtidal, rock					
	Atractophora hypnoides	subtidal, maërl beds				**HD**	
Dasya ocellata	*Dasya ocellata*	subtidal, rock					
	Gelidiella calcicola	subtidal, maërl beds				**HD**	
	Phymatolithon calcareum	intertidal, subtidal, maërl beds, kelp beds				**HD**	
	Schmitzia hiscockiana	subtidal, rock, cobble, kelp beds				**HD**	
	Schmitzia neapolitana	subtidal, cobble					
	Stenogramme interrupta	subtidal, rock & shells, maërl beds					
Vascular plants							
Centaurium littorale	*Centaurium littorale*	coastal grassland		**T**			
Cochlearia officinalis ssp. Scotica	*Cochlearia officinalis ssp. scotica*	coastal grassland, above HW on sand & shingle		**T**			
Crambe maritime	*Crambe maritime*	sand & shingle above HW		**T**			
Limonium procerum	*Limonium procerum*	low rocky cliffs above HW		**T**			
Mertensia maritime	*Mertensia maritime*	sand & shingle above HW		**T**			

Table 17: NI priority marine species, explanatory notes with reference to the potential impact of seaweed harvesting and suggested mitigation strategies.

Priority marine species Northern Ireland	Notes - potential impact of seaweed harvesting and suggested mitigation strategies
Porifera **Cnidaria** **Annelids** **Crustaceans** **Molluscs** **Bryozoans** **Echinoderms** **Enteropneusta** **Tunicates**	There is a risk of damage from trampling for intertidal species and of habitat removal (i.e. "clear-felling" of kelp forests) for subtidal species; the major impact of macroalgal harvesting would be the removal of primary producer biomass from the coastal ecosystem ***small scale harvesting*** for personal use is likely to have no impact ***artisanal scale harvesting*** is likely to have no impact ***commercial scale harvesting*** much more knowledge of the effects of biomass removal on the food webs supporting the filter feeding species and the species that prey on them through the trophic levels is required
Fish	***small scale harvesting*** for personal use is likely to have no impact ***artisanal scale harvesting*** is likely to have no impact ***commercial scale harvesting*** much more knowledge of the effects of biomass removal on the food webs supporting fish populations is required
Reptiles	the presence of marine turtles on the coasts of Northern Ireland is rare and so unlikely to be impacted by any level of macroalgal harvesting activity
Birds ***(shore feeding*** ***Coastal-water feeding*** ***Cliff and shore breeding*** ***Birds of prey)***	For all species of birds in coastal areas, resident or migrant, the major effects of seaweed harvesting are the potential for disturbance to the birds during access or harvesting, and the unknown consequences of primary producer biomass removal from the ecosystem. ***small scale harvesting*** for personal use is likely to have no impact ***artisanal scale harvesting*** should be undertaken sensitively with regard to disturbance ***commercial scale harvesting*** will require resource management, for which much more knowledge of the effects of biomass removal on the ecosystem is required; mechanical harvesting should not be permitted in protected areas
Mammals	***small scale harvesting*** for personal use is likely to have no impact ***artisanal scale harvesting*** should be undertaken in a species sensitive manner by informed personnel ***commercial scale harvesting*** should be restricted in areas where species disturbance could occur *NB. Lutra lutra & Phoca vitulina* potential for disturbance on shores; accessing sites on foot would have no more effect on the above species than normal access to the shore by members of the public. Frequent access to shores and near-shore waters should be discouraged

Priority marine species Northern Ireland	Notes - potential impact of seaweed harvesting and suggested mitigation strategies
Macroalgae	***small scale harvesting*** for personal use is likely to have no impact by trampling but collection of the species should be restricted ***artisanal scale harvesting*** personnel should be informed to avoid trampling sensitive species or harvesting them ***commercial scale harvesting*** of the species should be restricted; mechanical harvesting should not be permitted from these locations and habitats *NB. Ascophyllum nodosum* ecad *mackii* this species is only found where local current conditions form inshore tidal gyres in very sheltered bays; plants are susceptible to excessive trampling; access across the habitat should be restricted
Vascular plants ***Coastal and shingle bank vegetation***	These plants might be subject to trampling during access and egress to intertidal harvesting areas ***small scale harvesting*** for personal use is likely to have no impact ***artisanal scale harvesting*** personnel should be encouraged to avoid trampling sensitive species ***commercial scale harvesting*** more knowledge of the effects of biomass removal on this habitat is required; mechanised access across the habitat should not be permitted

For all species within the coastal zone (marine, subtidal, intertidal, cliffs, beaches, shingle, dunes and coastal marshes and grasslands) there is a major gap in understanding of the consequences of primary producer biomass removal from the area. The complex food web interactions of the coastal ecosystem (in its broadest sense) are poorly understood and have not been quantified.

Application of the precautionary principal approach is recommended.

- The removal of macroalgal biomass on a large scale (more than 5% of the standing biomass km^{-1} $year^{-1}$) should be banned.

- Any proposals for the mechanical harvesting of macroalgae should be refused.

7. Effect on coastal processes

7.1. Introduction

All ecosystems are controlled and organised by a set of key plant, animal and abiotic processes that engineer and structure the landscape or substrate (Widdows & Brinsley, 2002). The influence that aquatic vegetation such as macroalgal and seagrass beds has on coastal processes has long been recognised in qualitative terms. For example, aquatic vegetation clearly provides food and shelter for many marine organisms, influences biogeochemical cycles in the coastal zone, and dissipates wave energy and turbulence, so protecting the shore from erosion (Vasquez, 1995). However, little detailed experimental or analytical work has been completed that takes our understanding far beyond these statements.

The most detailed and quantitative studies are, not surprisingly, those of the engineers anxious about their structures and sensitive shorelines, and these can now be tied in with recent advances in our understanding of the resistance of individual seaweed thalli to the stresses imposed by wave action on the shore (e.g. Pratt & Johnson, 2002). The work on the impact of vegetation (i.e. collections of thalli), however, has largely been done with artificial "kelp plants" in flumes (e.g. Price et al., 1968; Ahrens, 1976; Ifuku et al., 1997; Løvås & Tørum, 2001) or theoretical studies using mathematical models (e.g. Kobayashi et al., 1993; Mendez & Losada, 2004), although the wave damping effects of a sublittoral kelp forest were studied by Mork (1996). However, there does not seem to have been any attempt to follow the changes in erosion patterns or wave impact on shorelines following the removal of sublittoral or intertidal vegetation, either in an experimental study or as a result of commercial exploitation.

7.2. Effect of beach cast cleaning/harvesting

The other area that has received a reasonable amount of attention is the effect of cleaning drift seaweed from beaches. The deposits of macroalgae that are cast up on sandy beaches are usually seen as a nuisance, especially in areas of high tourist value. Such material begins to decompose within two or three days of becoming washed up along the high tide line, and reduces the aesthetic quality of the beach and indeed in Northern Ireland, Local Area Authorities have in the past removed this material for tourist resorts and blue flag beaches.

Usually less than 10% of the biomass of marine macrophytes is consumed by herbivores. The remainder dies and decays, forming detritus that contains a high proportion of structural carbohydrate, which most animals cannot digest. The detritus is colonized by fungi and bacteria that take nitrogen and other nutrients from the water while using the plant tissue as their carbon source. This material becomes palatable to animals after a relatively short exposure to microbes. Ecosystem-scale studies suggest that many fish and invertebrates derive a significant part of their nutrition from the detritus food web. Protection of macrophyte beds in their natural state may be important to many organisms (Mann, 2000).

It has been reported that harvesting of this material in Australia can adversely affect the coastal and nearshore environment, because beach-cast macroalgae and seagrasses are an important component of these environments. Research on nearshore ecosystem dynamics suggests that wrack accumulations are a source of particulate and dissolved carbon and nutrients. The juveniles of economically important fish feed on amphipods living in the surf-zone accumulations of detached macroalgae. It is suggested that this decaying vegetation also provides protection from predators (Kirkman, & Kendrick, 1997). In areas where there are high concentrations of nutrients such as an upwelling system, the removal of nutrients from the system is unlikely to have highly significant effects, whereas in areas where nutrient influx is low the system may become nutrient-limited, thus preventing macroalgal growth (Archambault, 1999). According to the *FAO Fisheries Technical Paper 441* the harvesting of driftweed in Australia has a cap of 50% of the cast kelp (in the Australian seaweed industry the targeted algae are members of the genus *Durvillaea*). This limit appears to be set for unsubstantiated reasons (*FAO Fisheries Technical Paper 441*). One possible reason for this cap on harvestable material may be the lack of detailed information on the role of driftweed in the environment. It is plausible that the Australian authorities have adopted a precautionary approach to the management of this material.

While this material may be considered a nuisance to some, prior to significant decomposition, it can provide a source of raw material to companies, such as one in Northern Ireland, which produce specialised fertilisers for golf courses and botanic gardens. Although an essential component for the companies that utilise it, the cast material is also an important source of energy for detritivores and microorganisms in soft-shore ecosystems. Because of this, harvesting or cleaning can adversely affect some aspects of the coastal and nearshore environment. In Western Australia, Kirkman & Kendrick (1997) studied the movement of drifters towards the shore in an attempt to relate the productivity of offshore sublittoral vegetation to the amount of weed cast up on the local beaches, but they were unable to establish a clear correlation. Nevertheless, they recommended a number of priority areas for future research, including:

- "Assessment of biomass, density and annual production rates of living stands for each location where harvesting is occurring or is proposed;
- "Determination of the interannual variability of recruitment into living stands;
- "Assessment of the relative importance of wrack in recycling nutrients and detritus to near shore coastal ecosystems."

The effects of cleaning beach-cast seaweed on the ecology of sandy beaches has been studied on the Baltic coast of Sweden and in Australia. In Sweden, cleaning improved the recreational quality of the beaches (by reducing the organic content of the sand, and increasing water clarity), but did not have a major effect on the biodiversity of the littoral macrofauna (Malm et al, 2004). A comparable study in Australia, however, showed that the fauna on cleaned beaches was similar to that on beaches that did not have much drift weed (i.e. that were cleaned naturally by wave or current action), but the fauna on these beaches differed significantly from that on beaches which accumulated drift weed but were not cleaned (Lavery et al., 1999). It seems that the impact of cleaning or harvesting drift weed will depend on the site. In highly eutrophic conditions, harvesting of macroalgal deposits can be an effective management tool, since this will remove nutrients from the system that otherwise would have been recycled and become biologically available. However, when making decisions about whether harvesting will be a useful option, managers should conduct trials in specific sites. Washed up macroalgae also represents a patchy and highly unpredictable resource that is variable over time. Local knowledge of the effect of beach-cast material is lacking. There appears to be no information on the effects of this material on local biodiversity; incorporation of material into nesting material by birds; and the importance of the recycling process in coastal ecosystems.

7.3. Effect of removing living seaweeds on rocky shores

The effect of removing substantial quantities of living seaweeds (especially kelps or fucoids) on the ecology of rocky shores is more difficult to study quantitatively, and the work that was conducted in Strangford Lough following the quickly aborted trial harvesting of *Ascophyllum* near Killyleagh in 1976 (Boaden & Dring, 1980) provides a rare example of useful data. The study was conducted 2.5 years after the harvesting, when the *Ascophyllum* population had apparently recovered reasonably well. Nevertheless, detailed examination of the cover of animals on the sides and bottoms of large boulders from adjacent harvested and unharvested areas showed significant reductions in the cover of sponges, barnacles and mussels, as well as in the total cover of live animals, and the number of animal species. Although these effects could not be described as devastating for the ecology of the area, they had resulted from harvesting on a small scale (only 180 m of shore had been cut) and had persisted for 2.5 years. It is reasonable to assume that harvesting on a larger scale would have disproportionately larger effects because of greater sediment redistribution and the greater distances that organisms or their propagules would have to travel to recolonise areas that had been disturbed. These data, therefore, reinforce the arguments for restricting large-scale harvesting of canopy seaweeds, and ensuring that substantial areas are left unharvested, especially in regions of high biodiversity.

