Kelp harvesting in Bantry Bay: monitoring to meet licensing requirements

Part 1: pre-harvest survey, September 2016

A report for BioAtlantis Aquamarine Ltd. by Dr. Tasman Crowe[1], Dr. Paul Brooks[2] and Dr. Louise Scally[3]

1. *Associate Professor, School of Biology and Environmental Science, University College Dublin.*
2. *Postdoctoral Fellow, School of Biology and Environmental Science, University College Dublin.*
3. *Ecologist, MERC Consultants Ltd., Galway.*

Summary

A survey was conducted in Bantry Bay as part of the conditions of a license to harvest *Laminaria* in five different Areas (A-E). Its objectives were to (a) characterise the biota in advance of harvesting as a baseline for future comparisons (b) determine whether there were differences between (i) licensed Areas (A – E) and (ii) tracts within each Area.

Invertebrates, algae, fish and birds were sampled in a site in each of two tracts within each licensed Area between 5 and 15 September 2016. The methodology was based closely on that specified by BioAtlantis in a document agreed with the Department of the Environment. Minor adjustments were made to improve effectiveness and reduce risk.

In licensed Areas A and B on the south side of Bantry Bay, kelp habitat characterized by *Laminaria hyperborea*, was apparently confined to a narrow band (approximately 40 m wide). On the north side of the bay, the area of kelp habitat was slightly wider, but did not extend further than 200 m from shore. The average density of *L. hyperborea* plants varied among sites from 6.7 to 16.5 per m^2. Stipes were significantly longer in Area E (85 cm on average) and ranged from 50-70 cm on average in the other Areas. The average length of kelp, including both stipe and fully extended fronds, was 147 cm. The average age of kelp in the licence area was 3.4 years (Appendix 4).

Full lists of species present have been provided in this report (Appendix 3) and in Excel spreadsheets. From these lists, a set of approximately ten taxa / functional groups will be

selected to serve as indicators of potential impact in future surveys, as required by the licensing conditions.

As is common in ecological systems, we found variation in abundance and cover of taxa and in multivariate community structure between Sites within each Area. There were no systematic differences that might be expected to confound comparisons between experimental and control areas in the future. There were fewer differences between Areas.

The kelp biotope sampled is common around the coast of Ireland. All of the species recorded are common in infralittoral kelp biotopes in Ireland and no rare or unusual species were recorded. All of the algal species associated with the kelp stipes, or forming the understory on the rock surface, are common species associated with this biotope. Few birds were observed in the study sites.

Baseline data are now in place in preparation for harvesting. Future sampling and analysis will enable effects of harvesting to be evaluated and characterised.

1. Introduction

BioAtlantis Aquamarine Ltd. has been licensed to sustainably harvest *Laminaria* sp. in 750 Ha of Bantry Bay. This is split into a number of different Areas, A, B, C, D and E. As part of the licensing agreement, BioAtlantis Aquamarine Ltd. has agreed with the Department of the Environment, Community and Local Government that a baseline study of the area will be conducted prior to commencing harvest. This will be followed up with further sampling to assess the potential environmental effects of mechanical harvesting in areas populated by *Laminaria* over a 3 to 5 year period within the licensed area. Test and control sites were identified in each harvesting Area and the biota (algae, invertebrates, fish and birds) were sampled by scuba divers and boat-based observers. The objectives of the work described in this report were to (a) characterise the biota in advance of harvesting as a baseline for future (post-harvest) comparisons (b) determine whether there were differences between (i) licensed Areas (A – E) and (ii) tracts within each Area.

2. Methods

Sampling was primarily conducted from 5-16 September 2016 by MERC environmental consultants. The methodology used was based closely on that specified in the "Agreed Monitoring Programme as required by licence" developed by BioAtlantis in consultation with the Department (see Appendix 1). Minor modifications were made by Tasman Crowe, in consultation with Louise Scally of MERC consultants and John T. O'Sullivan of BioAtlantis. These are outlined and justified below. A case was also made for modifying the design so that there were two control and two harvested tracts in each Area, with a reduced number of quadrats in each and sampling only three or four of the five Areas to maintain a comparable total workload. This would have the advantage of enabling comparison of the effects of harvesting among Areas, but was not supported because such a substantial change could not be made without securing approval and there was not time for approval to be sought. Moreover, the existing design required a larger number of quadrats be used per site. The existing unreplicated block design is also powerful and will enable valid interpretation of the effects of harvesting in the bay as a whole.

In each Area (Figure 2.1), two suitable tracts within areas of dense kelp cover were identified using drop-down video. These were later allocated randomly to be either control or harvested. Tracts were 10 x 100 m and were oriented parallel to the shore at 8-12 m depth, such that they were fully within the kelp, which occupied only a narrow strip in many places. Coordinates and maps are provided in Appendix 2. At the centre of each, a 10 x 10 m plot was established. 15 quadrats (1 x 1 m) were placed randomly in each plot, rather than being arranged in a fixed Y pattern. Randomised sampling reduces risk of inaccuracy due to any underlying regularity of pattern and permits valid statistical comparisons of data from different times of sampling in the same area.

Invertebrates and algae were sampled in the quadrats as per the programme methodology except that (a) in this first sampling, all taxa were recorded as far as was possible rather than focusing on a subset of approximately 10 indicator taxa / functional groups; this was to enable suitable indicator taxa to be identified from a detailed baseline, (b) taxa that were extremely abundant or cryptic (hidden in crevices, etc.) were quantified within a 0.25 m^2 sub-quadrat to enable greater accuracy (this was rarely done in fact, and all data were scaled to the full 1 m^2 quadrat before analysis), (c) visual estimates of percentage cover included estimates of cover by kelp holdfasts and of the cover of organisms growing on them (but, as

per the protocol, not within them) (d) cover of epibiota was estimated on a percentage scale for two individual *Laminaria* stipes per quadrat. One of these was the nearest plant to the bottom right of the quadrat and the second the nearest plant to the top left of the quadrat, which effectively yielded a random selection of 30 plants per plot. The percentage cover of each the main characterising red algal species was enumerated. The length of each of these stipes was also measured, from the base of the holdfast to the base of the frond, to the nearest 5 cm (e) encrusting / colonial species of animals were recorded as percentage cover. A supplementary assessment was performed in June 2017 to measures the age of kelp and the length of kelp including both the stipe and fully extended fronds (Appendix 4)

Under-canopy species of fish were recorded by using fyke nets deployed in gangs of 3 positioned on the seabed for 48 hours at two of the sites. Species were taken from the nets identified and enumerated before release. Fish were also sampled in each of the 15 quadrats sampled per tract to give a more comprehensive sample of fish than would have been possible using fyke nets alone.

Due to concerns about the safety and effectiveness of trawling over rocks in such shallow water, above-canopy species of fish were recorded by conducting 4 x 5 minute watches per site by a diver viewing upwards from a vantage point on the reef. The watches were spaced out to cover a working period of 6 hours throughout the day.

An additional excursion to sample fish was conducted in June 2017. It involved the deployment of fyke nets in two additional Areas (D and E), bringing the total to four areas (including Areas B and C surveyed in September 2016). It also included visual surveys of species above and below the canopy.

Birds were recorded as per the instructions provided by BioAtlantis by email, with identification and enumeration of all birds observed within 50 m of the vessel during over a one hour period at each of the dive sites (two one hour periods per licensed Area).

In the analyses, no distinction is made between sites assigned to be harvested and sites assigned to be controls as no treatments had yet been applied. As such, the analyses involved two factors: Area (five levels) and Site nested within Area (two levels). Univariate measures (e.g. density of *Laminaria*, cover of encrusting coralline algae, etc.) were analysed with Analysis of Variance, with computations being done using GMAV5 for Windows (Underwood and Chapman 1998). Cochran's test of homogeneity of variance was used prior

to analyses and transformations were applied as required to stabilise variances (see individual Table captions for details). Post-hoc comparisons to identify differences among levels of significant terms were done using Student Newman Keuls (SNK) tests (Underwood 1997).

Multivariate data were analysed using PRIMER 6. Similarity matrices were constructed using Bray-Curtis similarity using the full lists of taxa in Appendix 3. This index summarise the similarity between pairs of assemblages (in different samples) based on the identities and numbers of taxa present (Clarke 1993). Patterns were visualised using non-metric Multi-Dimensional Scaling. Such plots are based on rank similarities, such that points representing pairs of assemblages that are the most similar to each other are plotted closest together and points representing pairs of assemblages that are the least similar to each other are plotted furthest apart (Clarke 1993). Differences among Areas and between sites were tested using PERMANOVA based on the model described above. In some cases transformations were applied to reduce the influence of highly abundant taxa (Clarke 1993). Dummy variables were introduced into multivariate analyses to minimise the effect of zero count data in Bray-Curtis similarity matrices.

Figure 2.1. Map of Bantry Bay, showing licensed harvesting Areas. **Bing Maps Aerial** - © Harris Corp, Earthstar Geographics LLC © 2016 Intermap Earthstar Geographics SIO © 2016 Microsoft Corporation. See Appendix 2 for expanded views of each Area, showing experimental and control tracts.

3. Results

In general the results of the preliminary survey, by drop down video and spot dives, indicated that only a relatively narrow band of kelp occurred within the licensed Areas that had any significant density of kelp (*Laminaria hyperborea*). In licensed Areas A and B on the south side of Bantry Bay, kelp habitat characterized by *L. hyperborea*, was confined to a narrow band (approximately 40 m wide). On the north side of the bay, the area of kelp was slightly wider, but not extending greater than 200 m from shore.

