License Application for Sustainable hand-harvesting of *Ascophyllum nodosum* at Clew Bay (SAC Site Code 1482). In accordance with National Parks & Wildlife Service conservation objectives for marine and coastal habitats and species and the EU Habitats Directive 92/43/EEC.

Appendix 1: Assessment of *A. nodosum* resources and associated biodiversity in Clew Bay SAC.

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Contents

Title: Assessment of *A. nodosum* resources and associated biodiversity in Clew Bay SAC.

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Abstract

The aim of this survey was to assess the levels of *A. nodosum* biomass within the Clew Bay complex and associated biodiversity within this biotope. In brief, measures were taken at eight sites within Clew Bay, including islands in the northern (Illannambraher, Inishcuil, Inishdaff), central (Inishcottle, Derrinish, Collan More) and southern (Inishlyre) regions of the complex, the entire survey taking place on the 26/09/2013 and analysis continuing over the following week. *A. nodosum* density was found to vary considerably between different sites, ranging from 1.34kg/m^2 in Inishcottle to 11.46kg/m^2 in Illannambraher. Evidence for recent hand harvest activities were found at several sites within the complex. Two harvest techniques appear to be employed which both involve the cutting of *A. nodosum* close to the holdfast and removal of (a) approximately 25% of plant or (b) >90% of the entire plant, the former representing the least invasive approach. *A. nodosum* density levels were lower than expected in a number of areas, including Collanmore. A trend towards reduced *A. nodosum* yield in areas of increased *Fucus sp*. cover was observed throughout the study, however this was not statistically significant (p-value = 0.106). Assessment of biodiversity demonstrates positive correlations between the quantity of *A. nodosum* and the numbers of winkles and limpets beneath the *A. nodosum* canopy per m^2 (p-values = 0.046* and 0.084$^\#$ respectively). In contrast, negative correlations between percentage *Fucus sp.* cover and winkle and limpet numbers were observed, however, these associations were not statistically significant (p-values = 0.058$^\#$ and 0.197 respectively). In conclusion, this study confirms the presence of substantial resources of *A. nodosum* in the Clew Bay complex, and points to a level of variability likely attributable to harvest activities which are currently ongoing in the area. In order to ensure maintenance of the complex relationships between *A. nodosum* and understory species, hand harvest activities must be performed in a manner which does not lead to extensive damage to the biotope.

Introduction

Levels of intertidal biomass of *Ascophyllum nodosum* have previously been assessed in the Clew Bay SAC. In particular, the study by Hession et al., (1998) represents the most comprehensive analysis of *A. nodosum* resources in Clew Bay undertaken to date and provides a strong platform in which to develop harvesting plans which are based on best scientific knowledge. From an analysis of 57 islands and coastlines within northern, central and southern areas, the entire complex is estimated as having resources sufficient to providing a sustainable yield of ~12,950 wet tonnes per annum. However, further measures of the *A. nodosum* biomass may be required in order to account for potential variability which may have arisen during the fifteen years since Hession et al., published their findings. Biodiverty within the Clew Bay complex has also been examined extensively since the mid-1990s (BioMar, 1995, Dúcha, 1999, Anon, 2002, Merc Consultants, 2006, NPWS, 2011A & 2011B). Several habitats and species of Clew Bay are protected as the complex is classified as a Special Area of Conservation (SAC Site Code 1482) under the EU Habitats Directive (92/43/EEC). Assessments of biodiversity and impacts on protected species in the SAC are ongoing (e.g. The Harbour Seal Pilot Monitoring Project, 2010 (NPWS 2011C)).

Biodiversity within the *A. nodosum* biotope itself has also been characterised in Clew Bay by Kelly L. et al., (2001). Studies such as these highlight the complex relationship that exists between *A. nodosum* and understory species, in particular, grazers such as limpet and winkles. Winkles provide an important function in this ecosystem as they also graze certain epiphytes from the surface of *A. nodosum*. Polyphenols produced by *A. nodosum* also serve as chemical defences to inhibit direct feeding by *Littorina littorea* (Geiselman, JA., and McConnell OJ, 1981). The *A. nodosum* canopy itself limits limpet numbers by supporting growth of unsuitable habitat, e.g. red algal turf (Jenkins et al., 2004). It has been shown that total clearing of *A. nodosum* can lead to reductions in the numbers of winkles (Littorina obtusata, Black & Miller (1991). Such an effect was also observed in a study of hand harvesting in Connemara, however, Clew Bay is characterised by a lower abundance of winkles with effects of hand harvesting also less apparent in this region (Kelly L. et al., 2001). *A. nodosum* canopy removal can also cause a breakdown of red algal turf, which in turn can lead to increases in limpet density and thus, enhanced grazing of *A. nodosum* fronds by limpets (Davies et al., 2007 and references therein). Experimental models show that limpet numbers can increase due to removal of *A. nodosum* assemblages, effects which may potentially persist years thereafter (Jenkins et al., 2004). Recent studies also point to the importance of both *A. nodosum* damage levels and associated *Fucus* coverage, in the capacity of the biotope to return to pre-disturbance state in the future (Araújo R et al., 2009 and 2011).

The aims of this present study were to build on the findings of Hession et al., 1998 and Kelly L. et al., 2001 and assess (a) the levels of *A. nodosum* biomass within the Clew Bay complex and (b) investigate the potential impact of hand harvest of *A. nodosum* on a numbers of species within this important bioptope.

Materials and Methods:

Site selection

Data derived from Hession et al., (1998) was used in preliminary estimates of total sustainable yield of *A. nodosum* within different areas of the complex. Sites deemed most likely to contain high density levels of *A. nodosum* were targeted for subsequent survey and analysis in order to assess for potential variability or changes in the *A. nodosum* levels during the 15 years since the original study by Hession et al., (1998). *A. nodosum* biomass levels were estimated at 18 sites by means of visual assessment from distances of approximately 50-100 meters using binoculars and digital camera. Eight sites were chosen for direct measurements of biomass per m^2 and associated biodiversity, including islands in the northern (Illannambraher, Inishcuil, Inishdaff), central (Inishcottle, Derrinish, Collan More) and southern (Inishlyre) regions of the complex. The survey was undertaken by scientific and engineering personnel at BioAtlantis Ltd, namely, on the 26th September, 2013.