8. Right of access to the seaweed resource

8.1. Introduction

The current legal status of seaweed harvesting appears to be entangled in myth of traditional and perceived rights to harvest. Historically, wrack rights in certain areas were distributed to the larger estates. In the 18th and early 19th centuries a seaweed harvesting industry developed in Strangford Lough. These estates either leased or harvested the stretch of shoreline that was under their control. In certain areas a dividing wall was constructed to demarcate the extent of a particular plot (McErlean et al. 2002).

The right to harvest seaweed from the shore line (otherwise known as wrack rights), varies from area to area. As stated, historic rights to intertidal seaweed in some locations, most notably Strangford Lough and Carlingford Lough, was assigned to certain estates. These rights may have been retained by the estate concerned, while in other instances where the estate has been broken up, the rights have been allocated accordingly. It appears that with the loss of interest in seaweed as a resource, the owners of the property may have forgotten or simply be unaware of their entitlements (Fraser McConnell, pers. comm.). The Crown Estate Commission (CEC) has in its possession detailed maps of their holdings. These maps also outline areas where there has been an admitted claim to a third party (see Figures 3–11 for representation of these maps). In a number of instances this admitted claim is to the National Trust (NT). Specific properties in the care of the NT may have clauses (in relation to wrack rights) written into their conveyances. Any leases from CEC state that we (the National Trust) do not have the right to remove sand, stone, beach or shingle, but seaweed and wrack are not referred to specifically (National Trust, comm.).

8.2. Ownership of Northern Ireland's foreshore

The Crown Estate holdings include the entire seabed out to the 12 mile UK territorial limit and have ownership rights to all minerals across the rest of the UK's portion of the European Continental Shelf. The Crown Estate (CE) is managed under the Crown Estate Act 1961 by the CEC, whose role is to maintain and enhance the value of the Estate, with regard to its good management (Crown Estate, 2005).

The majority of the foreshore around Northern Ireland, excluding several extensive areas where there have been admitted claims to third parties in the past, is owned by the CE. Almost all the seabed out to the 12 mile limit is also in The CE's ownership (Fraser McConnell, pers. comm.).

With the vast majority of the shoreline of Northern Ireland controlled by the CE, it is essential that this agency has a policy to ensure that the seaweed resource is managed correctly. This policy is as follows:

1) On receipt of an application for seaweed collection the CEC would advise the applicant that they must ensure that they have all other necessary consents and that they should consult the relevant Conservation Agency e.g. Environment and Heritage Service etc.

2) If the applicant confirms that the seaweed has been washed above the high tide mark the CEC would advise them that they should contact the owner of the beach and/or the Local Council to seek their consent.

3) Once the CEC has received confirmation from the relevant Conservation Agency that they are content for the activity to proceed and all other necessary consents have been obtained the CEC will issue a letter of consent. The terms of this letter will require the applicant to adhere to any conditions set by the relevant Conservation Agency.

The CE would not issue consent where the seaweed is protecting a beach as it would be illegal to do so under the terms of the Coast Protection Act (Emily Forsythe, pers. comm.).

Maps of the Northern Ireland coastline held by Brown McConnell Clark Ltd., were examined with special reference to the foreshore on March 2005 and April 2005. The foreshore (between mean high and mean low water) is mapped with colour indicating ownership. Pink colouration denotes CE ownership, blank areas denote areas leased by the CE and green areas denote private ownership or areas where there has been a historical admitted claim by the CE to private citizens. For the purposes of this report the areas of the foreshore in Northern Ireland which are not CE owned or leased, have been mapped and are shown below. The original maps of CE ownership (Northern Ireland) are available for inspection from Brown McConnell Clark Ltd.

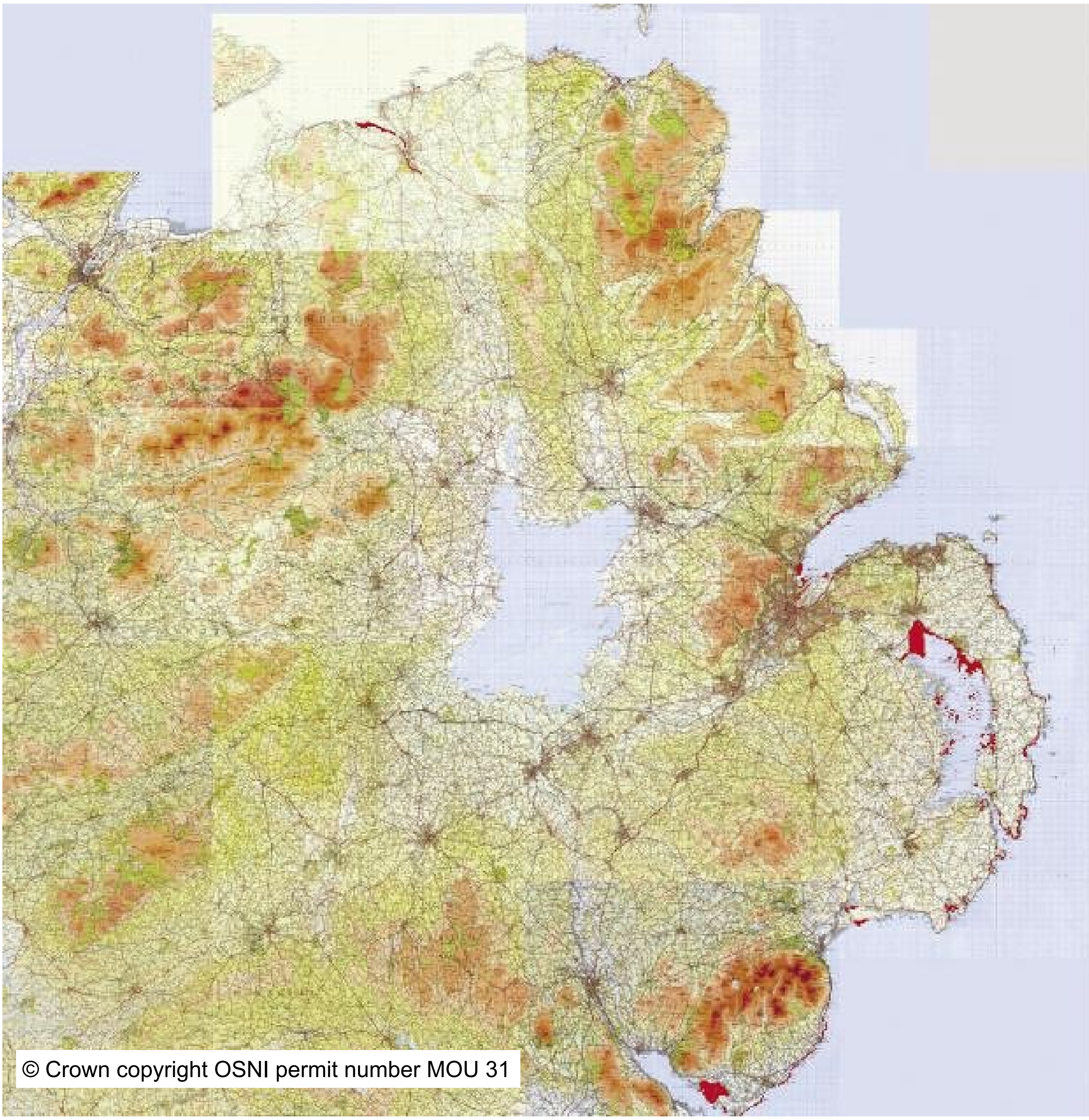

Figure 1: Map of Northern Ireland indicating intertidal areas NOT under control of Crown Estate (red).

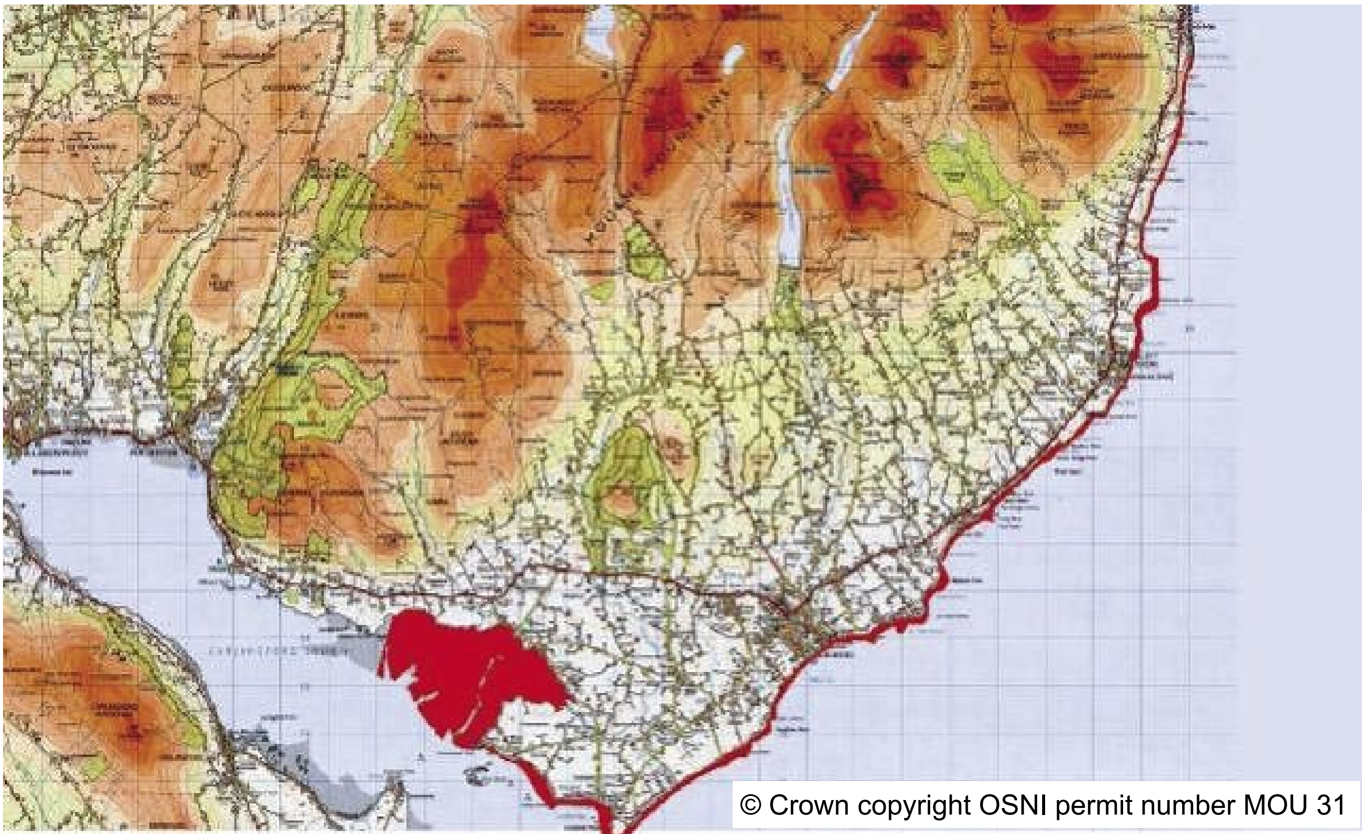

Figure 2: Map of south County Down indicating intertidal areas NOT under control of Crown Estate (red).