This narrow band was broadly consistent with *Laminaria hyperborea* biotope with dense foliose red seaweeds on exposed upper infralittoral rock (coded as IR.HIR.KFaR.LhypR.Ft in the JNCC Marine Habitat Classification for Britain and Ireland (Connor et al. 2003)). Below this zone the kelp became sparser and was more consistent with the biotope *Laminaria hyperborea* park with dense foliose red seaweeds on exposed lower infralittoral rock (IR.HIR.KFaR.LhypR.Pk). The survey areas were confined to the denser kelp bed areas closer to shore.

The habitat surveyed was thus broadly consistent with the biotope IR.HIR.KFaR.LhypR.Ft. This biotope is common on infralittoral rock in the depth zone 0 to 20 m Below Chart Datum on exposed to moderately exposed tide swept bedrock and boulders around all coasts of Ireland. The main noticeable variation from the standard biotope, was the lack of fauna that may be associated with this biotope (Connor et al. 2003). However, it is recognised that that Marine Habitat Classification biotopes, which were largely based on UK data sets, do not always match those found in Ireland. Complete species lists are provided in Appendix 3.

In the text below, the site designated to be experimentally harvested in each Area is denoted Site 1 and the site designated to be a control is denoted Site 2.

Laminaria and other kelps

The average density of *Laminaria hyperborea* plants varied among sites from 6.7 per m^2 (in one of the sites in Area E) to 16.5 per m^2 at one of the sites in Area A. The density of *Laminaria* plants did not vary significantly between Areas; however there were differences between sites in some Areas (Table 3.1a, Figure 3.1a). In both Areas A and E, Site 2 had significantly more *Laminaria* plants than Site 1 (Table 3.1a, SNK; Areas A & B; Site 2 > Site 1, $p < 0.01$). In Areas C & D, there were significantly more *Laminaria* plants at the first site (Table 3.1; SNK; C & D; Site 1 > Site 2, $p < 0.05$). In Area B there was no significant difference between sites (Table 3.1a, Figure 3.1a). Stipes were significantly longer in Area E

(85 cm) but there were no differences among other Areas (Table 1b, Figure 1b, SNK; Area; E > A = B = C = D, $p < 0.05$), in which average stipe length ranged from 50-70 cm. There were no differences in stipe length between sites. A supplementary assessment in June 2017 found that the total height of *Laminaria* plants including both the stipe and fully extended fronds was 147cm (Appendix 4). The age of *Laminaria* plants in the licence area was measured as part of the supplementary assessment and was found to be 3.4 years on average (Appendix 4).

Table 3.1 Analysis of a) density (n = 15) and b) length of *Laminaria* plants (n = 30).

Source of variation	a) No. of *Laminaria* per m^2					b) Stipe length				
	df	MS	F	*p*		df	MS	F	*p*	
Area = Ar	4	175.2833	1.46	0.3401	ns	4	9795.387	17.43	0.0039	**
Site(Ar)	5	120.3867	6.44	0	****	5	562.0433	0.81	0.5398	ns
Residual	140	18.6876				290	689.6663			

** denotes significance at $P < 0.01$, **** denotes significance at $P < 0.0001$, ns = no significant difference, df = degrees of freedom, MS = Mean Square, and F = F ratio.

Sacchoriza polyschides and *Saccharina latissima* were rare in the sites sampled: *Sacchoriza* occurred only in two quadrats in Site 1, Area A and in one quadrat in Site 2 Area E; *Saccharina* only occurred in one quadrat in Site 1 Area B and in one quadrat in Site 2 Area E.

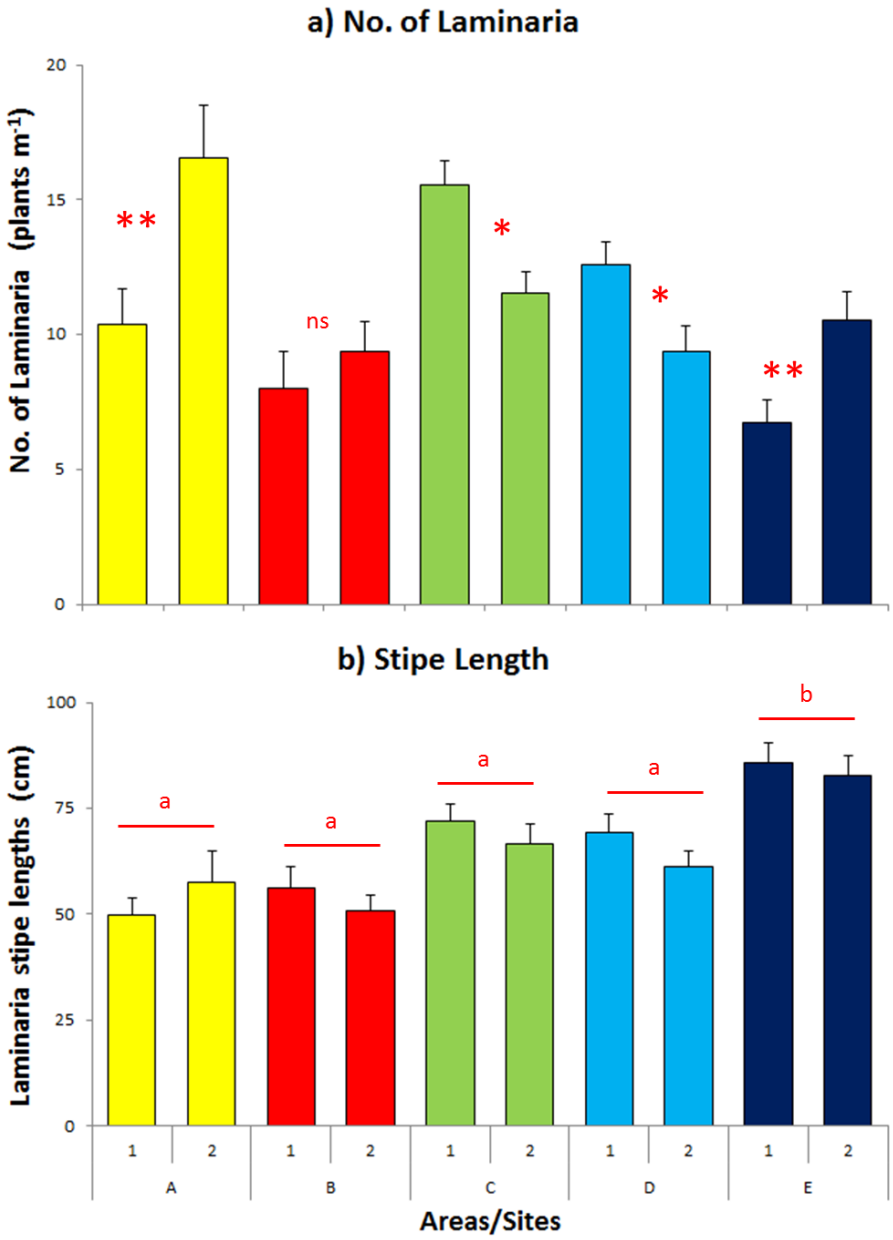

Figure 3.1. a) Density and b) length of *Laminaria* plants sampled at two sites (1 & 2) in each of five Areas of Bantry Bay. Shown are means and Standard Error, SE (n = 15 quadrats per site). Sites 1 and 2 are indicated for each Area. Differences between pairs of sites are indicated as follows: ns = not significant, * denotes P <0.05, ** denotes P<0.01. Differences between Areas are indicated by bars above pairs of sites: bars bearing the same letter (e.g. 'a') are not different from each other. These indications are only included for terms that were significant in the respective analyses.

Fauna and flora on rock surfaces

Kelp holdfasts accounted on average for up to 13.5% cover of rock surfaces. Cover of holdfasts varied between sites in three Areas (Table 3.2a, Figure 3.2a: Areas A, B & E; SNK; Site 2 > Site 1, $p < 0.05$). Encrusting Bryozoans made up a similar proportion of the cover and again varied between sites in two of the Areas surveyed (Table 3.2b, Figure 3.2a, SNK; Area C - Site 2 > Site 1, $p < 0.01$; Areas D– Site 1 > Site 2, $p < 0.01$). Crisiids were rare in Area A (average cover 3.3%), but accounted for up to 44% cover (in Site 2 Area C). Cover varied considerably between sites in most Areas. For example, significantly greater cover of Crisiids was found in Site 1 of Areas B & D than Site 2 (Table 3.2c, Figure 3.2c; Areas B&D; SNK; Site 1 > Site 2, $p < 0.01$) and significantly greater cover was found in Site 2 in Areas A and C (Table 3.2c, Figure 3.2c; SNK; Site 2 > Site 1, $p < 0.01$).

Cover at most sites was dominated by encrusting algae, particularly coralline algae, but also other reds and browns (Figure 3.2d, e), generally accounting for 50-100% cover on average, except in Area B where they covered only 35% of the rock surface. The percentage cover of coralline crusts varied between sites but only in two of the five Areas (Table 3.2d, Figure 3.2d; SNK: Area C - Site 1 > Site 2, $p < 0.01$; Area D - Site 2 > Site 1, $p < 0.01$). Cover of red and brown crusts varied between sites only at Area C (Table 3.2e, Figure 3.2e; SNK; Area C - Site 1 > Site 2, $p < 0.01$). Much of the remaining rock was covered by foliose algae, to a maximum cover of 44%, with an overall average of 30% (Figure 3.2f). The percentage cover of foliose algae also varied between sites, with significantly more foliose algae found at Site 2 in Area A (Table 3.2f, Figure 3.2f, SNK; Site 2 > Site 1, $p < 0.01$) and at Site 1 in Areas B and C (Table 3.2f, Figure 3.2f, SNK; Site 1 > Site 2, $p < 0.01$). In general, more foliose algae were found in Areas A and B than in the other Areas (Table 3.2f, Figure 3.2f, SNK; Area - A = B > C = D = E, $p < 0.01$). Sand was only found in Site 1 Area A (Table 3.2g, Figure 3.2g, SNK; Area A - Site 1 > Site 2, $p < 0.01$). There was no bare rock in any quadrat at any site.