Navigation, harvest equipment and data recording

Navigation within Clew Bay was undertaken by qualified, chartered skipper, given the difficulties associated with travel within this complex. The following equipment was used in assessing *A. nodosum* biomass and biodiversity within selected quadrants: $1m^2$ wooden quadrant marker, 50m long measuring tape, blade cutters, compass, digital weighing scales (25kg), large weighing bags, wet gear, gloves, Trimble Pro XRX GPS receiver and a digital camera (Nikon D3200 DSLR; DX 18-105mm VR Lens). All information was recorded using a data template developed specifically for this survey. While pictures were automatically date-stamped, the time-stamp was set at one hour ahead due to a technical error.

Parameters measured and data collected

Several general features were measured at each site, including: level of coastal exposure, infrastructure (i.e. ease of access, presence/absence of piers, etc) and seaweed potential (i.e. percentage of total coastline containing *A. nodosum*, density differences between coastlines, e.g. higher in E vs. W facing). Site-specific measurements included: location of survey (e.g. coming in on high tide), length of shoreline (low to high water), angle of shoreline (low to high water), presence/absence of mudflats/sandflats not covered by water at low tide, presence/absence of sand or shingle behind the fucoid areas and presence/absence of seals, otters or birds in the vicinity. Quadrant-specific measurements included: GPS co-ordinates, quadrant description (e.g. flat, uneven, mixed), quadrant dimensions (m^2), growth substrate within quadrants (e.g. reef, rocks, pebbles, boulders) and presence/absence and quantification where possible of the following species within the quadrant: *Fucus*, Red Algae (Tandy), Ephemeral green algae, other algae, winkles, limpets, barnacles, hydroid, fish (e.g. mullet), other (e.g. crustaceans).

Categorization of *A. nodosum* density by means of visual assessment.

Each site was initially classified in accordance with a visual assessment scale of *A. nodosum* density, prior to proceeding with precise measurements at specific locations. The visual assessment scale was developed on-site using Inishdaff a model location. Inishdaff is an island characterized by varying degrees of coverage (see Figure 1). The western side of Inishdaff has a short coastline with large proportions of the western side (approx. 90%) lacking growth of *A.*

nodosum (i.e. low coverage). Towards the southern side of the island, density is observed to increase with 50-70% of coastline containing patches of dense *A. nodosum* coverage (i.e. medium coverage). While growth is high in many sections of the south, there are a number of patchy areas. The northern side on the other hand is consistently dense throughout, with 80-90% of coastline containing dense *A. nodosum* growth (i.e. high coverage). This scoring system was applied throughout the survey with a total of 18 sites designated as 'low', 'medium' or 'high' in terms of levels of coast covered with dense growth of *A. nodosum*.

Direct measurement of *A. nodosum* biomass.

A. nodosum biomass was quantified at selected sites (n=8) as wet weight (Kg) per m^2 (see Figure 2 below). In brief, quadrant markers ($1m^2$) were constructed and positioned once the site was landed. Quadrants were marked along the border between the middle-upper *A. nodosum* zone at each site. In a number of cases replicates were chosen in close proximity. Locations were determined at the centre point of each quadrant through use of the Trimble Pro XRX GPS receiver (No.33302-51), at an accuracy of $\leq$1.0m. *A. nodosum* was harvested from each quadrant according to standard methods which involve cutting of plant between 150-180mm above the base (Kelly L. et al., 2001). *Fucus sp.* was removed before weighing in cases where inadvertent harvest occurred. A 25Kg Digital scale was used to weigh harvested *A. nodosum*, with the weight of individual bags also measured.

Measures of biodiversity

Each quadrant was assessed post-harvest for presence/absence of a number of key species identified by Kelly L. et al., (2001) in a previous assessment of biodiversity within the *A. nodosum* biotope. Numbers of winkles (*Littorina* sp.), limpets, barnacles, ephemeral green algae and crustaceans beneath the canopy were measured as individual counts per m^2. *Fucus sp.* was measured semi-quantitatively as the percentage of the quadrant area covered by *Fucus* vegetative growth. The presence of red algae (Tandy) and hydroid growth was also measured semi-quantitatively as the number of growth patches observed or approximate percentage of fronds containing growth of these species. Measures were approximated in cases where counts or densities could not be determined with absolute precision.

Data analysis:

Linear regression analysis was performed using GraphPad PRISM software (San Diego, CA, USA), as an exploratory tool in which to investigate the potential relationship with between different species and their densities within the *A. nodosum* biotope. Estimated values were rounded down in exceptional cases where precise number could not be determined. However, as this study was primarily qualitative in design, replicate numbers were insufficient to allow for direct statistical comparisons of measures between sites.

(i) West: low density (ii) South: medium density (iii) North: High density

(iv) Zones of *A.nodosum* growth (v) Upper-mid *A. nodosum* zone: Close-up

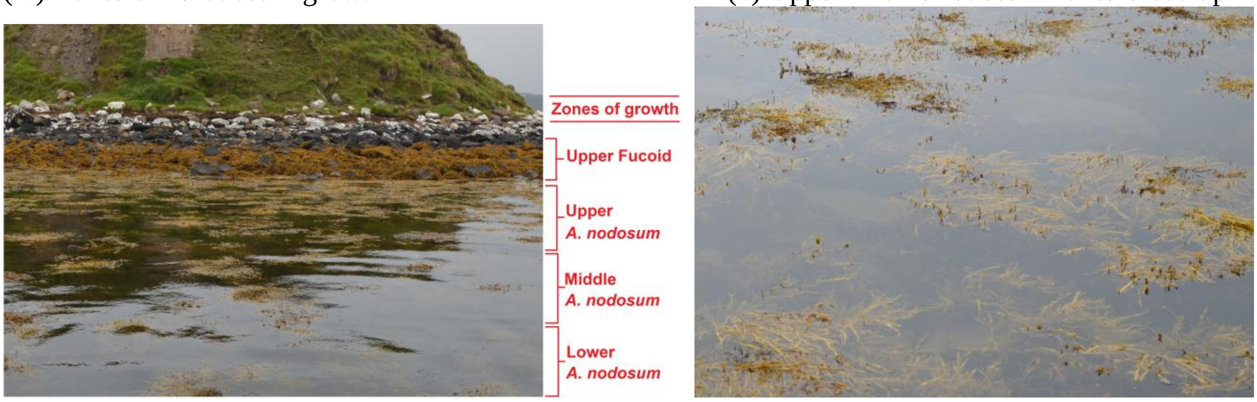

Figure 1 : *A. nodosum* visual assessment scale.