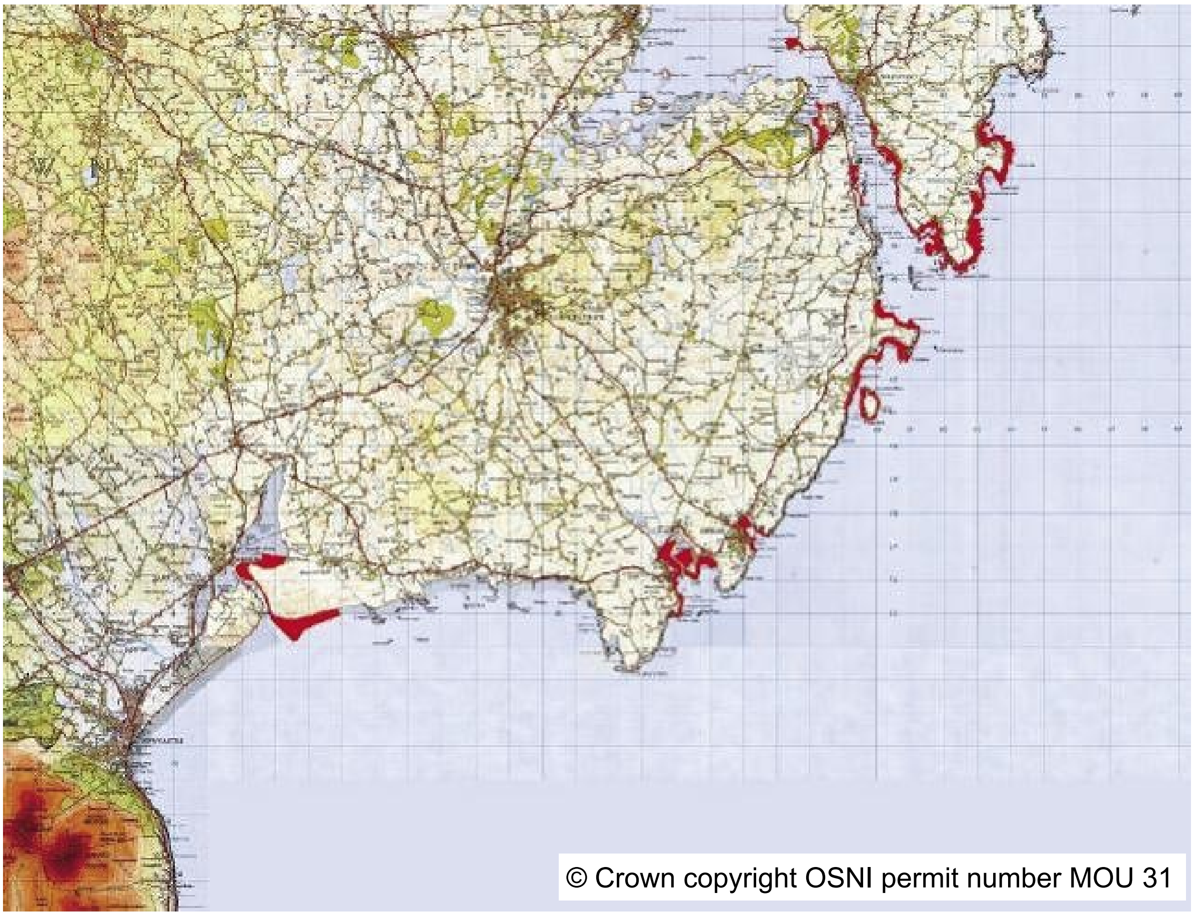

Figure 3: Map of south-east County Down indicating intertidal areas NOT under control of Crown Estate (red).

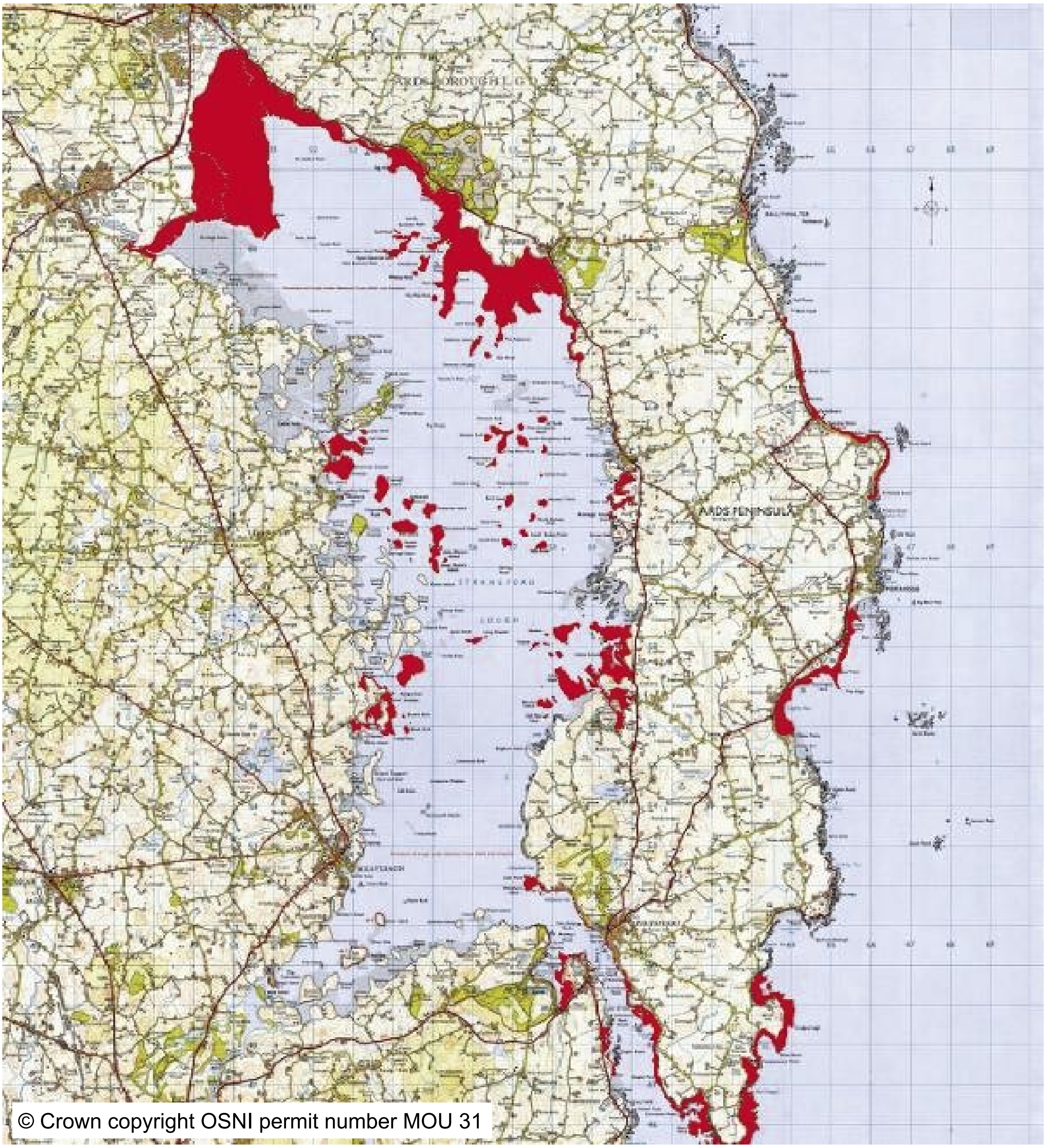

Figure 4: Map of Strangford Lough and Ards Peninsula indicating intertidal areas NOT under control of Crown Estate (red).

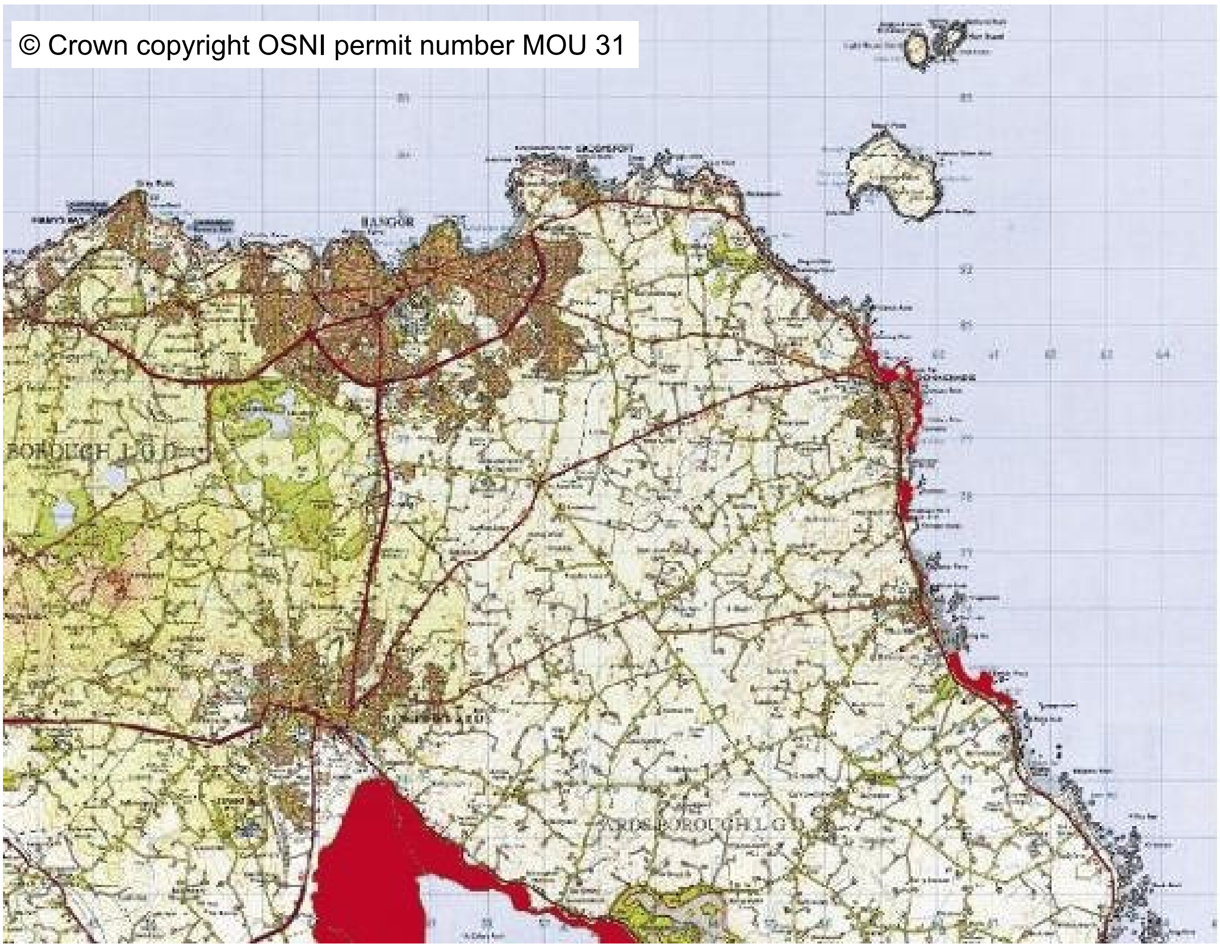

Figure 5: Map of north County Down indicating intertidal areas NOT under control of Crown Estate (red).