Full lists of fauna and flora found on rock surfaces are presented in Appendix 3. Multivariate analyses of those data using PRIMER revealed differences in assemblage structure among Areas for algae and fauna recorded as cover (Table 3.3, Figures 3.3, 3.4). These could not be resolved with post-hoc pairwise comparisons, however, suggesting that the differences are not strong. Communities also varied between sites in each of the Areas. Multivariate differences are not directional so there is little to be gained in interpreting these differences at this stage (using SIMPER analysis), when no treatments have been applied. The results are simply indicative of

the fact that communities are variable at quite small scales within Areas of Bantry Bay, but that on average, there is little difference between licensed Areas.

Table 3.2. Analyses of percentage cover on rock surfaces of a) *Laminaria* holdfasts, b) Encrusting Bryozoans, c) Crisiids, d) Coralline crusts, e) Red & Brown crusts, f) Foliose algae and g) sand. Data were transformed for a, b & c; Ln (x +1), Cochran's test: ns. Data were untransformed for d, e & f, Cochran's test: $p < 0.05$, $n = 15$.

Source of variation	a) Holdfasts					b) Encr. Byrozoans				
	df	MS	F	*p*		df	MS	F	*p*	
Area = Ar	4	1.5197	0.92	0.518	ns	4	6.3831	1.5	0.3291	ns
Site(Ar)	5	1.6497	5.99	0	****	5	4.2539	6.19	0	****
Residual	140	0.2753				140	0.6878			
	c) Crisiids					d) Coralline Crusts				
	df	MS	F	*p*		df	MS	F	*p*	
Area = Ar	4	10.0885	0.59	0.683	ns	4	3720.667	1.14	0.4338	ns
Site(Ar)	5	17.0107	20.12	0	****	5	3264.167	11.3	0	****
Residual	140	0.8453				140	288.7381			
	e) Red &Brown Crusts					f) Foliose algae				
	df	MS	F	*p*		df	MS	F	*p*	
Area = Ar	4	1974.7	2.7	0.148	ns	4	12512.74	5.98	0.0381	*
Site(Ar)	5	719.65	8.3	0	****	5	2091.867	9.65	0	****
Residual	140	86.48				140	216.8788			
	g) Sand									
	df	MS	F	*p*						
Area = Ar	4	266.66	1	0.48	ns					
Site(Ar)	5	266.66	8.2	0	****					
Residual	140	32.38								

* denotes significance at $P < 0.05$, **** denotes significance at $P < 0.0001$, ns = no significant difference, refer to Table 3.1 for details on other abbreviations used.

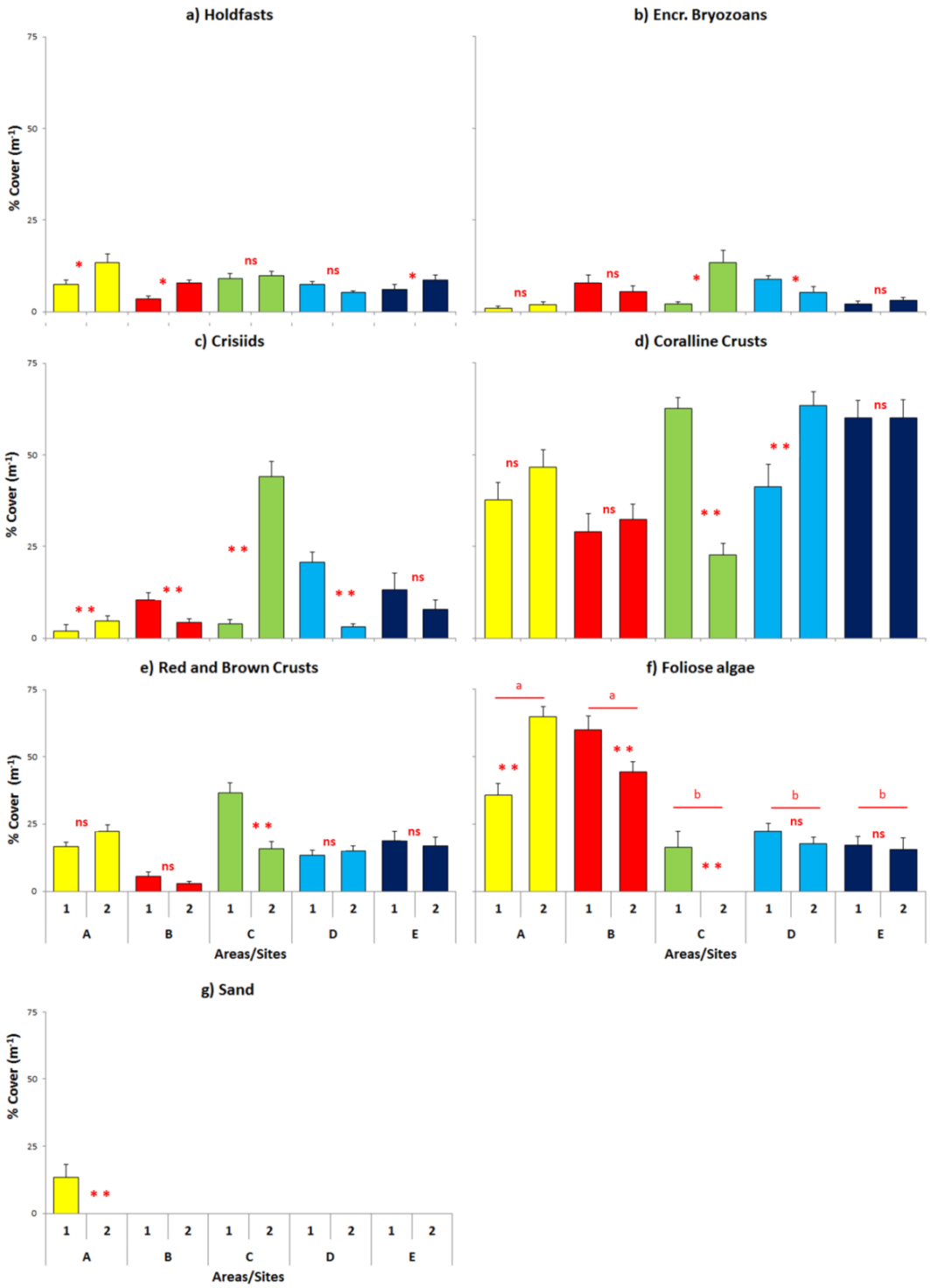

Figure 3.2. Percentage cover on rock surfaces at two sites (1 & 2) in each licensed Area of a) Laminaria holdfasts, b) Encrusting Bryozoans, c) Crisiids, d) Coralline crusts, e) Red & Brown crusts, f) Foliose algae and g) sand (n = 15). Differences between pairs of sites are indicated as follows: ns = not significant, * denotes P <0.05, ** denotes P<0.01. Differences between Areas are indicated by bars above pairs of sites: bars bearing the same letter (e.g. 'a') are not different from each other. These indications are only included on each graph for terms that were significant in the relevant analyses.

Table 3.3. PERMANOVA based on Bray–Curtis dissimilarity matrix calculated from data on a) algal species on rock and b) faunal species on rock (covering rock surfaces). Data were fourth root transformed (n= 15). Analyses involved 999 permutations of residuals under a reduced model. Full lists of taxa are available in Appendix 3.

Source of variation	a) Algal species on rock				
	df	MS	Pseudo-F	*P*(perm)	
Area = Ar	4	16157	1.357	0.176	ns
Site(Ar)	5	11904	7.507	0.001	***
Residual	140	1585.7			
	b) Faunal species on rocks (cover)				
	df	MS	Pseudo-F	*P*(perm)	
Area = Ar	4	4474.2	4.0734	0.027	*
Site(Ar)	5	1098.4	2.4516	0.007	**
Residual	140	448.02			

* denotes significance at $P < 0.05$, ** denotes significance at $P < 0.01$, *** denotes significance at $P \leq 0.001$, ns = no significant difference, refer to Table 3.1 for details on other abbreviations used.