This figure contains pictures taken at Inishdaff at high tide during the survey on the 16/09/2013. The western edge of Inishdaff (i) is characterized by large areas devoid of *A. nodosum* growth (picture taken at 10.37am. On the southern side of the island, there are large areas of dense growth, however, this is often patchy ((ii), picture taken 10.31am). The northern shores of Inishdaff (iii above) are characterized by dense growth throughout the entire stretch (picture taken at 10.40am). *A. nodosum* growth zones are marked (iv) along with a close-up of the general boundary between the upper-mid zone, where dense growth of *A. nodosum* was observed (v). This preliminary assessment served as a template in which to a visually score *A. nodosum* density levels at different sites.

(i)Quadrant at high tide (ii) Quadrant at low tide (iii) GPS coordinates (iv) Cutting of *A. nodosum*

Figure 2 : Direct measurement of *A. nodosum* biomass

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This figure contains pictures showing demarcation of 1m^2 quadrants during the survey**.** Quadrants were set at different times during the day, including high tide (i) and low tide (ii). GPS coordinates were taken from the centre of each quadrant using the Trimble Pro XRX GPS receiver (iii), followed by cutting of *A. nodosum*, approx. 150-180mm from the base (iv).

Results:

General shoreline description:

On approach to each site, several general features were assessed, including levels of coastal exposure and seaweed potential. Similar assessments were made for islands which were either passed en route to, or located in close proximity to survey sites. These details are outlined in Table 1. In accordance with Kelly L. et al., (2001), close attention was placed on the different areas and growth zones between high and low tide. Figure 3 outlines the extent of and general distribution of important species throughout the shoreline of Inishdaff and Illannambraher (examined at high and low tide respectively). The upper shoreline of Inishdaf is characterised by large rocks and boulders, with substantial levels of storm blown *A. nodosum* evident. Further down along the shoreline, substantial growth of *Pelvetia canaliculata* is evident which decreases gradually in density as *Fucus* spiralis growth appears further down along the shore towards the upper *A. nodosum* zone. The *A. nodosum* zone typically varies in density, often in accordance with the level of *Fucus*. Sp which may also be present. Illannambraher are characterised by high *A. nodosum* density,with relatively low levels of *Fucus sp.* (See Figure 3 (iii)).

A. nodosum biomass:

Wet weight of *A. nodosum* per m^2 was found to be highly variable between sites, ranging from 1.34kg/m^2 in Inishcottle to 11.46kg/m^2 in Illannambraher (Fig. 4 (i) – (iii)). Variations in *A. nodosum* biomass did not appear to correlate with latitude or longitude (p-values>0.1, data not shown). Table 2 provides a summary of biomass estimates and data obtained by direct measurement, along with a summary of current/ongoing harvesting activities where relevant.

Evidence for existing harvest activities

Of the 8 sites assessed directly, 3 exhibit strong evidence for recent hand harvest activities, namely Inishlyre, Collan More and Rockfleet Bay. While activity was also identified at other sites such as Illannambraher, Derrynish levels were lower. A close examination of Inishlyre indicates that there are two different techniques currently being employed in Clew Bay which involve cutting and removal of:

1) Approximately 25% of plant (Figure 5(i))
2) >90% of the entire plant (Figure 5 (ii)).

A close-up view of the remains of the harvested plants (Figure 5, ii and iv) indicates that cutting has occurred very close to the base of the holdfast in both cases. Unlike the second method which involves complete removal of the plant, only a relatively low proportion of the plant (approx. 25%) has been removed according to the first method. In terms of prevalence, both harvest methods were found to be widespread and interspersed in their occurrence throughout a numbers of sites, indicating the presence in Clew Bay of a number of harvesters with different techniques, approaches and overall objectives. These inconsistencies suggest an absence of training of harvesters or monitoring of activities in the area. In many cases, the harvest activities were found to occur within 1-2 m^2 of each other, indicative of substantial rates of harvest activities, either in terms of rate of occurrence and/or extent. Of note, the co-distribution of *Fucus sp.* and *A. nodosum* was generally consistent with what is expected to occur at sites which have been subjected to substantial levels of hand harvest activities, that is, an increased level of coverage of Fucus sp. post harvest. The photograph in Figure 6(i) is highly representative of the high density of Fucus sp. relative to *A. nodosum* at Collan More, a feature found to be widespread in the area. While similar trends were observed for many sites throughout the survey, overall, the relationship between *Fucus sp*. coverage and *A. nodosum* density was not statistically significant (Fig. 6 (ii)).

Assessment of biodiversity:

Following harvest at each site, numbers and levels of important species within the *A. nodosum* biotope were assessed (see Table 3 for details). Besides *Fucus sp*., the three most common species present were limpets, winkles (*Littorina* sp.) and the *A. nodosum* epiphyte, *Polysiphonia lanosa* (Linnaeus) Tandy, identified in n= 6, n=6 and n=5 sites, respectively. Figure 7 provides an example of the *A. nodosum* biotope post harvest at high tide with a number of limpets and winkles evident. A positive correlation was found between *A. nodosum* biomass and the number of winkles (*Littorina* sp.) residing beneath the canopy (r^2=0.582, P-value= 0.046*, Figure 8 (i)). A similar trend towards increased Limpet numbers was also observed, however, this was not statistically significant (r^2=0.482, P-value= 0.084#). In contrast, there was a tendency towards reductions in winkle and limpet numbers in areas with higher *Fucus sp.* coverage (Figure 8 (ii)), however, this was not statistically significant (r^2=0.634, p-value=0.058# and r^2=0.375, p-value=0.197 respectively).