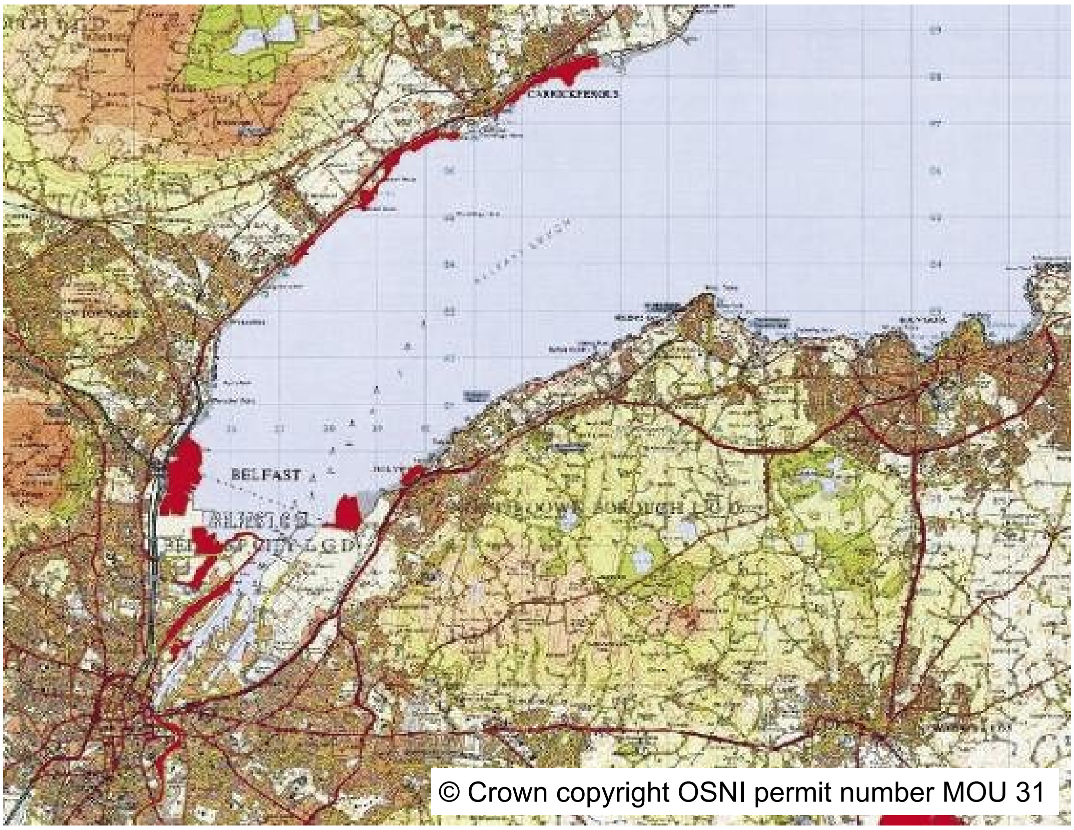

Figure 6: Map of Belfast Lough indicating intertidal areas NOT under control of Crown Estate (red)

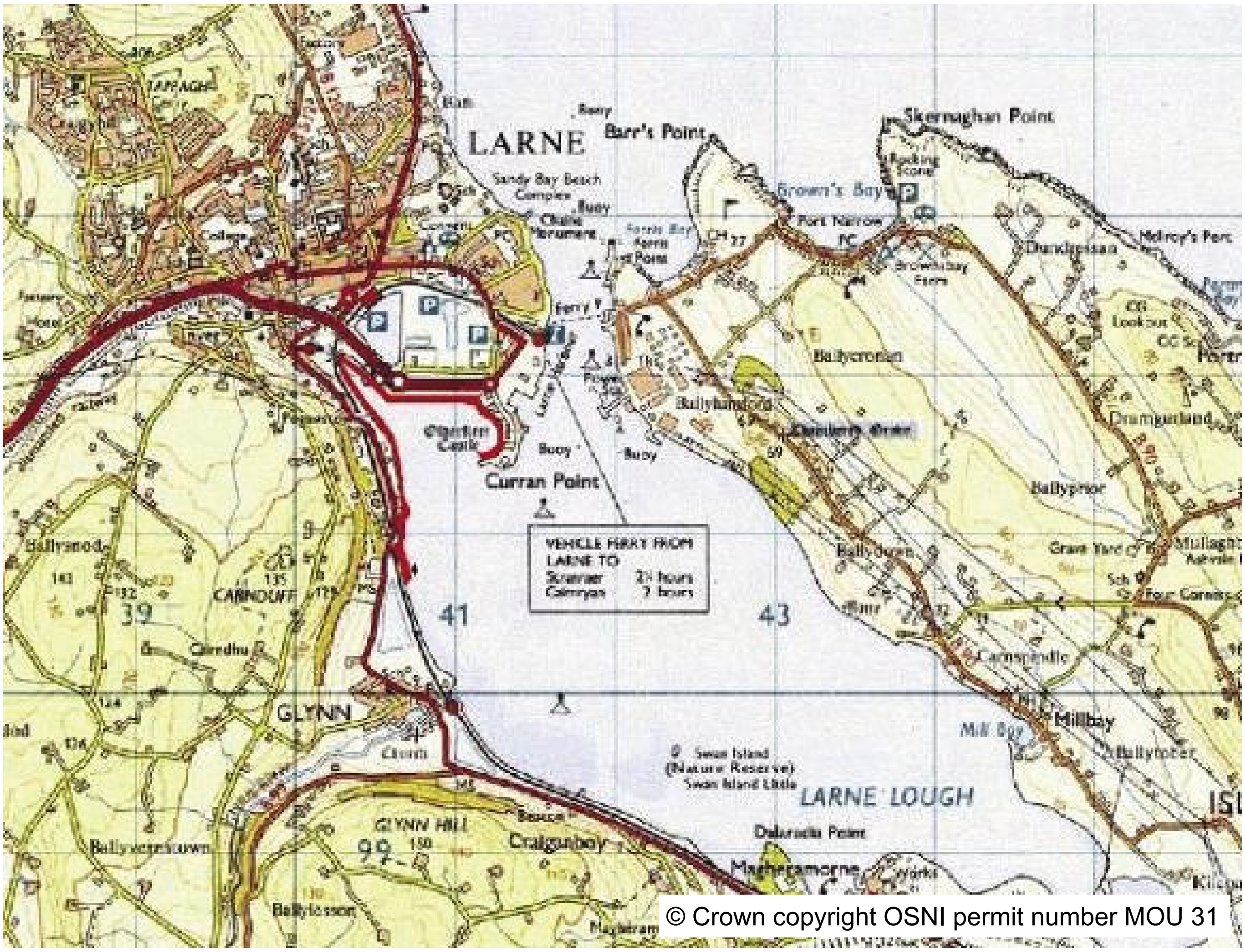

Figure 7: Map of Larne Lough indicating intertidal areas NOT under control of Crown Estate (red).

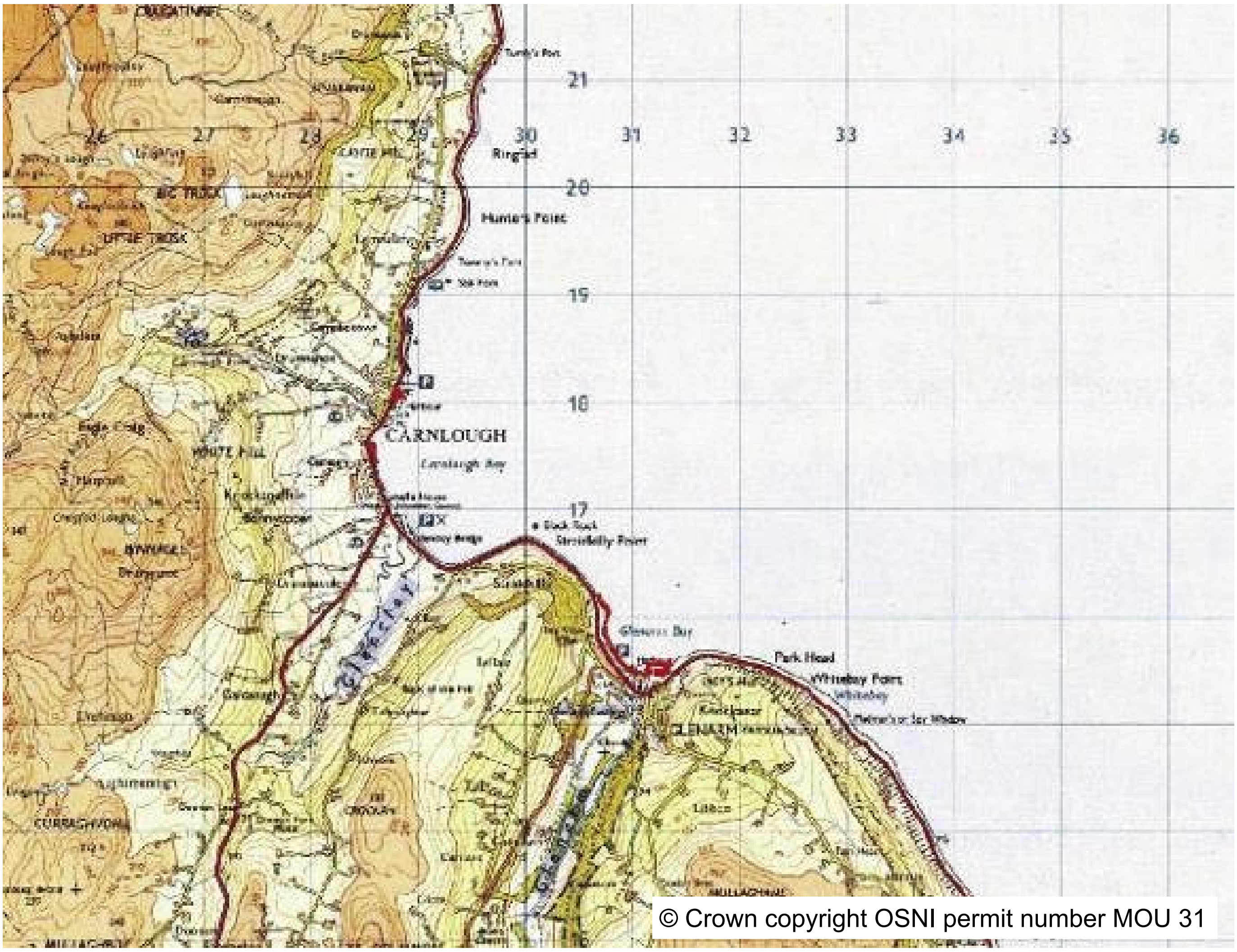

Figure 8: Map East Antrim coastline indicating intertidal areas NOT under control of Crown Estate (red).

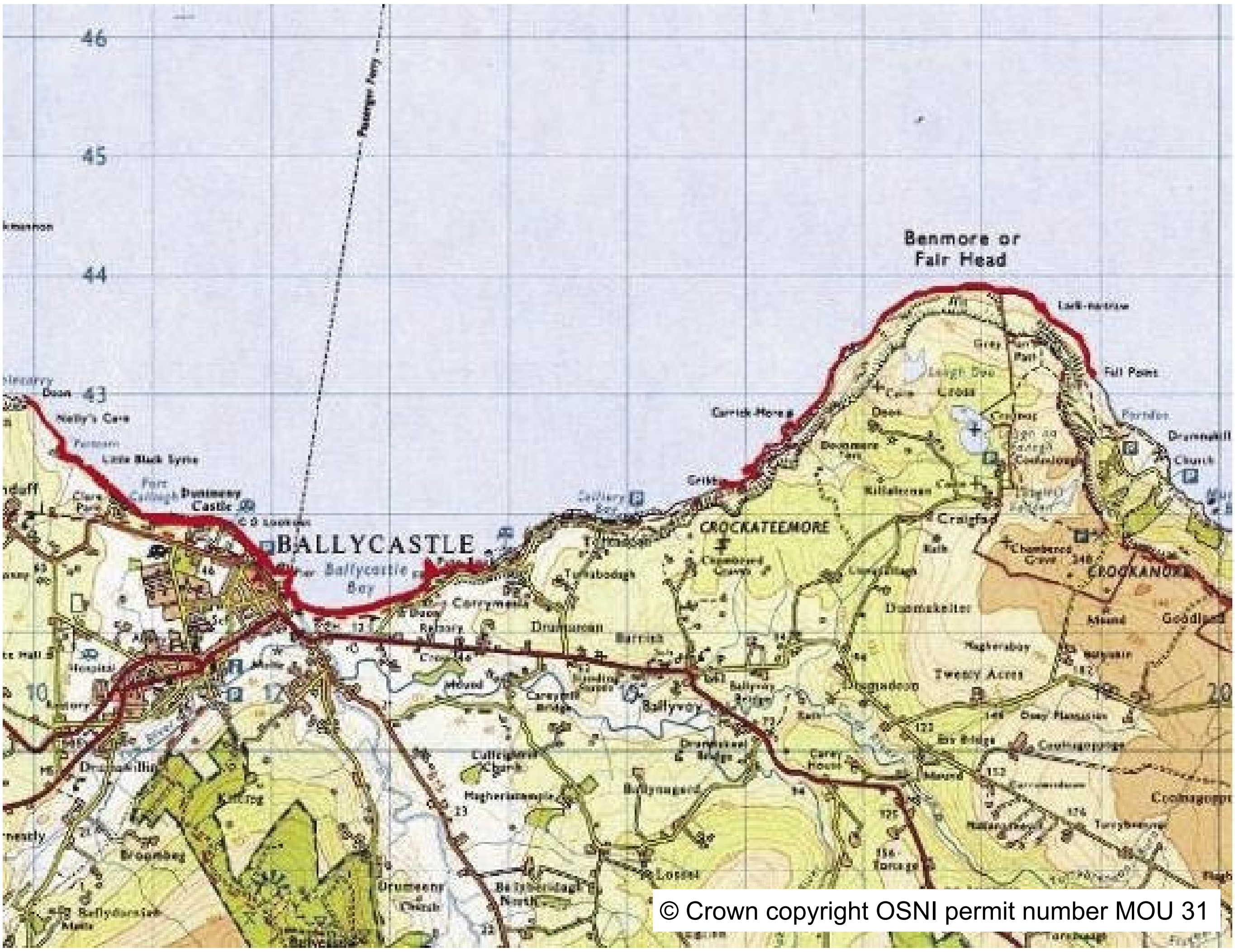

Figure 9: Map of north County Antrim indicating intertidal areas NOT under control of Crown Estate (red).