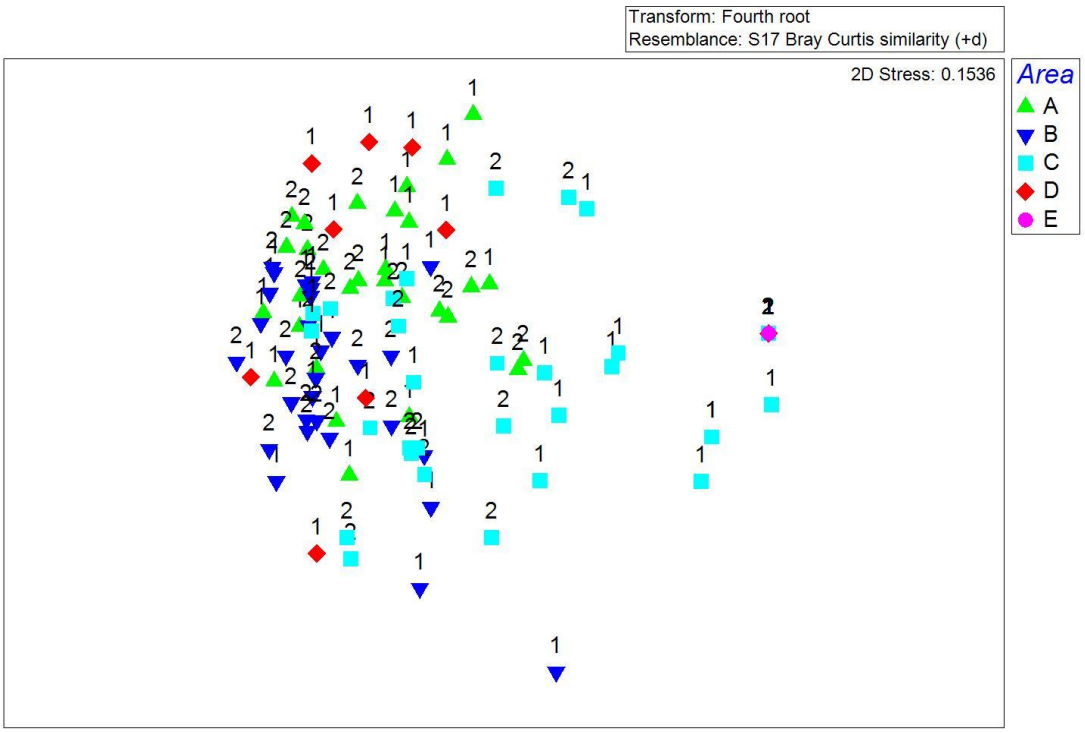

Figure 3.3 nMDS plots of algal assemblages (based on full species lists, Appendix 3) on rock surfaces at two sites in each of five Areas in Bantry Bay. Data were fourth root transformed, n= 15.

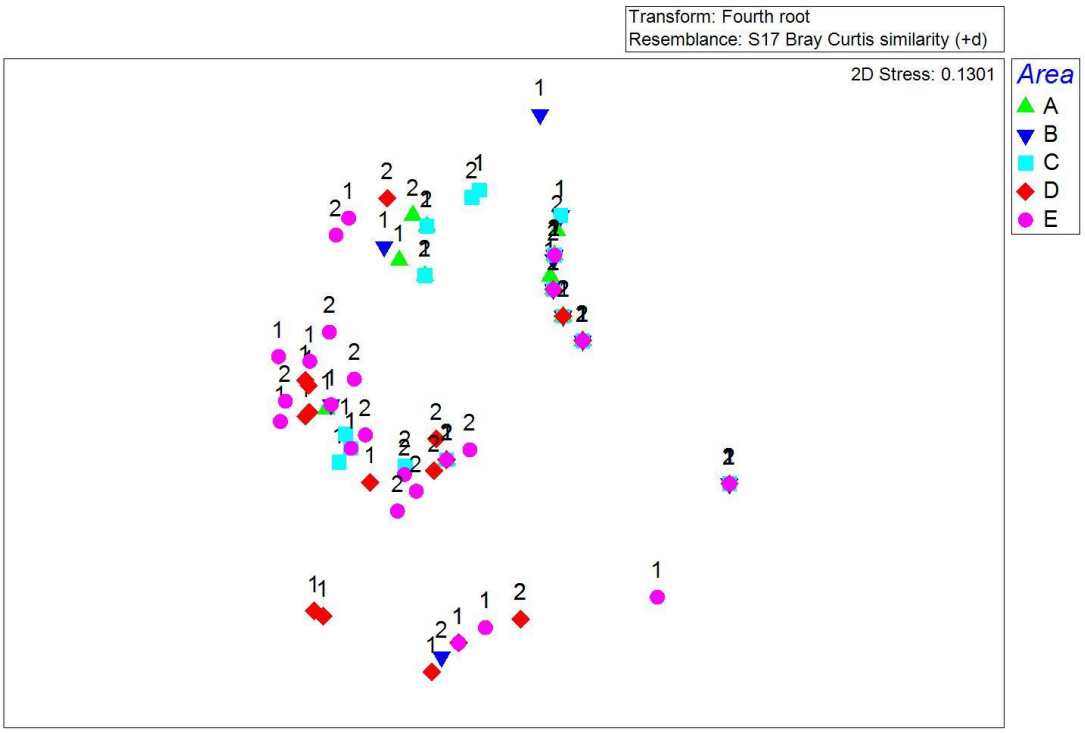

Figure 3.4. nMDS plots of assemblages of sessile animals covering the rock surface (based on full species list, Appendix 3) at two sites in each of five licensed Areas in Bantry Bay. Data were fourth root transformed, n= 15.

Cover of epibiota on stipes

Cover of epibiota on stipes of *Laminaria* varied considerably among individual stipes. On average, 25% of the surface of stipes was bare of epiota (range 12-43%, Figure 3.5a), 44% was covered by encrusting bryozoans (range 25-61%, Figure 3.5b) and 36% was covered by algae (range 24 to 54%, Figure 3.5c), almost exclusively red algae (Appendix 3).

There were significant differences between sites for all three variables, but no significant differences between Areas (Table 3.5, Figure 3.5). In Areas B & C, Site 1 had significantly more bare space on stipes than the other site (Table 3.4a, Figure 3.6a, SNK; Site 1 > Site 2, $p < 0.01$) and in Area A, Site 2 had significantly greater cover of bare space (Table 3.5a, Figure 3.5a, SNK; Site 2 > Site 1, $p < 0.01$). In Area A, Site 1 had significantly higher cover of encrusting bryozoans on stipes than at Site 2 (Table 3.5b, Figure 3.5b, SNK; Site 1 > Site 2, $p < 0.05$), whereas in Areas B and D, cover of encrusting bryozoans was greater at Site 2 (Table 3.5b, Figure 3.5b, SNK; Site 2 > Site 1, $p < 0.01$). In Area C, stipes had significantly greater cover of epiphytic algae at Site 2 (Table 3.5c, Figure 3.5c, SNK; Site 2 > Site 1, $p < 0.01$).

A full list of taxa found on stipes is presented in Appendix 3. Multivariate analyses revealed variation in community structure between sites within each Area, but no differences on average among Areas (Table 3.5, Figure 3.6).

Table 3.5. Analyses of percentage cover of organisms on *Laminaria* stipes including a) percentage area of bare stipe, b) encrusting Bryozoans and c) cover of algae epiphytes. Data were untransformed, Cochran's test: $p < 0.05$, $n = 30$.

Source of variation	a) Bare stipe				
	df	MS	F	*p*	
Area = Ar	4	3977.313	0.95	0.505	ns
Site(Ar)	5	4175.51	7.53	0	****
Residual	290	554.4511			
	b) Encr. Byrozoans				
	df	MS	F	*p*	
Area = Ar	4	5874.453	1.57	0.3121	ns
Site(Ar)	5	3733.403	6.1	0	****
Residual	290	612.1826			
	c) Algae on Stipes				
	df	MS	F	*p*	
Area = Ar	4	3054.03	0.98	0.4932	ns
Site(Ar)	5	3112.388	4.57	0.0005	***
Residual	290	681.6548			

*** denotes significance at $P < 0.001$, **** denotes significance at $P < 0.0001$, ns = no significant difference, refer to Table 3.1 for details on other abbreviations used.