A number of other species were identified within the *A. nodosum* biotope. Growth of the hydroid, *Dynamena pumila Linnaeus* was found on tips of *A. nodosum* at three sites (Inishcuil, Inishlyre and Derrinish West). Barnacles were rare but found to be dispersed extensively on a large stone located within the quadrant assessed Illannambraher. Ephemeral green algae was observed at Inishcuil and Derrinish west, with a single occurrence of an unidentified species of red algae recorded as growing at the base of the canopy in the former. An undetermined species of fish (single individual) was observed as swimming amongst the *A. nodosum* canopy in Inishdaff. The fish was approx. 2 inches long, slender and brown in colour. Fish were not observed amongst the canopy assessed at Inishcottle. Presence/absence of fish within test quadrants was not determined at other sites, as further assessments were undertaken at low tide. Crustaceans were not observed in any of the quadrants assessed.

The presence or absence of important species and habitats in the vicinity of the sites were recorded (see Table 4). There was no instance of mudflats/sand flats not covered by water at low tide or sand/shingle behind the fucoid areas detected at the eight sites which were assessed. Otters were not encountered during the survey. Seals were absent from all sites in which direct measures were made. The only instance in which seals were spotted or encountered was at 10:18am en route to Inishdaff (See Figure 9). A single seal was lying at a point raised in the water amongst rocks containing growth seaweed growth (Illanascraw). The boat was travelling at a constant speed at approximately 60 meters way and did not stall when passing. The seal was undisturbed by the passing of the boat and did not enter the water at any stage. Seagulls were spotted at Collano More and Illannambraher (n=1 and 7 respectively). At the Illannambraher site, the seagulls were present on low tidal water approximately 15 meters from the shore. Their behaviour was undisturbed by the activities.

Evidence of other activities in the SAC

While travelling northwards towards Illannambraher, a number of areas relating to fisheries activities were identified (Figure 10 (i)-(iii)). Rockfleet Bay was also identified as an area of relevance to the fisheries community (Figure 10(iv)).

Island No./ Name	Arrival: departure times	Level of coastal exposure	Infra-structure (i.e. ease of access,	Presence/ absence of piers, etc	**Seaweed potential**		
					Visual est. (from boat)	**% of total coastline containing *A. nodosum.***	**Density differences between coastlines, e.g. higher in E vs. W facing**
Inishdaff	10.35-11.25	Sheltered	Fair: Shoreline is quite shallow.	none	High	~70% in south, ~80-90% in north & <10% in west.	South side has high coverage. Very high coverage in the north, low on the west.
Inishcottle	12.00-12.50	Sheltered	Good	Presence of a pier. Causeway also thought to be present.	Low	N/D. The back of the island was not assessed.	Density appears to be reasonably constant
Inishlyre	13.56-14.56	Sheltered	Good	private pier	Low	n/d	Island was assessed across eastern section only.
Collan More	13.16-13.35 15.25-15.53	Some-what sheltered	Fair. Shallow water in places.	n/d	Low-medium	N/D. Highly variable. There are areas without any *A. nodosum* while others have apparently higher densities.	The southern shore of the NW tip has high density of *A. nodosum*. However, density is low on the east coast. The NE region is characterised by patchy *A. nodosum* and *Fucus* cover. However, high density patches of *A. nodosum* do occur, albeit spread over a wide area amongst substantial *Fucus* growth.
Collan Beg	Did not land	n/d	n/d	n/d	None	n/d	n/d
Inishgort	Did not land	n/d	n/d	n/d	None	n/d	n/d
Inishbee	Did not land	n/d	n/d	n/d	None	n/d	n/d
Derrinish (west)	16.20-17.00	Mainly sheltered	Good. But difficult to access at low tide.	n/d	Very high	n/d	N/D. However, *A. nodosum*. Appears to cover entire shore of island.
Inishgowla	Did not land	n/d	n/d	n/d	Very high (similar to Derrinish).	n/d	n/d
Calf Is.	Did not land	n/d	n/d	n/d	Very high (similar to Derrinish).	n/d	n/d
Inishlaughil	Did not land	n/d	n/d	n/d	Dense	n/d	n/d
Inishcuil	17.36-17.56	Sheltered	Fair: Access is good once site is reached.	n/d	high	>90%	No differences apparent. Entire island appears covered with *A. nodosum*.
Inishcara	Did not land	n/d	n/d	n/d	Dense	n/d	n/d
Illannambraher	18.20-18.35	Sheltered	Good	n/d	High	~70%	n/d
Illanmaw	Did not land	n/d	n/d	n/d	Dense	n/d	n/d
Inishfeis	Did not land	n/d	n/d	n/d	Dense	n/d	n/d
Rockfleet Bay	19.10-19.32	Sheltered	Very good	Pier present	Low-medium	n/d	Highly variable

Table 1 : Summary of general features measured during the survey

Island No./Name	Arrival: departure times	Picture ID	*A. nodosum* density		Evidence for recent harvest activities
			Visual estimation (from boat)	Actual (kg/m^2)	
Inishdaff	10.35-11.25	DSC_0018-0083	High	8.37	X
Inishcottle	12.00-12.50	DSC_00136-140	Low	1.34	X
Collan More (Trip 1)	13.16-13.35	none	Low	n/d	X
Inishlyre	13.56-14.56	DSC_00181-186	Low	4.16	✓ (pic#181-184)
Collan More (Trip 2)	15.25-15.53	DSC_00188-190	Medium	5.58	✓ (pic#188-190)
Collan Beg	Did not land	DSC_00191-193	No seaweed	n/d	n/d
Inishgort	Did not land	DSC_00195-196	No seaweed	n/d	X
Inishbee (west face & tip of the island)	Did not land	DSC_00197-200	No seaweed	n/d	n/d
Derrinish (west)	16.20-17.00	DSC_00204-245	Very high	9.76	✓
Inishgowla	Did not land	DSC_00246-256, 258, 259	Very high (comparable to Derrinish west).	n/d	n/d
Calf island	Did not land	None	Very high (similar to Derrinish).	n/d	n/d
Inishlaughil	Did not land	DSC_00260, 261	Dense cover	n/d	n/d
Inishcuil	17.36-17.56	DSC_00281-285	High	7.34	X
Inishcara	Did not land	DSC_00288-292	Dense cover	n/d	n/d
Illannambraher	18.20-18.35	DSC_00292-294	High	11.46	✓
Illanmaw	Did not land	None	Dense cover	n/d	n/d
Inishfeis	Did not land	None	Dense cover	n/d	n/d
Rockfleet Bay	19.10-19.32	DSC_00295_306	Low-medium	3.02	✓

Table 2 : *A. nodosum* density at sites assessed either directly or indirectly through visual assessment.