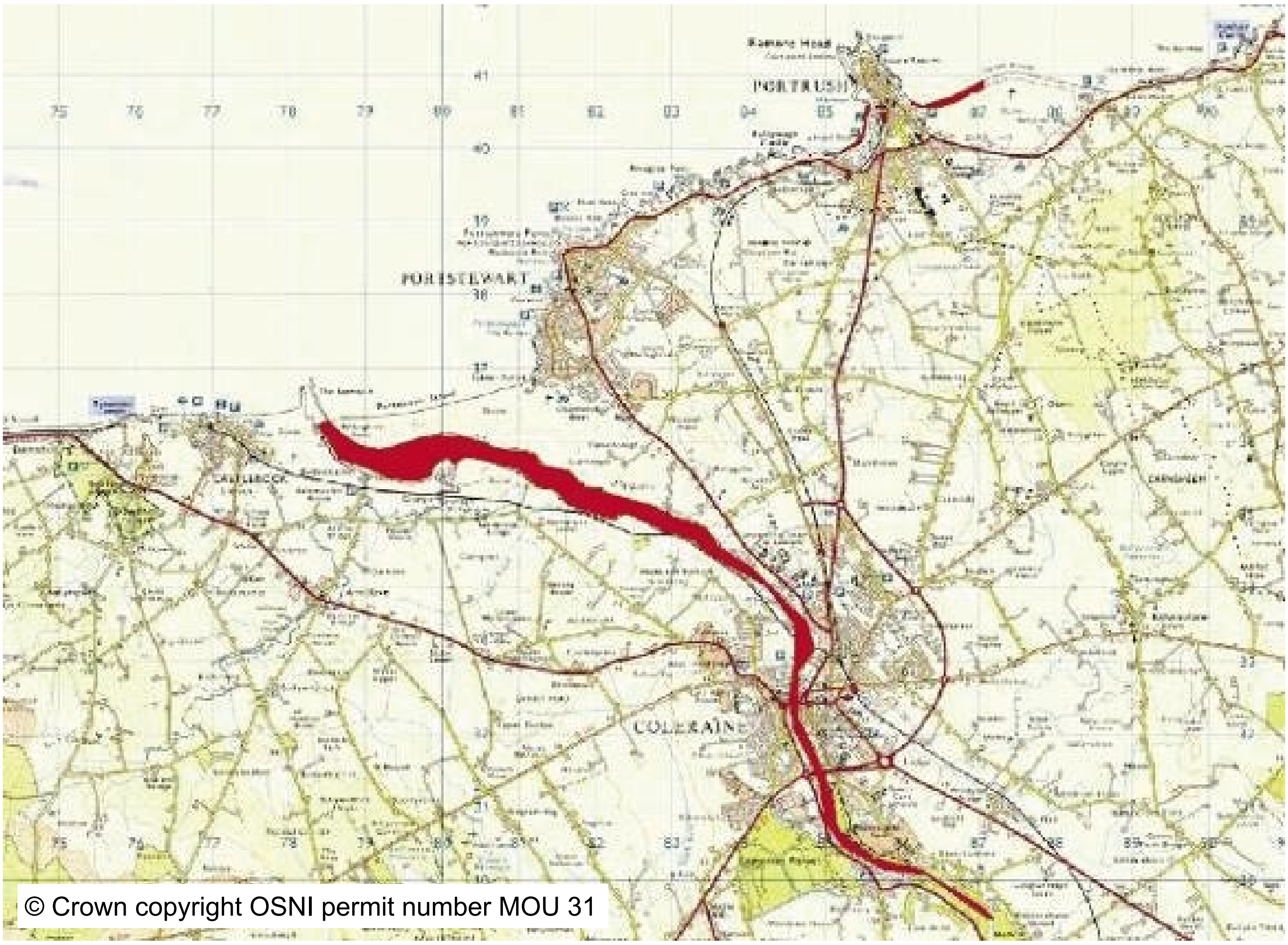

Figure 10: Map of Coleraine and Portrush indicating intertidal areas NOT under control of Crown Estate (red).

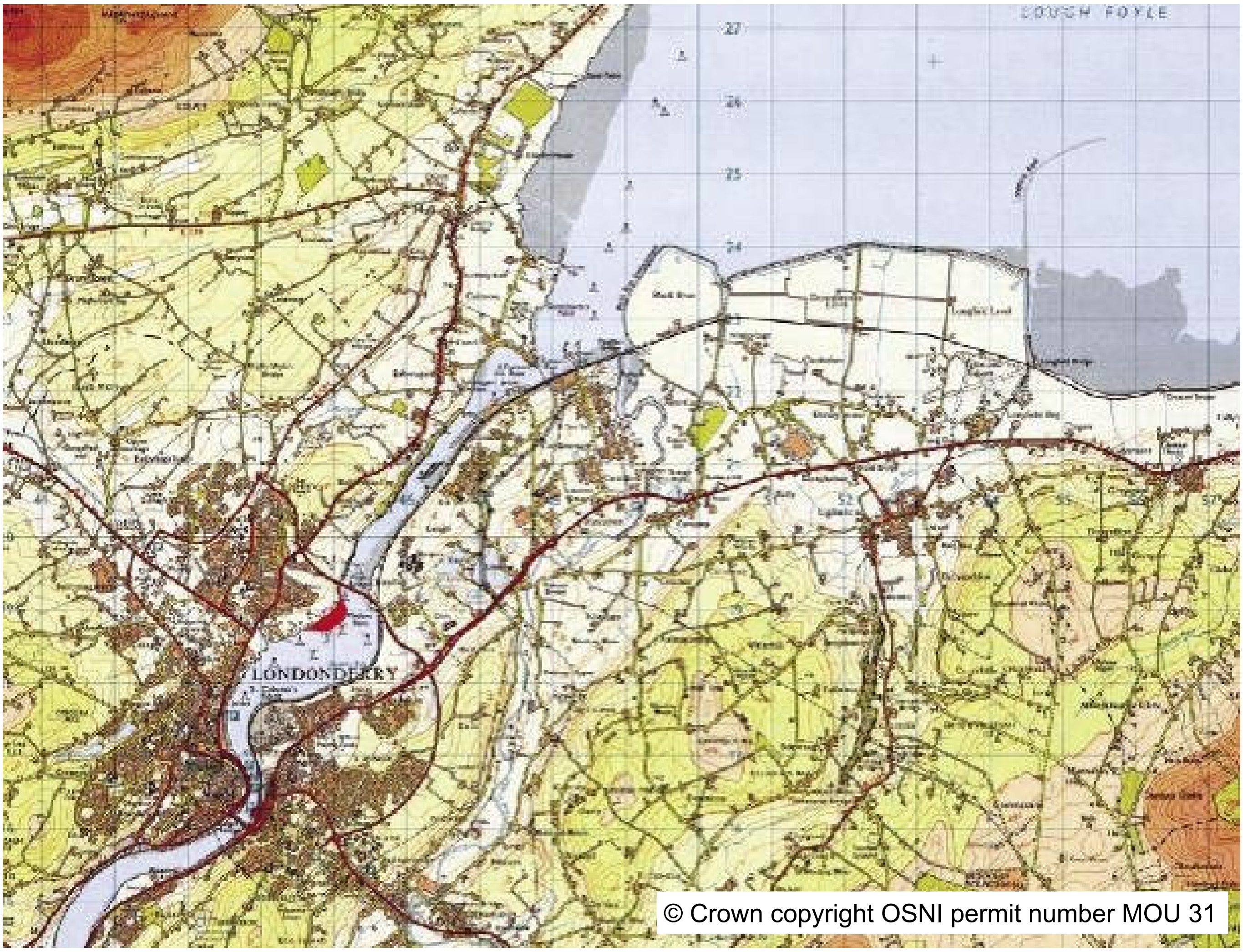

Figure 11: Map of Lough Foyle indicating intertidal areas NOT under control of Crown Estate (red).

8.3. Right of access to the seaweed resource

The following passage has been extracted from a court judgment (Adair v National Trust and another; Chancery Division [1998] NI 33 21 November 1997 Girvan J.) (Girvan, 1997).

In upholding the proprietary interests of the landowner of the foreshore the Courts have held that there is no right to cross the foreshore to bathe (see *Blundell* v *Catterall* (1821) 5 B&Ald 268 and *Brinckman* v *Matley* [1904] 2 Ch 313) or to hold meetings or deliver sermons (*Llandudno Urban District Cotincil* v *Woods* [1899] 2 Ch 705) or to place chairs on it (*Ramsgate Corporation* v *Debling* (1906) 70 JP 318) or to go there to gather seaweed (*Hove* v *Stowell* (1833) Al & Nap 348 (IR)). Where such activities are permitted it is because of the tolerance or forbearance to the landowner and not by virtue of a claim of right.

The fact that members of the public have a right to swim or bathe in the sea does not imply a right to cross the foreshore to exercise that right. Similarly the right of members of the public to take seaweed floating in the sea does not mean that they have a right to lift seaweed lying on the foreshore. Thus Lawson J in *Brew* v *Haren* (1877) 11 ILTR 66 stated --

"...seaweed driven above the high water mark, of course, belongs to the owner of that land. The right of the public to take it when floating provided he can do so without trespassing on the soil of an individual is as clear as their right to catch fish in the ocean but when seaweed has once touched the shore and can only be taken from it the public right ceases and that of the Crown or its grantee commences."

As Miss Forsythe of the Crown Estate has stated in her correspondence, the region above the high tide mark is generally not under the control of the Crown Estate. This section of the shore line (as indicated in the above judgment) is owned / controlled either by private citizens or in some cases Local Authorities. When acquiring harvesting rights of this area, a Northern Irish company must seek permission from the applicable authority and the owners of the land.

Unlike the intertidal environment, the subtidal has remained in the control of the Crown Estate. Thus the subtidal seaweed resource remains the "property" of the CE. To access this supply of seaweed, permission must be sought from the CE. Then the appropriate impact assessments to fulfil the requirements of the CE must take place.

8.4. Site designations

Areas of Special Scientific Interest are defined in the Nature Conservation and Amenity Lands (N.I.) Order (NCALO) 1985 (with 1989 amendment).