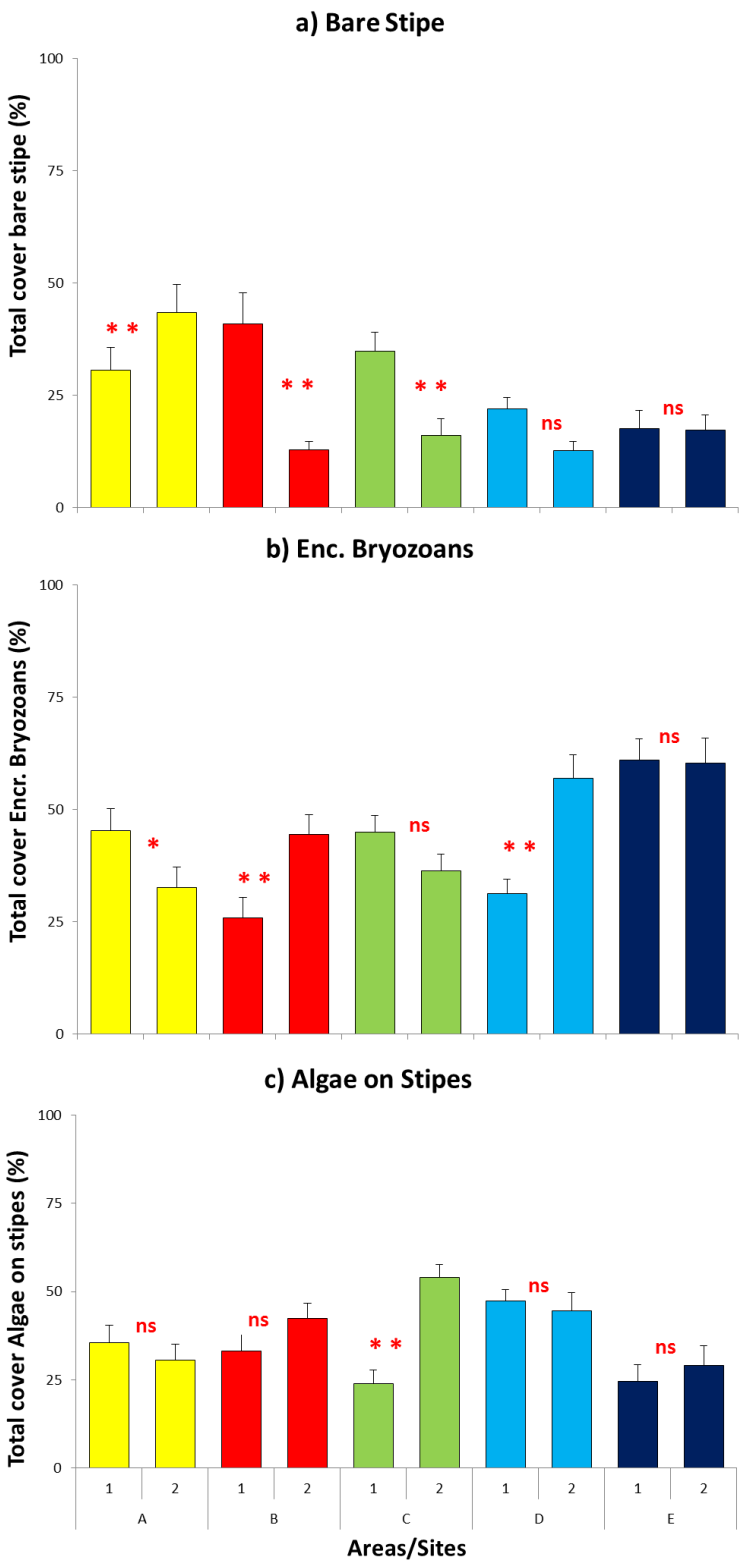

Figure 3.5. Percentage cover of biota on Laminaria stipes at two sites in each Area of Bantry Bay. a) bare stipe, b) encrusting Bryozoans and c) algal epiphytes. Shown are means and SE (n = 15). Differences between pairs of sites are indicated as follows: ns = not significant, * denotes P <0.05, ** denotes P<0.01. Differences between Areas are indicated by bars above pairs of sites: bars bearing the same letter (e.g. 'a') are not different from each other. These indications are only included on each graph for terms that were significant in the relevant analyses.

Table 3.5. PERMANOVA based on Bray–Curtis dissimilarity matrix calculated from data on species growing epibiotically on *Laminaria* plants (see Appendix 3 for species list). Data were fourth root transformed (n= 30). Analyses involved 999 permutations of residuals under a reduced model.

Source of variation	df	MS	Pseudo-F	*P*(perm)	
Area = Ar	4	5252.3	0.82994	0.622	ns
Site(Ar)	5	6328.5	6.8944	0.001	**
Residual	290	917.92			

*** denotes significance at $P \leq 0.001$, ns = no significant difference, refer to Table 3.1 for details on other abbreviations used.

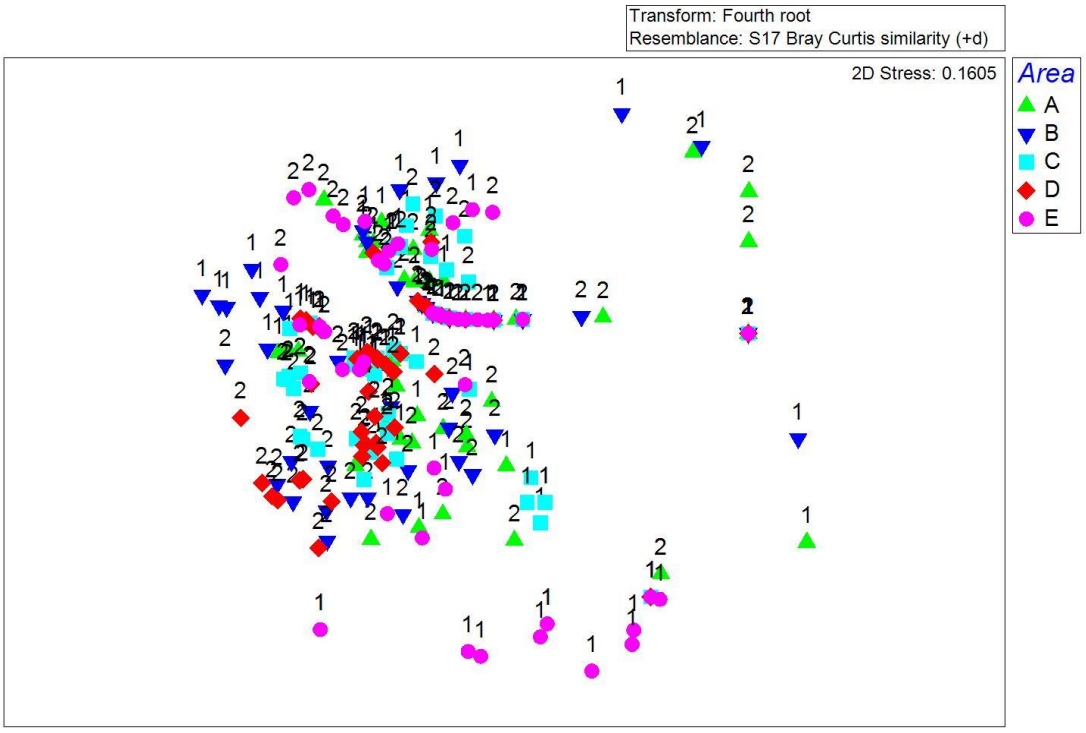

Figure 3.6. nMDS plots of assemblages found on stipes of *Laminaria* (based on full species lists, Appendix 3) at two sites in each of five Areas in Bantry Bay. Data were fourth root transformed, n= 15.

Fauna recorded as counts: including echinoderms, gastropods and decapods

Note that all taxa analysed in this way were counted in the full 1 m^2 quadrat, so 'numbers per quadrat' can be taken to mean numbers per m^2. The number of echinoderms recorded varied between sites in all surveyed licenced areas. On average, *Asterias rubens* were the most abundant echinoderms recorded with means ranging from 0.2 -10.8 individuals per quadrat (Figure 3.7a). *Echinus esculentus* was the next most abundant with mean number of this species ranging from 0.2 - 1 .133 individuals per quadrat (Figure 3.8b). Four other species of echinoderms (*Marthasterias glacialis*, *Luidia ciliaris*, *Holothuria forskali* and *Antedon bifida*: see Appendix 3) were also recorded but were rarer in comparison. Densities of all echinoderms combined ranged from 0.21 – 1.94 individuals per quadrat (Figure 3.7c).

There were significant differences between sites for all three taxa but no significant differences between Areas (Table 3.6a, Figure 3.7). In Areas C & D, Site 1 had significantly higher mean numbers of *A. rubens* than the other site (Table 3.6a, Figure 3.7a, SNK; Site 1 > Site 2, $p < 0.01$) and in Area A, Site 2 had significantly higher mean numbers of this species (Table 3.6a, Figure 3.7a, SNK; Site 2 > Site 1, $p < 0.01$). In Areas D & E mean number of *E. esculentus* per quadrat was higher at Site 1 (Table 3.6b, Figure 3.7b, SNK; Area D: Site 1 > Site 2, $p < 0.05$, Area E; Site 1 > Site 2, $p < 0.01$). In Areas A & E, Site 1 had significantly higher mean numbers of echinoderms than Site 2 (Table 3.6c, Figure 3.7c, SNK; Area A: Site 1 > Site 2, $p < 0.01$, Area E; Site 1 > Site 2, $p < 0.05$). In contrast in Areas C & D, Site 2 had significantly greater numbers of echinoderms recorded in quadrats (Table 3.6c, Figure 3.7c, SNK; Area C: Site 1 > Site 2, $p < 0.05$, Area D; Site 1 > Site 2, $p < 0.01$). In total the number of echinoderm species was consistent between sites in all licenced areas with a minimum of three species found in each site (Figure 3.9a). In Areas C & E, Site 2 contained the most echinoderm species found across all areas, with a total of four species (Figure 3.9a).

Numbers of individual grazing gastropods recorded also varied between sites in all areas and on average the number of individuals ranged from 0 – 0.44 per quadrat (Figure 3.8a). Species of gastropods were recorded at sites in all licensed areas except for Site 2 in Areas A & C with the highest number of species recorded (5 species) at Site 1 in Area E (Figure 3.9c; and see Appendix 3).

There were significant differences in the average number of gastropods per quadrat between sites but this only occurred in Area B, where on average Site 2 had significantly greater numbers than

Site 1 (Table 3.7a, Figure 3.8a, SNK; Area B: Site 2 > Site 1, $p < 0.01$). There were no differences among licensed areas (Table 3.7a, Figure 3.8a).

Decapods were relatively rare and were only recorded at four sites in three of the licensed areas (Figure 3.8b; Appendix 3), with a minimum of one species recorded per site. However three species of decapod were recorded at Site 1 in Area D (Figure 3.9b).

There were significant differences in the average number of decapods per quadrat but only in Area D, where Site 1 had significantly greater numbers than Site 2 (Table 3.7b, Figure 3.8b, SNK; Area D; Site 1 > Site 2, $p < 0.01$). There were no differences between licensed areas (Table 3.7b, Figure 3.9b).

In total across all faunal species in the licenced areas, there were thirty three species from six Phyla recorded as counts in quadrats (see Appendix 3). The number of faunal species recorded in quadrats at each site in the licensed areas ranged from a minimum of five species found in Site 1 area B and a maximum of 13 species found in Site 1 in Area E (Figure 3.9d). On average, the number of individual faunal species recorded per quadrat ranged from 2.4 – 18.13 (Figure 3.8c).