Site	Species density/m²										
	A. nodosum density (kg/m²)	No. of replicates	†*Fucus* coverage (%)	‡Red Algae (Tandy)	Ephem. green algae (n)	Other algae	Winkles (n)	Limpets (n)	Barnacles (n)	‡Hydroid	Fish (n) (e.g. mullet)	Crustaceans (n)
Illannambraher	11.46	1	5	>5	0	0	>15	32	≥50	0	n/d	0
Rockfleet Bay	3.02	2	50	>2.5	0	0	1.5	3.5	0	0	n/d	0
Inishcuil	7.34	1	1	<5	5	1	14	14	0	<5	n/d	0
Inishdaff	8.37	1	n/d	0	0	0	4	5	0	0	1	0
Inishcottle	1.34	4	18.3	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Derrinish West	9.76	1	10	0	1	0	8	7	0	~15$^{\Phi}$	n/d	0
Collan More	5.58	2	12.5	2	0	0	5	12.5	0	0	n/d	0
Inislyre	4.16	2	26.3	0	0	0	0	0	0	1	n/d	0
Total no. of sites containing flora or fauna	8	n/a	8	5	2	1	6	6	1	3	1	0

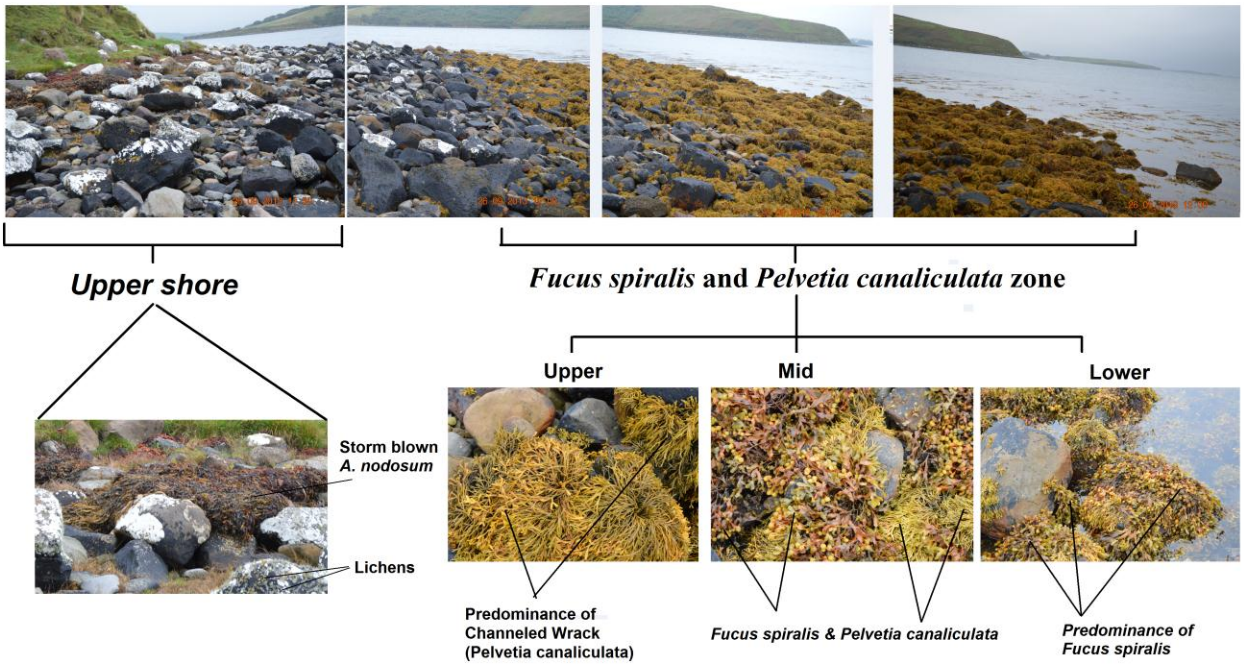
Table 3 : Biodiversity within the *A. nodosum* canopy

Key: n; represents direct number or 'counts' of species within the canopy per m².
†Percentage of the quadrant area covered by *Fucus sp.* vegetative growth.
‡ The presence of red algae (Tandy) and hydroid growth was also measured semi-quantitatively as the number of growth patches observed or
Φ Approximate percentage of fronds containing growth of these species.
>, <, Values estimated in cases where absolute figures could not be determined.

Site	Presence of:				
	Mudflats/ sandflats not covered by water at low tide	Shingle behind the fucoid areas	Harbour seals	Otters	Birds
Illannambraher	x	x	x	x	✓ Seagulls (n=7)
Rockfleet Bay	x	x	x	x	x
Inishcuil	x	x	x	x	x
Inishdaff	x	x	x	x	x
Inishcottle	x	x	x	x	x
Derrinish West	x	x	x	x	x
Collan More	x	x	x	x	✓ 1 seagull standing in *A. nodosum* zone.
Inislyre	x	x	x	x	x
Total	0	0	0	0	n=2 sites

Table 4 : Important habitats and species in the vicinity of sample sites.

(i) Upper shore & *P. canaliculata/Fucus spiralus* zones



(ii) A. nodosum zones of growth

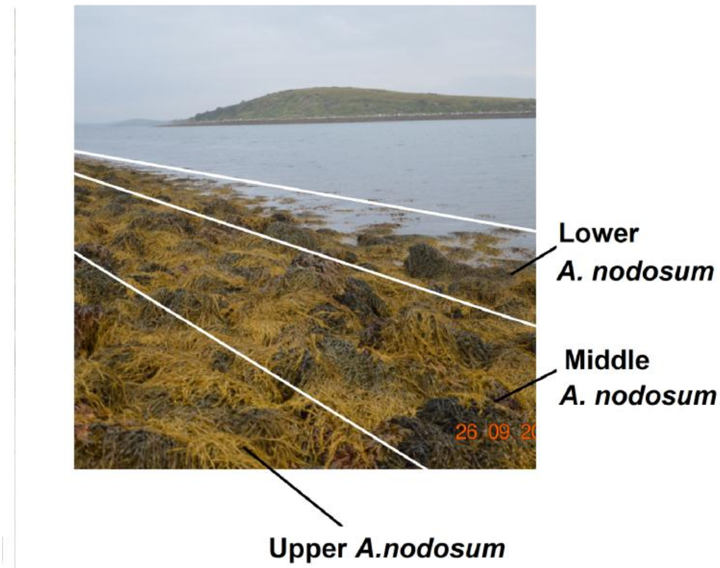


Figure 3: General shoreline description
(i) Representative photographs taken at Inishdaff close to tide showing the different layer of the shoreline and associated growth of *Fucus* spiralis and Pelvetia canaliculata.
(ii) The photograph on the bottom left was taken at low tide at Illannambraher. This site is characterised by high *A. nodosum* density and low levels of *Fucus* sp. White lines highlight the upper, mid and lower *A. nodosum* zones.