Where the Department, ..., is satisfied that an area of land is of special scientific interest, by reason of its flora, fauna or geological, physiographical or other features, and accordingly needs to be specially protected, the Department shall make a declaration that the area is an area of special scientific interest.

The designation of an area as an ASSI will have certain implications for the activities that can take place in the location. There are restrictions put in place to protect the habitats in question. In the declaration of an ASSI for Carlingford Lough the following stipulations (among others) appeared:

- Any activity or operation which involves the damage or disturbance by any means of the surface and subsurface of the land, including ploughing, rotavating, harrowing, reclamation, and extraction of minerals, including rock, sand, shingle, shell, gravel and peat.
- The destruction, displacement, removal or cutting of any plant, seed or plant remains, other than for:
    - Plants listed as noxious in the Noxious Weeds (Northern Ireland) Order 1977;
    - Normal cutting or mowing regimes for which consent is not required;
    - The exercising of rights on established wrack beds.

In 1992, the European Community (EC) adopted the *Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora*, known as the Habitats Directive. The Habitats Directive requires member states to designate Special Areas of Conservation (SACs) for habitats (listed in Annex 1) and species (Annex 2) considered to be most in need of conservation at a European level.

9 Commercial seaweed harvesting management

9.1. Introduction

Marine macroalgae provide habitats for numerous species of fish, invertebrates and plants. Although these plants are considered as a resource, they provide a habitat for numerous organisms. Just as seaweeds influence the biotic environment, equally they have a significant influence on the physicochemical elements of the environment. Approaches to harvesting management must take this into account and as such strategies should adopt a precautionary approach and not just allow maximum exploitation. It can also be said that seaweeds have the potential to provide substantial boosts to the economy of rural areas and the overall economy of Northern Ireland.

As is the case in all management schemes, it is unlikely that there could ever be a zero risk management strategy developed. Nonetheless, sustainable and ecofriendly practices can and should be implemented to ensure minimal environmental damage.

Some implications of commercial seaweed harvesting have been known from the 18th and early 19th centuries. During this time a linen industry thrived in the Strangford Lough area, dependent on seaweed for the production of dyes. Significant quantities of *Ascophyllum* and other species of macroalgae were harvested from Strangford Lough, with possible effects on the local ecosystem. In 1744, Harris suggested that one of the reasons for herring stock decline in Strangford may have been kelp burning during the spawning season; the removal of seaweed in sheltered bays may also have contributed to declining numbers (McErlean et al., 2002). The ecological impact of macroalgal harvesting depends on the scale and frequency, intensity, and percentage removal of the harvest as well as the characteristics of the life history of the organism harvested and the phenological attributes of the community (Vasquez, 1995).

For the various species of marine algae that are, or have the potential to be, commercially harvested different management strategies must be applied or developed from sound scientific knowledge to maintain an ecosystem in favourable status.

In countries and regions of the world where the seaweed harvesting industry is in a more advanced phase of development than in Northern Ireland, management strategies have been adopted that aim to sustain the crop and the associated ecosystems. Some of these, along with the implications of harvesting certain species of seaweed, are summarised below.

9.2. Maërl

The term maërl is a used to describe several species of calcified marine algae which grow as unattached nodules on the seabed. Maërl is slow-growing, but over long periods its dead calcareous skeleton can accumulate into deep deposits, overlain by a thin layer of pink, living maërl. In favourable conditions maërl can form extensive beds and has been commercially exploited in other European countries for use in agriculture as well as the cosmetic, pharmaceutical and other industries. The maërl habitat frequently supports a rich community of associated flora and fauna. Where dead maërl is washed up on beaches it is often mistaken for coral, as it has a superficially similar appearance (Northern Ireland Habitat Action Plan, Maërl Beds, Final Draft – April 2003).

Although maërl is not specifically listed in Annex I of the *European Community (EC) Habitats Directive*, it is a recognised characteristic of *Coastal Lagoons* and *Submerged sandbanks covered by seawater all of the time*. They are also a characteristic feature of the Annex I habitats *Large shallow inlets and bays* and *Mudflats and sandflats not covered by the tide at low water* (Northern Ireland Habitat Action Plan, Maërl Beds, Final Draft – April 2003). Maërl does however enjoy a certain degree of special protection under the "Habitats Directive". Both *Phymatolithon calcareum* and *Lithothamnion corallioides* (two maërl forming species) are listed on Annex V(b) whereby, if subject to exploitation, management measures must be implemented to ensure that the resource is maintained at a favourable conservation status (Vize, 2005). At present there is no reliable information which indicates what level of exploitation (if any) allows for sustainable development (Guiry, 1996).

9.3. *Porphyra* harvesting

Porphyra has become an important sea-vegetable resource worldwide. Several species, most notably *P. tenera* are cultivated in Japan and other far eastern countries. Natural populations are also exploited for the food market. In Northern Ireland, natural stocks of *Porphyra,* probably *P. umbilicalis* are subject to small scale harvesting along the Antrim coastline.

Three separate manipulative studies of *Porphyra* populations (Roland & Coon, 1984, British Columbia; Nelson & Conroy, 1989, New Zealand; and Griffiths et al., 1999, South Africa) have each independently verified the fact that *Porphyra* may be harvested with no effect on the target population providing harvesting was not so extensive as to significantly reduce sporophyte populations.

In South Africa, Griffith et al. (1998) recommended management practices for this species. It was proposed that regularly spaced patches, and in particular dense patches, should be left throughout the eulittoral after harvesting to allow for growth and sporulation of the unharvested *Porphyra* gametophytes. The frequency of harvesting of *Porphyra* on a stretch of shore should be limited. It was envisaged that a management strategy such as the one outlined here would also lower the effect on the associated fauna such as marine molluscs and ensure a sustainable resource.

9.4. Seaweed harvesting in practice

9.4.1. Seaweed harvesting in Wales
Commercial seaweed harvesting in Wales is confined to the rocky shores of south and west Wales from the Gower to Pembrokeshire. The harvesting, for *Porphyra* spp. (laver bread) is done largely by the same people that work the cockle beds in the Burry Inlet. They use the cockle processing plants to boil and can the laver bread. When there is a shortage in south Wales the collectors often go to the West of Scotland to supplement stocks, or as has been happening more recently get it sent down fresh from collectors in Scotland (Gabrielle Wyn, pers. comm.).

The industry is worth about half a million a year to the Swansea area economy. Some of the firms sell the laver bread fresh locally, some can the laver bread in south Wales and some send it to Holland to be canned. It is sent around the world from the canning plants. There is little or no commercial collection in mid and North Wales. CCW has a single consent on a SSSI in Pen Llyn in North Wales for the collection of *Fucus* sp. for fertiliser on a small holding.

Management issues:
CCW does not have any specific policies/position statements on seaweed harvesting and the impacts of these activities on the marine environment. If harvesting is carried out within a designated site then we would use the current legislative processes to deal with it:

- If carried out in an SSSI/SAC by an Owner Occupier (or third party with the permission specific or implied by the O/O) then CCW would (under the Countryside and Right of Way act and Habitats Directive regulations) assess the extent of the operation and issue consent or not depending on the impact on the features.
- If carried out in an SSSI by a third party without the permission of the Owner Occupier CCW would seek to liaise with the collectors to look for the best way to minimise any impact on the SSSI/SAC features.
- If carried out within a SAC by a third party in Wales there is currently no control mechanism, although the assembly as the body responsible for the implementation of the Habitats Directive in Wales could (if the harvesting was damaging the nature conservation value of the site) introduce the required controls e.g. authorising a CCW bylaw under regulation 36, or by making a special nature conservation order to protect the features of the site.

At present there is no evidence to suggest that any seaweed collecting activities in Wales are damaging the features of protected sites (Gabrielle Wyn, pers. comm.).

9.4.2. *Ascophyllum* (“rockweed”) harvesting strategy in New Brunswick, Canada
In 1995, a novel *Ascophyllum* harvesting programme began in New Brunswick. Recent collapses of some important fisheries in Atlantic Canada prompted a precautionary approach to management of these natural resources. Although this area was subject to traditional harvesting of *Palmaria palmata*, it had no previous harvesting of *Ascophyllum*. Outlined below is the management plan and the implementation of this plan as taken from two separate sources (Sharp & Bodiguel, 2001; and Ugarte & Sharp, 2001).

1. The preliminary plan
Interest had been expressed by local and international seaweed harvesting companies. This initial attention prompted the establishment of a management committee. This group was cognisant of the need to have in place a management strategy that protected the ecosystem and allowed for economic gain. A study was commissioned that reviewed international and local biological information on *Ascophyllum* productivity. These studies led to the formulation of a scientifically derived baseline for the overall plan. Standing crop estimates and productivity measures were utilised to establish annual quotas.

2. Inputs from stakeholders to the preliminary management plan
In the second phase managers set a harvest quota of 7% of the estimated standing crop as a precautionary approach to management. Companies, individuals, or associations who were interested in harvesting *Ascophyllum* were asked to submit a proposal. These proposals were to address how the stated development objectives (maximise employment, sustainable harvest, sound business principles and environmentally acceptability) would be achieved. Proponents were required to include: a harvest management plan

outlining a three year schedule of annual raw material requirements, a map showing which sectors would be harvested, a plan detailing the projected levels of exploitation by sector, the frequency of re-harvest, mechanisms to assess the impact the impact of harvesting on the resource and a description of the type of controls to ensure effective management.

3. The pilot harvest
The third phase of the management process began in 1995 with the commencement of the pilot scale harvest. In this phase the harvesting company was required to submit a new management scheme plan for the harvest of *Ascophyllum* at the beginning of each year. This management plan was to include the projected annual harvest by sector of shoreline. At the end of each year the company was to provide the government with vital statistics on the resource including records of monthly purchases from other harvesters, price paid, location, and harvest dates. The Rockweed Management Committee conducted three reviews of the company's performance at pre-season, mid-season and post-season meetings. These reviews were designed to investigate problems with harvesting strategies and ensure the company was fulfilling its obligations. Finally, an independent third party was to be hired by the company to audit the recorded landings of rockweed. This review was designed to ensure that the company complied with the yearly management strategy and the overall strategy of harvesting the resource. A research programme on the effects of harvesting also ran alongside to the harvesting. This programme focused on three major components; *Ascophyllum* biology, the habitat, and associated fauna.

4. Final recommendations
This phase marked the end of the pilot harvest and the final review of the information derived from the study, the monitoring plan and the performance of the company. In April 1999 a formal peer review committee, Regional Assessment Process (RAP), analysed the information gathered during the three year pilot harvest. Although it was agreed that the harvest impact was minimal and of short duration, it was advised to continue the harvest maintaining a precautionary approach in light of other knowledge gaps

9.4.3. Proposed Quota Management System in New Zealand
'Seaweed' is defined under section 2 of the New Zealand Fisheries Act 1996 as: "…all kinds of algae and sea-grasses that grow in New Zealand fisheries waters at any stages of their life history, whether living or dead". 'Beach-cast seaweed' is defined under section 2 of the same Act as: "…seaweed of any species that is unattached and cast ashore".

The Quota Management System (QMS) was introduced in 1986. It controls the total commercial catch from all the main fish stocks found within New Zealand's 200 nautical miles. It was introduced to prevent over fishing, which had reached dangerous levels in some inshore fisheries; and to improve the economic efficiency of the fishing industry. At present the following 7 species are proposed to be added to the New Zealand Quota Management System:

- *Macrocystis pyrifera*
- *Gracilaria chilensis*
- *Pterocladia lucida*
- *Lessonia variegata*
- *Durvillea antarctica*
- *Ecklonia radiata*
- *Porphyra* spp.

The above species have been identified as the current economically viable species and as such merit management. The process of adding these species to the QMS has been initiated despite the fact that there are no reliable biomass estimates for all species concerned. The New Zealand Minister of Fisheries considers that the QMS framework provides better tools for sustainable management, enhancing fisheries for all resource users.