There were significant differences in the average number of individual faunal species per quadrat between sites but no significant differences across licensed areas (Table 3.7c, Figure 3.8c). In Areas A & E Site 2 had significantly higher average number of species than Site 1 (Table 3.7c, Figure 3.8c, SNK; Area A: Site 2 > Site 1, $p < 0.01$, Area E; Site 2 > Site 2, $p < 0.05$). In contrast, in Site D there was a significantly higher average number of species recorded in Site 1 (Table 3.7c, Figure 3.8c, SNK; Area A: Site 1 > Site 2, $p < 0.01$). There were no significant differences between sites in the other two licensed Areas (Figure 3.8c).

Table 3.6. Analyses of count data for a) *Asterias rubens*, b) *Echinus esculentus* and c) all echinoderms recorded at two sites (1 & 2) in each licensed area in Bantry bay (see Appendix 3 for full list of echinoderms). Data were transformed; Ln(x) +1: Cochran's test: ns, *n* = 15.

Source of variation					
	a) *Asterias rubens*				
	df	MS	F	*p*	
Area = Ar	4	1.6803	0.15	0.9565	ns
Site(Ar)	5	11.4223	24.25	0	****
Residual	140	0.4711			
	b) *Echinus esculentus*				
	df	MS	F	*p*	
Area = Ar	4	3.36	1.31	0.379	ns
Site(Ar)	5	2.56	4.28	0.0012	**
Residual	140	0.5981			
	c) All echinoderms				
	df	MS	F	*P*	
Area = Ar	4	4.2354	0.53	0.7198	ns
Site(Ar)	5	7.9638	16.19	0	****
Residual	140	0.4919			

** denotes significance at $P < 0.01$, **** denotes significance at $P < 0.0001$, ns = no significant difference, refer to Table 3.1 for details on other abbreviations used.

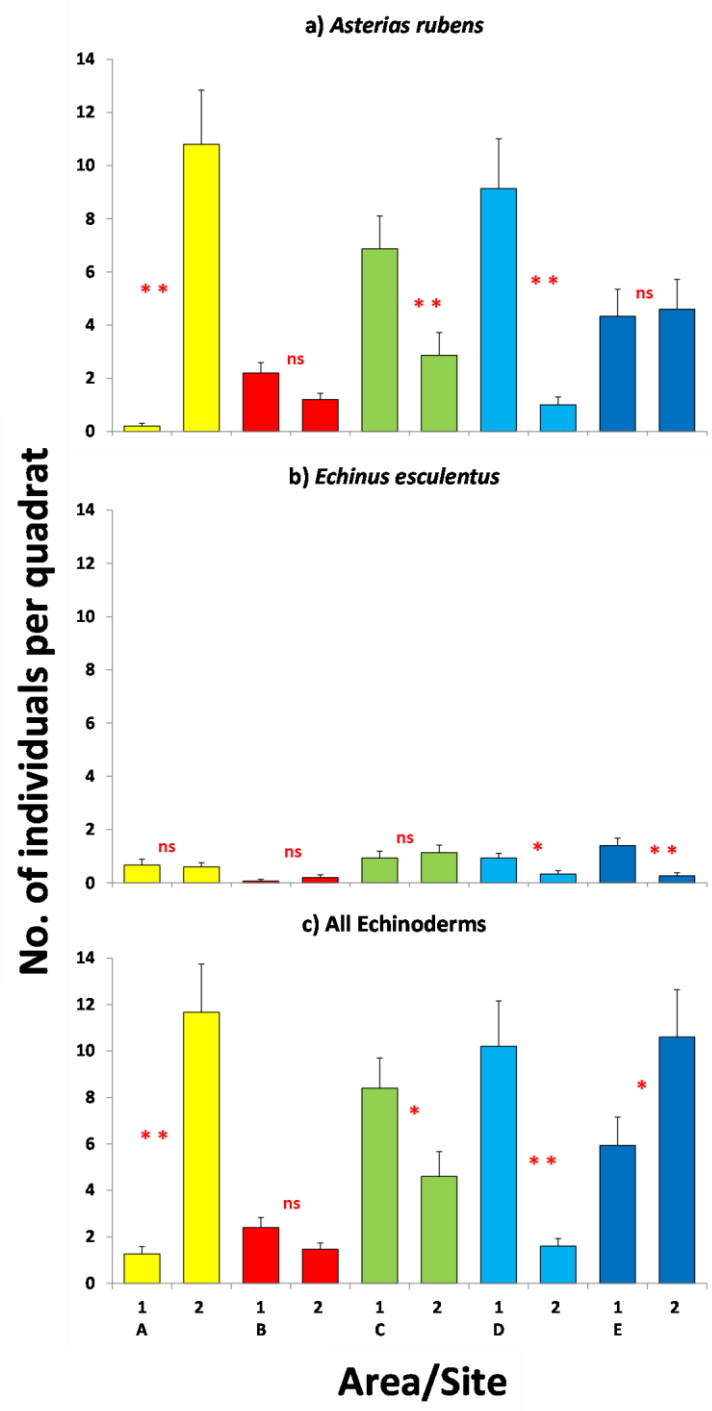

Figure 3.7 Mean numbers of individuals per quadrat of a) *Asterias rubens*, b) *Echinus esculentus* and c) All Echinoderms recorded as counts at two sites (1 & 2) in each licensed area in Bantry bay (see Appendix 3). Shown are means and SE (n = 15). Differences between pairs of sites are indicated as follows: ns = not significant, * denotes P < 0.05 and ** denotes P < 0.01.

Table 3.7 Analyses of count data for a) grazing gastropods, b) decapods and c) all faunal species recorded in quadrats at two sites (1 & 2) in each licensed area in Bantry bay. Full species lists can be found in Appendix 3. Data were transformed; Ln(x) +1: Cochran's test: ns, *n* = 15.

Source of variation					
	a) Grazing gastropods				
	df	MS	F	*P*	
Area = Ar	4	4.8233	2.56	0.1656	
Site(Ar)	5	1.8867	3.52	0.005	**
Residual	140	0.5362			
	b) Decapods				
	df	MS	F	*P*	
Area = Ar	4	0.7733	1.1	0.4461	ns
Site(Ar)	5	0.7	3.77	0.0031	**
Residual	140	0.1857			
	c) All faunal species				
	df	MS	F	*P*	
Area = Ar	4	6.1419	0.99	0.4895	ns
Site(Ar)	5	6.2023	10.57	0	****
Residual	140	0.5867			

** denotes significance at $P < 0.01$, **** denotes significance at $P < 0.0001$, ns = no significant difference, refer to Table 3.1 for details on other abbreviations used.

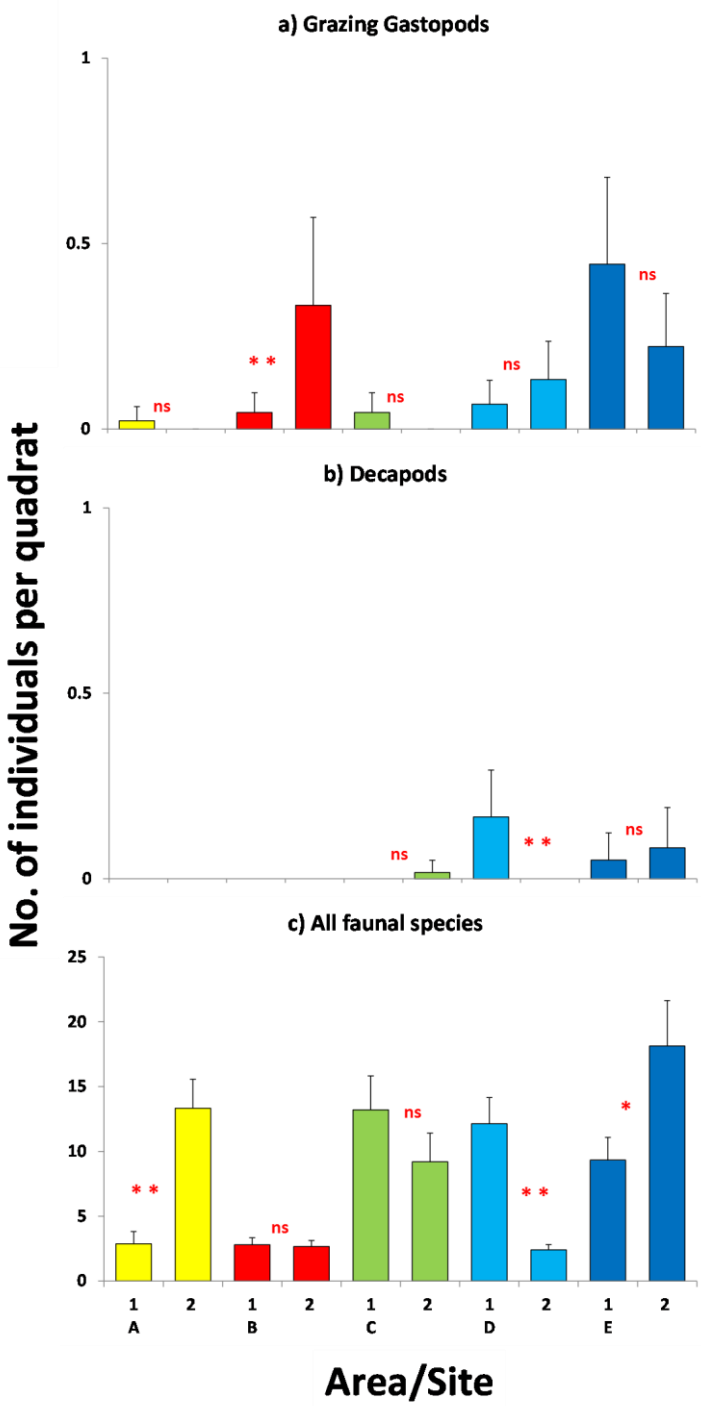

Figure 3.8 Mean numbers of individuals per quadrat of a) grazing gastropods, b) decapods and c) all faunal species recorded as counts at two sites (1 & 2) in each licensed area in Bantry bay (see Appendix 3). Shown are means and SE (n = 15). Differences between pairs of sites are indicated as follows: ns = not significant, * denotes P <0.05, ** denotes P<0.01.