(i) Inishcottle

(ii) Illannambraher

(iii) Measures of *A. nodosum* density.

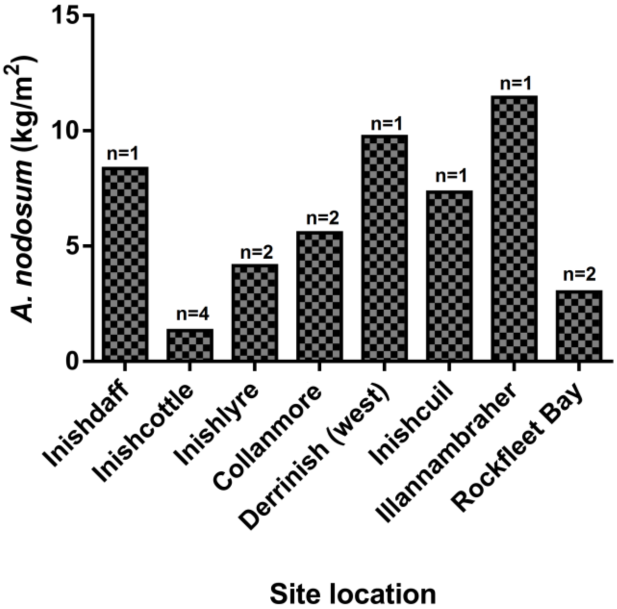


Figure 4 : Measurement of *A. nodosum* biomass.
Representative photographs of the shorelines of (i) Inishcottle and (ii) Illannambraher. (iii) *A. nodosum* density (kg/m^2) in 8 different sites as determined by direct measures in 1m^2 quadrants. Numbers of replicate quadrants are indicated above each bar. In cases where a single replicate was highly representative of the overall site, no further samples were taken.

Figure 5 : Evidence for recent harvest activities in Inishlyre.
The pictures in this figure provide examples of two methods currently being used to harvest *A. nodosum* in Clew Bay. Method (i) above left involves removal of approximately 25% of the plant, close to the base (<150mm). Method (ii) involves almost complete removal of the plant very close to the base (<150mm). Close up are also provided in each case. Note: these photographs are highly representative of harvest activities identified as occurring on several islands.

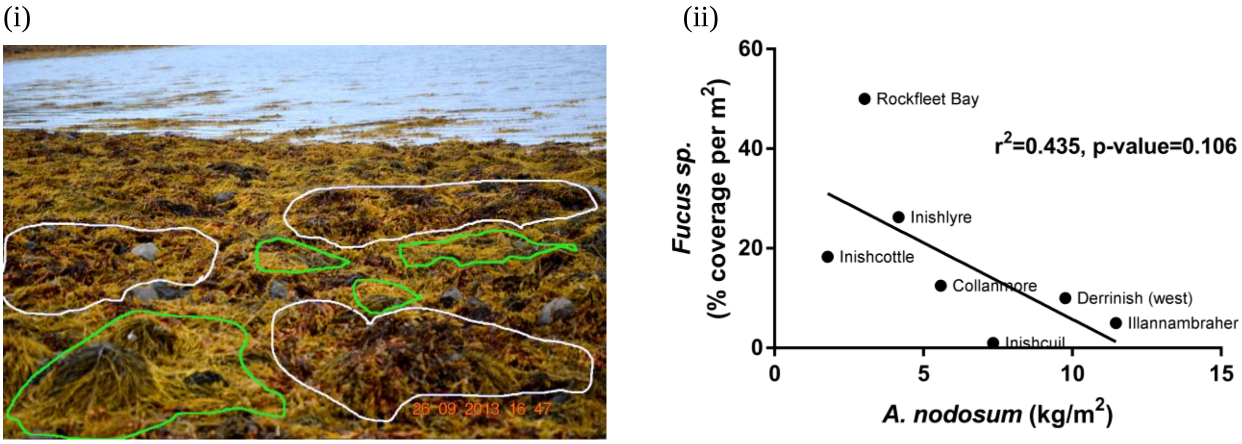


Figure 6 : Density & coverage of *A. nodosum* & Fucus sp.
(i) Photograph showing typical co-distribution of *A. nodosum* & *Fucus sp.* on the southern side of the north western tip of Collanmore. Areas containing substantial *A. nodosum* biomass are circled in green, while areas with med-high *Fucus sp.* coverage are indicated in white. (ii) Linear regression analysis of *A. nodosum* density (kg/m^2) and *Fucus sp.* coverage (n=7 sites). Inishdaff was not included in the analysis given that *Fucus sp.* had been quantified by weight rather than by percentage coverage in this instance.