Table 18: Principles for setting proposed Quota Management Areas (QMAs)

Principles in setting proposed QMAs	Fisheries Management Outcomes
1. Management areas should be based principally on the biological characteristics of the stock.	• Sustainability requirements of the 1996 Act (based around "stock") are met.
2. The stock boundaries should take into account the existing characteristics of the fishery (known fisheries, relevant fisheries management issues).	• Sensible stock boundaries. • Simplified allocation of quota. • Reduced business compliance costs.
3. Where practicable, QMAs for species that are taken together in the same fisheries should be aligned.	• Integrated management of inter-related stocks. • Reduced complexity and business compliance costs.
4. QMAs with new boundaries may be appropriate for species with populations whose distributions do not align with existing QMA boundaries.	• Sensible stock boundaries. • Sustainability requirements of the Act are met. • Improved control of harvest and reduced risk to the aquatic environment.
5. Subject to the principles noted above QMAs should be as large as possible.	• Reduced complexity and business compliance costs. • Flexibility for exercise of customary rights.

The New Zealand Minister of Fisheries has announced that he will defer a decision on introducing seaweed species into the quota management system (QMS) for the time being. This will give more time to consider the implications of management proposals being discussed. This may include the relationship between wild harvest and aquaculture, the specific requirements for mussel spat attached to drift seaweed, and the aquaculture industry's reliance on this spat for green-lipped mussel cultivation. There is a need to determine whether the QMS should be applied to one or more states of seaweed, i.e. attached or drift, and whether a stock should comprise one or more species. This will allow more time for the Ministry of Fisheries to work out the supporting framework for managing these species in terms of definition of stock, reporting and compliance regimes. The next opportunity available to introduce seaweed species into the QMS will be 1 October 2006 (Dave Allen, pers. comm.).

9.4.4. Tasmanian seaweed management

There is currently no direct harvesting of native seaweeds in Tasmania due to their ecological importance to marine ecosystems and fisheries resources. Harvesting of seaweed in Tasmania is presently confined to three activities:

1.The collection of beach cast Bull Kelp (*Durvillaea potatorum*) on King Island and the northern west coast;

2.Harvesting of the introduced Japanese Sea Kelp (*Undaria pinnatifida*) on the east coast;

3.The localised collection of beach cast seaweeds and seagrasses.

Akin to the system of issuing licences to commercial and recreational fishermen in Northern Ireland, the Tasmanian method of controlling Marine Plant harvesting depends on a licensing protocol. The legislation that governs fisheries in Tasmania defines "seagrass, seaweed and other aquatic vascular plants, algae, diatoms, euglenoids and any other marine plants" as fish, thus negating the need to enact separate laws for any industry that exploits marine plants. The Tasmanian controls in seaweed do not end with attached beds of algae but also include detrital material/beach cast material: "Fish is any aquatic organism of any species, whether dead or alive, which, in the normal course of events, spends part or all of its life in the aquatic environment"

No licence is required when seaweed is collected for private use. A daily limit of 100 kg per person for cast seaweed applies. Collection is only permitted from beaches with public access. Seaweed attached to the sea floor must not be harvested (The Department of Primary

Industries, Water and Environment, 2005).

10. Recommendations for management through voluntary measures

10.1. Development of codes of practice

The right to harvest aquatic resources carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources (FAO, 1995). To achieve sustainable and integrated use of aquatic resources, which takes into account both the fragility of coastal ecosystems and the finite nature of their natural resources, appropriate policy, legal and institutional frameworks should be adopted by governments (FAO, 1995). The utilisation of seaweed resources should also be managed for conservation and to ensure sustainable use. However, from consultation with local government agencies (EHS, SNH, EN and CCW) it is apparent that at present there is no effective management of seaweed harvesting in the British Isles. A number of options are available for managing commercial seaweed harvesting in Northern Ireland. These are outlined in table 19, and several of these options further elaborated in sections 9, on current management methods in practice worldwide.

Codes of Practice and Codes of Conduct are voluntary methods of management. Code of Practice is defined by the Fisheries Administrative (2001) as a code prescribing principles and standards for responsible practices with the end in view of ensuring the effective conservation, management and development of the (seaweed harvesting) industry. Codes of Conduct are to a large degree similar to Codes of Practice. They are developed to provide principles, guidelines and recommended practices applicable to the conservation and management of aquatic resources and their ecosystems, and are supported by examples of management experiences from different countries (Macintosh & Ashton, 2004). For the purposes of this report, we shall consider "Code of Conduct" and "Code of Practice" as one and the same.

Consultation with governmental, non governmental and associated organisations and parties was undertaken during the preparation of this report to enable the development of recommendations or voluntary measures for seaweed harvesting in Northern Ireland. Contact has been made with Irish Seaweed Centre (Dr. Robert Wilkes), Scottish Natural Heritage (David Donnan, Senior Fisheries Advisor), Countryside Council for Wales (Intertidal Survey Team), English Nature, Ministry of Fisheries New Zealand (Dave Allen, Senior Fisheries Advisor), the Crown Estate, the WWF (Marine Policy Officer), Joint Marine Partnership WWF Northern Ireland & Ulster Wildlife Trust (Kate Hutchingson, Irish Seas Policy Officer) and Marine Conservation Society.

The responses were limited, due in part to the relatively small scale of commercial seaweed harvesting in Wales, Scotland, England and Ireland. English Nature has commented that there is currently no seaweed harvesting in England (Leigh Jones pers. comm.). SNH has confirmed that currently there is very little seaweed harvesting ongoing in Scotland, with only one subtidal seaweed licence issued by the Crown Estate at present (David Donnan, pers. comm.). Gabrielle Wyn of CCW supplied the most in-depth report of the status of seaweed harvesting and management of this activity in Wales (see section 9.4.1).

Very limited information on recommendations is available in the United Kingdom. We understand that there are no codes of practice for seaweed harvesting in existence in the British Isles. Therefore, we have sought advice from elsewhere, particularly New Zealand, where marine conservation is at a much more advanced stage than in the United Kingdom. However it can be said that Codes of conduct, in theory are an excellent idea, however to be successful they will require effective promotion and education. In practice, this is more likely to be successful if backed by reinforcement and policing on site (Fowler, 1999).

Table 19: Options for managing seaweed collection adapted from Fowler (1999).

Management Option	Advantages	Disadvantages
Code of Conduct for collection	• Designed to control the conduct of harvesting activities e.g. through voluntary agreement of methodology used for collection and bag limits • Potentially important and valuable means of regulation	• Resources and support are required for education and promotion on and off site to ensure compliance
Participation in local management plans	• The management plan process for designated sites could provide an opportunity to incorporate management of harvesting	• Resources are also required to ensure long-term commitment to participation in the plan.
Prohibition or licensing of large scale commercial activities	• Landowners may regulate commercial harvesters through formal licences	• Difficult to enforce a ban
Bag limits	• Designed to conserve the resource and impacts by limiting the activity • Should be applicable to low level collectors (personal and artisanal use: see Table 9)	• Very difficult to enforce. • May cause an increase in collection.
Licensing of large scale commercial operations (See Table 9 for definitions of seaweed harvesting scales). Note: this was a recommendation for management from workers in this industry in NI.	• Those wishing to harvest extensive areas of the shoreline or large quantities of seaweed biomass must apply for licences in which conditions will be applied • The application process ensures that licence holders are informed of management issues and requirements	• Successful implementation requires resources for education, administration and enforcement

Management Option	Advantages	Disadvantages
Zoning	• This may be voluntary or backed by legislation and could include: • Permanent exclusion zones to protect specific areas • Temporary and rotational zonation, enabling stocks to recover between harvesting	• Permanent exclusion can be more effective because it is better understood and requires less administration and management resources. • Rotational zoning can be more difficult to manage and offers less protection to habitats and long-lived species.
Closed seasons	• Designed to protect the targeted resource or other wildlife during vulnerable times, such as breeding and spawning seasons.	• Peak demand may coincide and therefore affect breeding, bird migrations/over wintering seasons.
Fisheries Legislation	• Including seaweed under fisheries law (DARD Fisheries) could enable harvesting activities to be controlled policed and enforced.	• Limited resources in fisheries management, difficulties introducing legislation and regulating non-commercial collection

10.2. Recommendations for the Code of Best Practice

Recommendations for the Code of Best Practice have been drawn up following the survey of workers in the Northern Ireland seaweed industry, reviews of published and grey literature and the consultation of UK and international environment agencies. The following recommendations for managing commercial seaweed harvesting through voluntary measures, Code of Best Practice and possibly regulation of these activities:

Permits

- All required permission/approval to be obtained (see Figure 2).
- For large scale harvesting a full EIA/EIS should be undertaken (see Table 9 for a definition of small to large scale harvesting activities)

Reporting and monitoring

- Standardised recording and reporting format for commercially harvested biomass and species.
- Standardised monitoring protocol for effects of seaweed harvesting, e.g. photos, etc.

No-take zones

- Possible no harvest zones, protected for conservation purposes.
- Recommendation of avoidance of certain vulnerable areas or features of the environment (designated sites and areas with coastal backing, such as dunes that are prone to erosion).
- Assign areas that are not to be harvested adjacent to the harvesting site i.e. no take zones

Harvesting rotation

- A sufficient rotational time between successive harvesting in any one site should be allowed, to facilitate the regeneration and recovery of the resource and associated ecosystem (rotation time can be species dependent, see section 10.2).
- In any selected harvested area it is advised that a small area is left unharvested to provide a reproductive pool for recolonisation.

Harvesting techniques

- Seaweed should be harvested using only hand harvesting methods, including hand grabbing, raking, knives or sickles for cutting.
- No mechanical harvesting should be allowed. There has been little or no research done in Northern Ireland on the potential effects of mechanical harvesting may have on the environment, so practice should not be allowed
(Precautionary Principle: UN Rio Declaration).
- The manner in which harvesting may be carried out should be species-specific; recommended harvesting practices are outlined in section 10.2.
- Ensure that the holdfast is left intact for species that can regrow from holdfasts (e.g. Chondrus crispus).
- In the case of species for which meristem tissue is in the targeted plant region (e.g. Laminariales), allow juvenile plants to remain uncut and leave suitable unharvested areas and sufficient rotational time between successive harvesting (species dependent) in any one site (for example 4-7 year rotation is required between successive kelp harvesting at any particular site (Wilkinson, 1995)).
- Limit quantities (bag limits) that companies/persons can harvest
- Limit the percentage of the biomass that can be harvest in the area
- Outline proposed harvesting techniques and establish ways to minimise the effects of the harvesting activities.

Environmental protection measures

- Drift beach-cast seaweed should be collected from the shore using non mechanical means (no diggers or bulldozers should be permitted on the shore).
- No removal of sand/sediment/substrate should be permitted
- Employ practices to reduce damage/ disturbance to the surrounding environment e.g. avoiding disturbing rocks, avoid use of tractors on the shoreline, and avoid trampling of associated/adjacent habitats in the area

10.3. Recommended species-specific harvesting practices

Ascophyllum nodosum

Listed as a priority species for conservation action in Northern Ireland, harvesting *Ascophyllum nodosum* should be carried out in a minimally damaging manner. It is recommended that *Ascophyllum* should be harvested by hand cutting, using a knife or sickle only. A cutting height of 15-25cm above the holdfast (i.e. 15-25cm above the anchor point) should (Environment

& Resources Technology, 1995). A harvesting cycle of 3-4 years is recommended to enable the recovery of the stock and *Ascophyllum's* associated community (Environment & Resources Technology, 1995).

Chondrus crispus and Mastocarpus stellatus

Chondrus and *Mastocarpus* should be permitted to be harvested only by hand, using a cutting implement. Only the frond should be collected, not the holdfast, to minimise the impact on the holdfast and enable regeneration. Seasonal harvesting is recommended to provide sufficient time for recovery of the habitat and crop (Environment & Resources Technology, 1995).