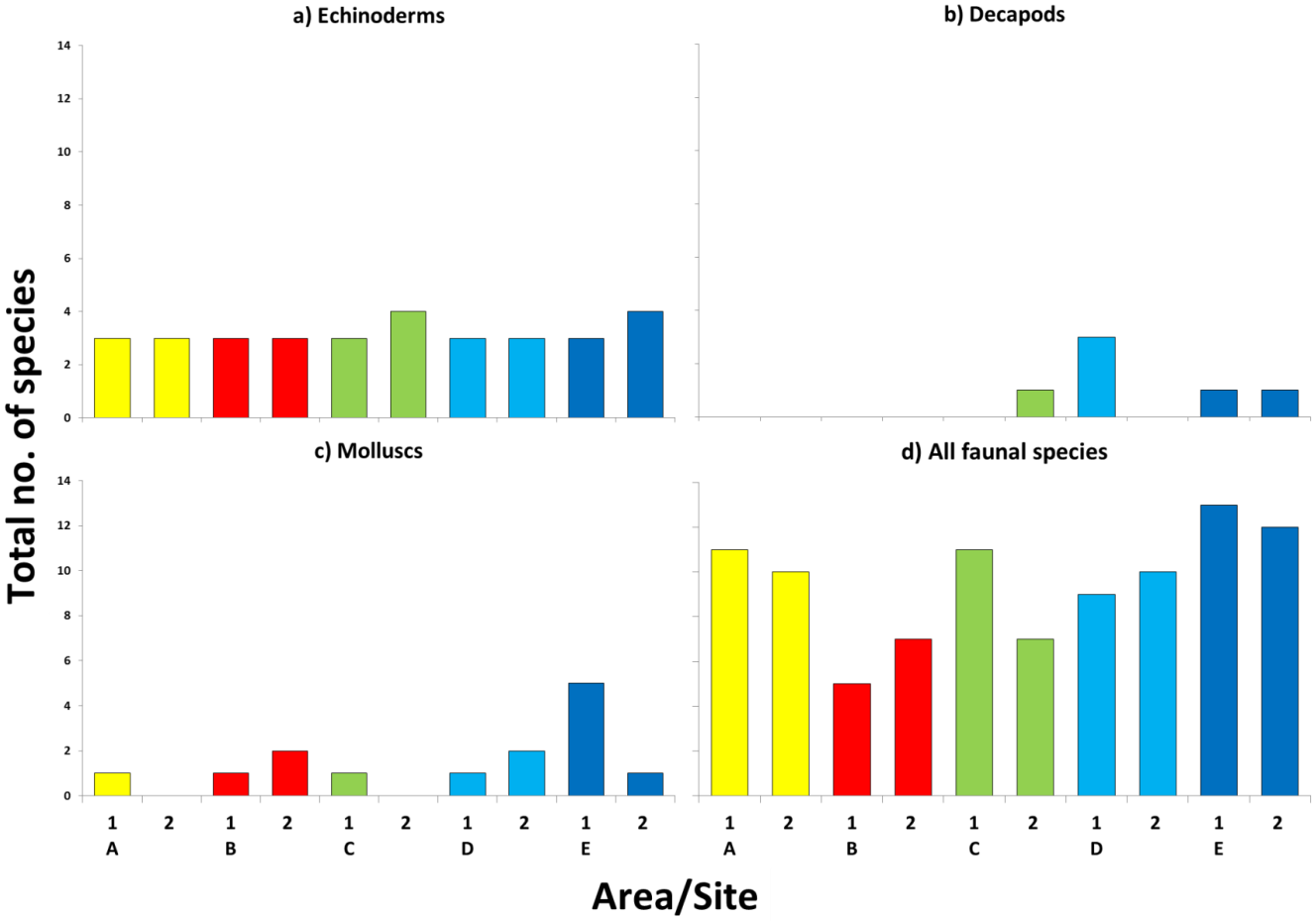

Figure 3.9 Total numbers of species of a) echinoderms, b) decapods, c) grazing gastropods and d) all faunal species recorded in quadrats at two sites (1 & 2) in each licensed area in Bantry Bay (see Appendix 3 for full list of taxa).

Multivariate analyses of the assemblage of fauna recorded as counts using PRIMER revealed differences in assemblage structure among Areas for fauna recorded as counts of individuals (Table 3.8, Figure 3.10; see Appendix 3 for list of taxa). As with the multivariate data presented in the section on species recorded as percentage cover, these differences between Areas could not be resolved with post-hoc pairwise comparisons, suggesting that the differences are not strong. Multivariate differences are not directional so there is little to be gained in interpreting these differences at this stage (e.g. using SIMPER analysis), when no treatments have been applied. The results are simply indicative of the fact that communities are variable at quite small scales within Areas of Bantry Bay, but that on average, there is little difference between licensed Areas. Equally, there were no significant differences between sites in each of the Areas (Table 3.8, Figure 3.10).

Table 3.8. PERMANOVA based on Bray–Curtis dissimilarity matrix calculated from data on faunal species on rock (counts of individuals). Data were fourth root transformed (n= 15). Analyses involved 999 permutations of residuals under a reduced model.

Source of variation	df	MS	Pseudo-F	*P*(perm)	
Area = Ar	4	8201.3	1.2059	0.3	ns
Site(Ar)	5	6800.9	6.9112	0.001	***
Residual	140	984.04			

*** denotes significance at $P \leq 0.001$, ns = no significant difference, refer to Table 3.1 for details on other abbreviations used.

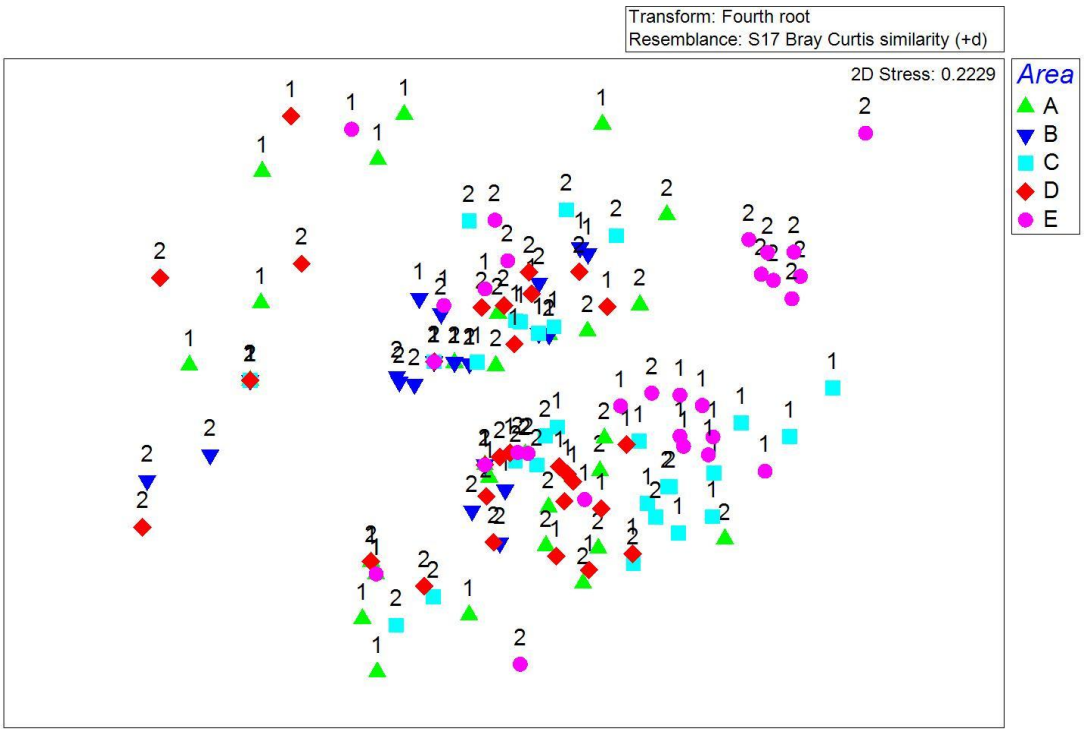

Figure 3.10 nMDS plots of assemblages of animals (fish and invertebrates) counted as individuals (based on full species lists, Appendix 3) on or near rock surfaces at two sites in each of five Areas in Bantry Bay. Data were fourth root transformed, n= 15.

Fish sampled in September 2016

A range of fish species were captured under the canopy using fyke nets in Areas B and C in September 2016 (Table 3.9) and others were observed under the canopy during quadrat surveys at all sites and Areas (Table 3.10) and in timed observations of the water column above the canopy (Table 3.11). The species captured by fyke net are all common within infralittoral reef habitats in Ireland.

Table 3.9. Number of individual species of fish caught in gangs of three fyke nets deployed for 48 hours in two selected Areas of Bantry Bay (Areas B & C) in September 2016.

Species	**Area B**	**Area C**
Scyliorhinus stellaris (Bull Huss)	4	2
Labrus bergylta (Ballan wrasse)	3	1
Crenilabrus melops (Corkwing)	5	2
Pollachius pollachius (Pollack)	1	1
Trisopterus minutus (Poor cod)	1	0
Cancer pagurus (Edible crab)	3	2
Taurulus bubalis (Scorpion fish)	1	0
Conger conger (Conger eel)	0	1

Table 3.10. Fish observed under the canopy during quadrat surveys in two sites in each of the five Areas in September 2016. Shown are means of 30 1 m^2 quadrats per Area (i.e. 15 quadrats in each tract).