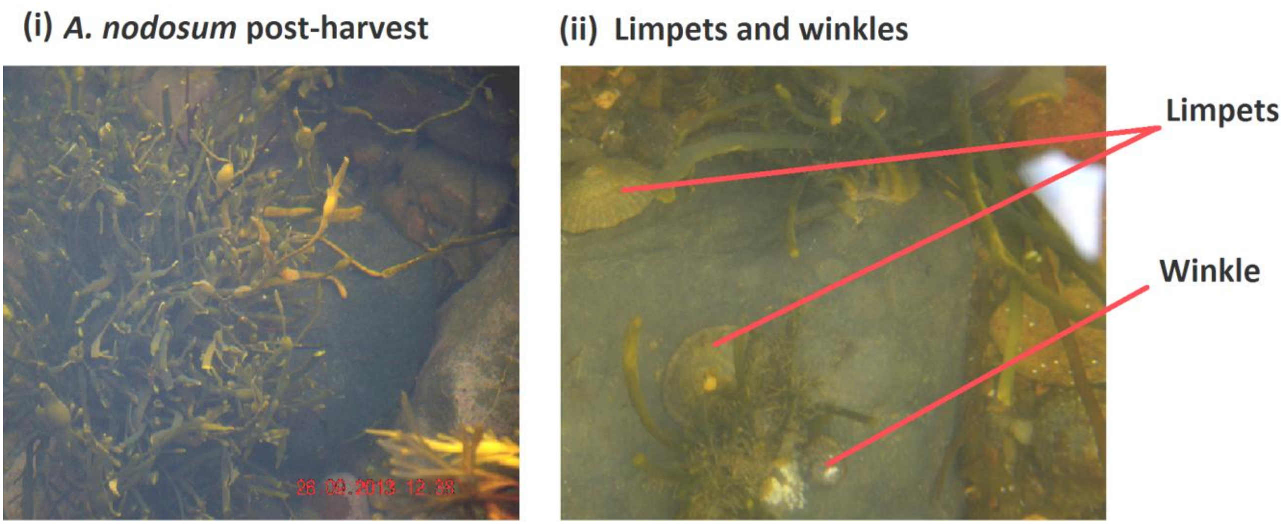


Figure 7 : *A. nodosum* biotope, post harvest (Inishdaff at high tide).
These photographs were taken from a test quadrant at Inishdaff. The presence of winkles, limpets and the remains of *A. nodosum* post-harvest are indicated.

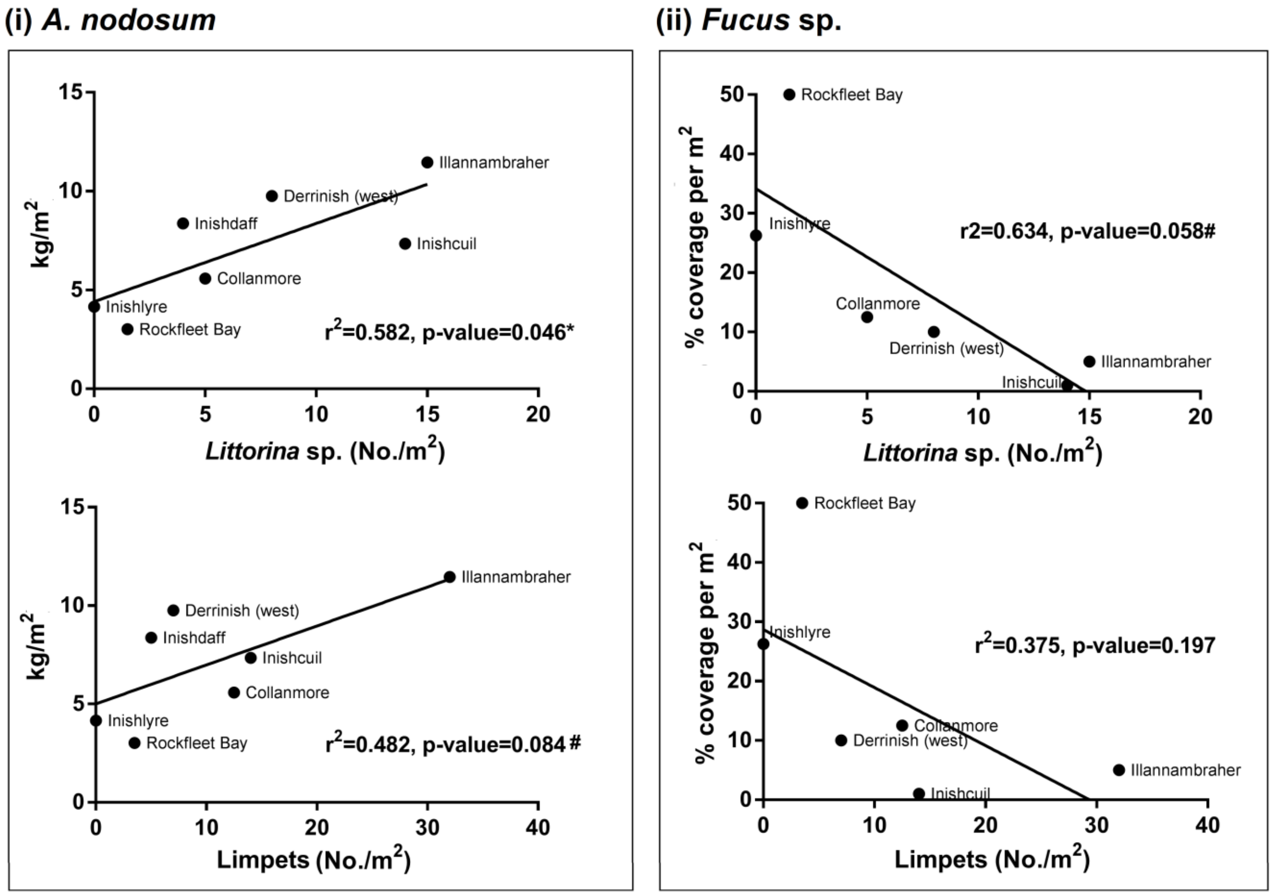


Figure 8 : Correlations between species within the *A. nodosum* biotope and levels of intertidal seaweed.
(i)The potential relationship between *A. nodosum* density and numbers of limpets and winkles (*Littorina* sp.).
(ii) The potential relationship between percentage cover of *Fucus sp.* and numbers of limpets and winkles. Results of linear regression analyses are indicated on each plot. Significance is denoted by an asterix, '*' (i.e. p-value <0.05), while trends are indicated with the '#' symbol (i.e., p-value<0.1).