Fucus vesiculosus (and F. serratus)

Harvesting is recommended to be carried only by hand, using cutting equipment to cut individual plants at a height of 15-25cm.The plants should not be pulled from the substrate. Some regeneration will occur from the holdfast

Himanthalia elongata

Harvested for sea vegetables, the plant should be collected by hand. The plant should only be cut on the strap-like reproductive frond, a few cm above the button-like frond using appropriate cutting equipment.

Kelps ***(Laminaria digitata, L. hyperborea, L. saccharina and Alaria esculenta)***

Kelp plants are recommended to be harvested by hand cutting harvesting techniques. When the targeted section of the plant is the frond then the plant should be cut 5-10 cm above the base of the frond, which will enable regeneration of the individual plant. Stipes should not normally be harvested as drift material is a good source (known as "sea sticks" in Irish). If necessary to harvest stipes they should be cut to allow holdfast fauna to relocate. A harvesting cycle of 4-7 years is recommended for the recovery and regeneration of kelp stocks, the latter time period is advised for the recovery of the kelp communities and associated flora and fauna (Wilkinson, 1995).

Palmaria palmata

Collection of individual plants should only be carried out using hand-harvesting techniques, taking the plants from *Laminaria* stipes and rock surfaces. Cutting or pulling of *Laminaria* stipes from the substratum should not be permitted for the purpose of *Palmaria* harvesting.

***Porphyra* spp.**

It is recommended that plants are harvested at low tide by hand. Plants should be cut above the holdfast using a cutting implement, to enable regeneration (Sanderson & Prendergast, 2002). It is also recommended that un-harvested areas of *Porphyra* are left adjacent to the harvested areas. This precaution should allow sufficient sexually reproducing plants to repopulate the target site while also providing sufficient grazing material for intertidal molluscs and other associated fauna (Griffin et al., 1999)

Corallina officinalis

Corallina should be harvested but hand, being cut and not pulled as they will regenerate from the holdfast.

***Ulva* spp.**

No particular controls are required for Ulva species.

11. Potential research topics

1. Conduct harvesting trials for each commercially harvested species, using different harvesting methods and monitoring the effect on the target species and associated flora and fauna.

2. Carry out investigative studies on the physical impact of harvesting on shores

3. Investigate gamete and propagule (e.g. zygote) dispersal distances as a determining factor for the distance required between harvesting and the adjacent non harvesting area to ensure recovery of resource.

4. Surveys of County Council beach cleaning practices.

5. Macroalgal biomass surveys should be conducted for the entire Northern Ireland coastline, as currently only estimates for Strangford Lough have been determined.

6. The current distribution and biomass of *Ascophyllum nodosum* in Northern Ireland should be determined.

7. Investigate the role beach cast (drift) macrophytes have on coastal ecosystems in Northern Ireland.

8. Investigate the effect of beach cast algae on protected dunes such as Murlough.

12. Closing remarks and recommendations

The seaweed industry worldwide represents a sector of the fisheries industry that contributes an estimated US$ 6 billion to the global economy of which US$ 5 billion is for food products for human consumption (FAO No. 441, 2003). The FAO commissioned the most recent review of the world fisheries and aquaculture (FAO, 2004). Total industrial use of seaweeds was approximately 7.5-8 million tonnes of wet seaweed per annum. Seaweed harvesting and aquaculture activities take place in about 35 countries, including both the northern and southern hemispheres.

Precautionary principles require that environmental managers should be careful about making decisions where there is ignorance about the underlying issues. If a mistake is going to be made, it should be "in favour" of long-term environmental welfare (Underwood, 1997). With the various methods of management of seaweed resources that are employed worldwide it is important to realise that each has been based on local and international scientific observations. If the seaweed resource of NI is to be exploited in either small or large scale, a protocol of adaptive management, much like the case of *Ascophyllum* harvesting in New Brunswick region of Canada, should be engaged. A method of conservation like this would tend to the side of caution but as new and up to date scientific knowledge became available it would influence the preservation strategy.

Broadly speaking, seaweed can be found in three different states: attached to the substrate; free floating; or beach cast. The three characteristics of each of the three states are set out in Table 20.

Table 20: Key Characteristics of Seaweed States (adapted from *Introduction of New Stocks into the Quota Management System on 1 October 2005; Consultation Document, 2004*).

	Attached	Free Floating	Free Floating
Ecological Role	• Canopy forming • Critical habitat important for recruitment of many species • Structural importance modifying wave flows and energy	• Can still be growing and reproducing • Disposal of species • Settlement surface for mussel spat	• Important food source and shelter for invertibrates and shore birds • Nesting materials for seabirds • Potential beach building material
Additional Comments		• Can entangle in fishing equipment	• Can accumulate and decay rapidly
Commercial Use	• Pharmaceutical • Human consumption		• Compost

During the course of this research into commercial seaweed harvesting activities in Northern Ireland, it emerged that the industry has gone through several phases of growth and decline. At present the seaweed harvesting industry of NI is relatively small. It appears that this situation, at present, will remain the *status quo* despite the fact that there is room for substantial development due to the unexploited biomass of seaweed. Each worker that agreed to be interviewed indicated to us a desire to develop his/her business but as of yet said that they have not seen any viable area in which to expand their practice.

Recommendation 1
Establish a forum of seaweed workers and interested parties in Northern Ireland which would investigate potential funding to aid growth in this sector. This body should also be charged with recommending best harvesting practices and providing the information directly to the seaweed harvesters / seaweed harvesting company.

One point that warrants further work and publicity is the legal right and requirements in relation to harvesting seaweed in Northern Ireland. Each individual connected with this industry shared confusion about or complete lack of knowledge of the legal aspects of seaweed harvesting. Following research into this topic it is understandable that this situation has developed. Seaweed has been neglected from any comprehensive piece of legislation to govern its removal or protection within the environment.

Recommendation 2
Notify all workers of the current situation and requirements regarding seaweed harvesting. More comprehensive regulations that aim to prevent habitat damage and/or destruction should be established as a matter of urgency. The area of "wrack rights" should be investigated further in order to establish holders of these rights and areas associated with these privileges. Wrack rights should also be examined to establish the merits of retaining or abolishing these in order to facilitate sufficient protection and regulation of this resource.

The literature survey of applicable legislation governing the seaweed resource highlighted the extreme lack of regulations that are in place to protect these habitats. At present, it is only the internal policies of the Environment and Heritage Service, Crown Estate, and the National Trust that are preventing detrimental exploitation of the seaweed habitat. This economically viable, yet potentially environmental destructive activity has become an after thought by many policy makers and regulators.

Recommendation 3
It is essential that seaweed is afforded protection through legislation because there is the very real possibility that the internal policies of agencies concerned may change over time. This situation could be addressed in a manner that encompasses most anthropogenic activities within the marine environment of the UK's territorial waters. The Prime Minister announced his commitment to a government Marine Bill in a speech to the Prince of Wales' Business and the Environment Programme in September 2004. He said "I believe there are strong arguments for a new approach to managing our seas, including a new Marine Bill" (WWF website). At present it is not clear if the coastal waters of Northern Ireland will be included in any such bill that may arise from this measure but there are strong arguments for the inclusion of our coastal waters.

Despite extensive surveys such as the Northern Ireland Littoral and Sublittoral surveys, the distribution of commercially viable stocks of seaweed is not apparent along vast majority of the coastline. Only presence/ absence data for the macroalgal species found in Northern Ireland are available

Recommendation 4
To ensure adequate management strategies for this resource a survey of the marine environment of Northern Ireland should be undertaken to identify areas that harbour commercially viable stocks of seaweeds.

The effects of harvesting various species of seaweed have been examined by many workers but studies of this nature have rarely been conducted in Northern Ireland. While the results of these surveys can be used to infer the potential effects of harvesting seaweed in local waters they may not give the true picture of the resilience or vulnerability of seaweed and the associated habitats.

Recommendation 5
Experimental removal trials should be carried out within Northern Ireland's territorial waters. An assessment such as this would yield a more accurate picture of the likely impacts of extensive exploitation of seaweed could have on protected habitats; commercially and recreationally important fisheries; migrating bird populations; and other communities intimately associated with seaweed populations.

The use of beach-cast material does not appear to require any permission from environmental agencies. However, although this form of seaweed can be seen as unsightly and a nuisance to many, it also provides a habitat for invertebrates and thus may present an important food supply for coastal bird species.

Recommendation 6
The effects of removing quantities of beach cast macrophytes should be assessed. Reports of the consequences that this activity has suggest that there may be a negative effect on the environment. Unfortunately most work undertaken has been conducted in the southern hemisphere, as such its relevance to the situation in Northern Ireland must be assessed and local studies undertaken to fill gaps in knowledge.

The economic exploitation of seaweed should be conducted in a "sustainable manner". The definition of sustainable manner as used in this report is as follows: "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs"
With this in mind it seems prudent to follow a precautionary approach to seaweed harvesting.

Recommendation 7
Mechanical harvesting of seaweed may prove to cause severe damage to the sustainability of the seaweed industry and the associated organisms of this habitat. Therefore it is urged that moves are made to prevent any and all harvesting of seaweed by mechanical means.

An excellent example of seaweed harvesting management in practice is the New Brunswick *Ascophyllum nodosum* harvesting in Atlantic Canada. This policy followed an adaptive management methodology to allowing harvesting take place in an area previously untouched.

Recommendation 8
Should large scale commercial seaweed harvesting be permitted, it is essential that adequate quotas are applied and that monitoring protocols are put in place to reduce the impact that these activities will have. It is also important to act on information that comes to light as the monitoring plan proceeds i.e. if a change is noticed that may be damaging to the ecosystem either change' harvesting practice or halt harvesting activities until the system has sufficient time to recover.

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15. Appendix 1

Company Date

Name:

1. What seaweed species do you harvest/collect? (Please list below)
And the estimated quantity per year harvested?

Species **% plant removed**

2. What harvesting methods do you use (please tick below)?

Collect on the shore ☐ **Use boat/s** ☐ **Diving** ☐

Hand ☐ **Mechanical** ☐

What equipment is used?

Do you remove all of the plant ☐ **or a fraction of the plant** ☐

Please specify approximately what proportion of the plant is harvested

3. How do you choose your harvesting site?

4. How many collectors do you use?

Are these activities a year round activity or seasonal? Please select below

Seasonal ☐ **Year round** ☐ **periods of no harvesting** ☐

If seasonal, please indicate what time periods

What weather conditions do you operate under? Please select below ____________________

All weather ☐ **Good weather** ☐

5. What influences your ability to employ collectors/harvesters?

6. What factors have influences the development of your business i.e. economic factors, competition, etc.?

7. What guidelines does your company abide by when collecting seaweed to insure the sustainability of the seaweed resource?

8. Do you have collecting guidelines? If so what are they?

9. Would you consider adopting a recommended code of practice with the aim of ensuring that this resource remains viable in the future?

10. Have you gained consent to harvest seaweed from

Environmental Heritage Service ☐

Wrack right holders ☐

Land owners (Crown Estate, Councils, Private) ☐

Other Please specify ______________________________

11. Have you had any difficulties in gaining permission to harvest seaweed?

Government agencies ☐ **Please specify**

Wrack right holders ☐ ______________________________

Landowners ☐ ______________________________

____

12. What are your end products? Please specify below

Is there a particular market you target? Please state below

13. What processing treatments do you use? (e.g. washing, drying…)

14. Have you had any support from the following in establishing your business?

Government ☐

Invest Northern Ireland ☐

European Union ☐

Private sectors ☐

Other (please specify)

15. What would you like to see implemented to help develop this industry?

16. How do you personally see this industry developing?

17. Would you like the seaweed industry in Northern Ireland to be controlled through regulations such as licences?

Yes ☐

No ☐

Please include any recommendations for regulatory measures below.

Environment & Heritage Service
www.ehsni.gov.uk

Our aim is to protect, conserve and promote the natural and built environment for the benefit of present and future generations.

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