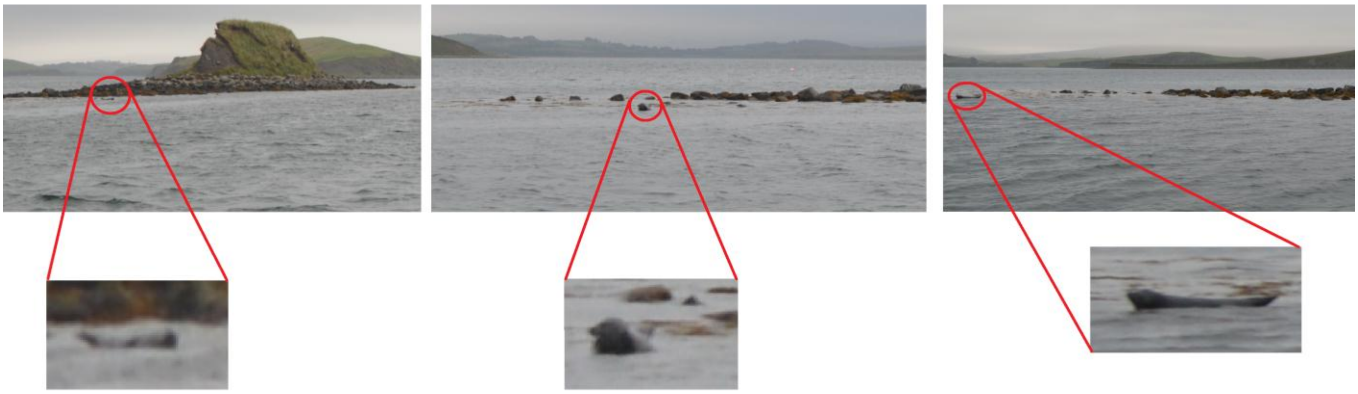


Figure 9 : Presence of an individual harbour seal at Clew Bay
The pictures above were taken in quick succession from the passing boat at 10:18am (Illanascraw). While observing the boat, the seals behaviour was undisturbed.

(i)

(ii)

(iii)

(iv)

Figure 10 : Fisheries-related activities

Discussion:

While this study confirms the presence of substantial levels of *A. nodosum* resources in the Clew Bay Comples, densities were lower than expected at a number of sites. There was striking evidence of recent *A. nodosum* hand harvest activities in Clew Bay, to levels considered as significant and potentially indicative of a thriving local industry in the region. Indeed, the sample points at Collanmore and Inishlyre were characterised by a high incidence of *A. nodosum* harvest points, coupled to a considerable degree of *Fucus sp.* cover. This would be consistent with the findings of Kelly L. et al., (2001) and others, which demonstrate significant increases in cover as a result of opportunistic growth by invading *Fucus*. sp. due to uncontrolled *A. nodosum* harvest.

Another unexpected finding from this study was that at least two different methods are currently being employed to cut *A. nodosum* seaweed. Both methods are seemingly severe as they involve cutting the weed very close to the base near the holdfast, not leaving behind what would be considered a sufficient level of material. The least severe of these methods involve removal of approximately 25% of the plant, albeit very close to the holdfast. This suggests that these individuals are approaching their work with sustainability and re-growth of *A. nodosum* in mind and may point to a level of local knowledge in the area as to the best approaches to be employed in their work. However, other approaches to harvesting on Clew Bay were notably harsh with the presence of *A. nodosum* 'stumps' widespread in many areas. These methods leave considerably less than 150mm of *A. nodosum* behind at the point of cutting, which is not in line with the ranges or limits ordinarily applied by harvesters in Ireland (150-180mm, Kelly L. et al., 2001; 200mm, http://www.arramara.ie/Harvest.asp). The prevalence of these activities are suggestive of harvest practices in the area which are not well informed, either by traditional, local knowledge or best practice approaches for harvesting of this species. The individuals involved may be inadvertently prolonging the *A. nodosum* recovery period and in turn, leaving the harvest sites open to invasion by opportunistic species (e.g. *Fucus sp.*). The cumulative effects of these activities may account for the lower than expected levels of biomass recorded for several islands. For example, while Collanmore was described by Hession et al., 1998 as having strong potential for sustainable harvest, this present study characterises Collanmore as having lower than expected yield per unit area. This was observed both at the south eastern tip of the island and the southern side of the north-western tip of the island, where density levels ranged from low to medium. Each site showed substantial evidence of two types of hand harvest activities.

Biodiversity measurements were undertaken in this study in order to characterise the distribution of a number of species common to the *A. nodosum* biotope. Positive correlations were observed between *A. nodosum* density and numbers of winkles and limpets beneath the canopy, the former of which was statistically significant. This highlights the importance of the complex relationships which exist between *A. nodosum* and understory species. The association between winkle numbers and *A. nodosum* density may be consistent with the findings of Kelly L. et al., (2001), who reported reductions in numbers of winkles post hand harvest, most notably at a Connamara site in winter. Araujo et al. (2009) demonstrate a short term negative effect of intense damage to *A. nodosum* (e.g. human trampling) on lowering of the abundance of *A. nodosum*, *Fucus sp.* and understory species (e.g. limpets), coupled to an increase in the abundance of ephemeral green algae. It is possible that the general reduction in winkles and limpets in areas of reduced *A. nodosum* cover may therefore have arisen as a consequence of recent harvest activities. In addition, species such as limpets are known to migrate and seek alternative food sources in the event of reductions in food supply (Davies et al., 2008 and references therein). Migrations towards alternative food resources may explain the overall trends towards reduced winkle and limpet numbers in areas of lower *A. nodosum* and the correspondingly higher numbers in areas of increased *A. nodosum*.

Assessments were made throughout the survey as to the presence or absence of species and habitats protected under EU Law. A single individual harbour seal was encountered on just one occasion as the boat passed within approximately 60 meters. The seal was undisturbed by our presence. This is consistent with reports which indicate a level of tolerance of harbour seals to brief and passing presence of vessels which do not pay attention to the seals themselves (Johnson et al., 2007). Disturbances are mainly caused by vessels that linger or move at slow pace (e.g. kayaks and stalled boats) along haul out sites. Aside from harbour seals, there were no other incidents or observations relating to other protected species or habitats within the complex during this survey.

Conclusions:

Overall, these findings demonstrate a high level of variability in *A. nodosum* density within the complex, a substantial level of underlying harvest activities in the area in general, and a number of important correlations between *A. nodosum* density and species within the biotope. These preliminary findings confirm those of previous studies and provide important information as to the potential effects that hand harvesting may have in this area. In order to ensure maintenance of the complex relationships between *A. nodosum* and understory species, hand harvest activities must be performed in manner which does not lead to extensive damage to the biotope. In this context, methods which ensure that weed is not cut less than 150mm from the holdfast are essential at the very least. Other methods which ensure that relatively small portions of the canopy are removed rather than the entire plant are also favourable.

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