Species	**Mean A**	**Mean B**	**Mean C**	**Mean D**	**Mean E**	**Overall Mean**	**Std Err.**
Taurulus bubalis	0	0	0	0.1	0.033	0.027	0.004
Symphodus melops	0.467	0	0	0.033	0	0.1	0.021
Chirolophis ascanii	0	0	0	0.033	0	0.007	0.002
Ctenolabrus rupestris	0.167	0	0	0.033	0	0.04	0.005
Gobiusculus flavescens	0	0	3.567	0.033	0.133	0.747	0.073
Labrus mixtus	0.033	0	0.067	0	0	0.02	0.004
Labrus bergylta	0.067	0	0	0	0	0.013	0.003
Parablennius gattorugine	0.17	0.20	0	0	0	0.073	0.023
Gadus morhua	0	0	0.067	0	0	0.013	0.003

Table 3.11. Total numbers of fish of different species observed above the canopy in each Area of Bantry Bay during 4 x 5 minute visual sampling periods, in September 2016.

Species	**Area A**	**Area B**	**Area C**	**Area D**	**Area E**
Pollachius pollachius (Pollack)	19	7	0	24	42
Labrus bergylta (Ballan wrasse)	3	13	6	2	2
Crenilabrus melops (Corkwing)	4	2	2	2	3
Merlangius merlangus (Whiting)	0	30	0	0	0
Ctenolabrus rupestris (Goldsinny wrasse)	1	0	0	0	1
Labrus mixtus (Cuckoo wrasse)	2	0	0	0	3
Gadus morhua (juvenile Cod)	0	0	0	0	1
Scomber scombrus (Mackerel)	10000	0	0	0	0
Scyliorhinus stellaris (Bull Huss)	1	0	0	0	0
Gobiusculus flavescens (Two-spot gobies)	15	40	250	0	0
Scyliorhinus canicula (Lesser spotted dogfish)	0	0	1	0	0

Fish sampled in June 2017

For individual species caught in fyke nets, there was variation in the species observed in individual Areas (Table 3.12). In particular four species found in Area E were not observed in fyke nets in Area D, those being the bull huss (*Scyliorhinus stellaris)*, the cork wing wrasse (*Crenilabrus melop*), the brown crab (Cancer pagurus) and the velvet swimming crab *(Necora puber*). In contrast, three species found in Area D were not observed in Area E, the ballan wrasse (*Labrus bergylta*), the common prawn (*Palaemon serratus)* and the Conger eel (Conger conger) (see Table 3.12).

Visual sampling under and above kelp was done in all Areas in September 2016 (Tables 3.10, 3.11) and in June 2017 (Tables 3.13, 3.14), presenting an opportunity to compare these fish assemblages between sampling times. Under canopy, some species were only seen in September (*Taurulus bulbalus, Symphodus melops, Chirolopus ascanii, Gadhus morhua*); others were only seen in June (*Crenilabrus melops* and unidentified juveniles). Other species were present at both times, specifically *Labrus bergylta, Labrus mixtus, Ctenolabrus rupestris, Gobiusculus flavescens, Parablennius gattorugine*. These were generally rare and either restricted to one or two areas at each time (e.g. *Parablennius gattorugine, Labrus bergylta*) or found in all Areas at one time or both (e.g. *Ctenolabrus rupestris, Labrus mixtus*). Above the canopy, more species

were observed in September than in June, with eleven species observed in September of which six were also observed in June. All of the six species observed in June had also been observed in September. Numbers of some species (e.g. *Pollachius pollachius*, *Labrus bergylta*, *Crenilabrus melops*) were much greater in June than in September. Others, such as *Ctenolabrus rupestris* and *Labrus mixtus* were rare at both times and observed in only one or two Areas at each time.

Table 3.12. Number of individual species of fish caught in gangs of three fyke nets deployed for 48 hours in two Areas of Bantry Bay (Areas D & E) in June 2017.

Species	**Area D**	**Area E**
Scyliorhinus stellaris (Bull Huss)	0	1
Labrus bergylta (Ballan wrasse)	1	0
Crenilabrus melops (Corkwing)	0	2
Scyliorhinus caniculus (Lesser spotted dogfish)	2	1
Palaemon serratus (Common prawn)	2	0
Cancer pagurus (Edible crab)	0	1
Necora puber (Velvet swimming crab)	0	2
Conger conger (Conger eel)	1	0

Table 3.13. Fish observed under the canopy during quadrat surveys in the kelp habitat control site in each of the five Areas. Shown are means of 30 1 m^2 quadrats per Area (i.e. 15 quadrats in each tract) sampled in June 2017.

Species	**Common name**	**Mean A**	**Mean B**	**Mean C**	**Mean D**	**Mean E**	**Overall Mean**	**Std Err.**
Labrus bergylta	Ballan wrasse	0	0.13	0.07	0	0	0.04	0.02
Labrus mixtus	Cuckoo wrasse	0.07	0.07	0	0.13	0.07	0.07	0.03
Ctenolabrus rupestris	Goldsinny wrasse	0.33	0.07	0.07	0.07	0.2	0.15	0.04
Crenilabrus melops	Corkwing wrasse	0	0	0.07	0.13	0.13	0.07	0.03
Gobiusculus flavescens	Two-spot goby	0.07	0.47	0.07	0.07	0.2	0.17	0.05
Parablennius gattorugine	Tompot blenny	0.07	0	0	0	0	0.01	0.01
Juvenile Undet.	Juvenile Undet.	0	0.2	0.13	0.07	0.13	0.11	0.04

Table 3.14. Total numbers of fish of different species observed above the canopy in each Area of Bantry Bay during 4 x 5 minute visual sampling periods at the kelp habitat control site, in June 2017.

Species	**Common name**	**Total A**	**Total B**	**Total C**	**Total D**	**Total E**	**Overall Total**
Scyliorhinus canicula	Lesser-spotted dogfish	0	0	0	1	1	2
Pollachius pollachius	Pollack	57	13	18	47	37	172
Labrus bergylta	Ballan wrasse	6	25	7	11	14	63
Crenilabrus melops	Corkwing wrasse	5	6	7	19	7	44
Ctenolabrus rupestris	Goldsinny wrasse	3	0	0	0	0	3
Labrus mixtus	Cuckoo wrasse	0	0	1	0	0	1

Birds

Some common bird species were observed in the different Areas (Table 3.15). Numbers were not very great for most species. The most abundant species was the common gull, of which fifteen individuals were sighted within 50 m of the boat in Area C. It is likely that the common gull were attracted to the survey area by the presence of the vessel, resulting in the higher number for this species during counts. Of the species recorded, five of these (Great black-backed gull, Manx shearwater, Guillemot, Oyster catcher and Sandwich tern) are amber listed species, indicating they are of conservation concern, while Herring gull is red listed. **Amber listed** birds are those of medium conservation concern while **Red List** birds are those of highest conservation concern.

All species identified in this survey are already known to be present in Bantry Bay. Shag, Common gull, Greater black back gull, Herring gull, Oyster catcher, Sandwich tern and Turnstone were previously reported as being present in Bantry Bay (I-WeBS). Fulmar, Manx shearwater and Black guillemot were previously reported as being present in Bantry Bay (Balmer, 2013).

Individuals were sighted and recorded rather than groups. With the exception of common gull, all were in transit and feeding/diving and foraging behaviour was not seen. Common gull landed, but this is likely due to the presence of the boat, which attracts them.

Table 3.15. Number of individual bird species observed in each Area of Bantry bay during sampling periods. Blank spaces indicate that no individuals of the species were seen in the Area.

Species	**Area A**	**Area B**	**Area C**	**Area D**	**Area E**
Fulmar (*Fulmarus glacialis*)		4			
European shag (*Phalacrocorax aristotelis*)		6		1	
Common gull (*Larus canus*)	2	3	15	1	
Great black-backed gull (*Larus marinus*)	1				1
Herring gull (*Larus argentatus*)	1	1	4	1	4
Manx shearwater (*Puffinus puffinus*)	2	2			
Black guillemot (juvenile;*Cepphus grille*)		2			
Oystercatcher (*Haematopus ostralegus*)			1		
Sandwich terns (*Sterna sandvicensi*s)				2	
Turnstone (*Arenaria interpres*)				1	
Little egret (*Egretta garzetta*)				1	

4. Concluding remarks

Two similar tracts have been identified in each of the licensed Areas in Bantry Bay. They have been allocated to be harvested or left as controls to enable potential impacts of harvesting to be identified by sampling after three and five years. The GPS positions of the tracts and their designations as experimental or control tracts have been provided in appendix 2 and in GIS format.

A baseline dataset has been collected and analysed. Full lists of species present have been provided in this report (Appendix 3) and in Excel spreadsheets. This exceeds the brief, but it was considered valuable to collect a full dataset in this first visit, ensuring as comprehensive a consideration of the taxa present as possible. From these lists, a set of approximately ten taxa / functional groups will be selected to serve as indicators of potential impact in future surveys, as required by the licensing conditions. It is not necessary to make select these taxa / functional groups until the second survey takes place and delaying the final selection enables more time to make carefully considered decisions. If required, however, the list can be selected more urgently based on the dataset that has been presented here.

As is common in ecological systems, we found significant variation in abundance and cover of taxa and in community structure between sites within each Area (i.e. at comparatively small scales). There were no systematic differences that might be expected to confound comparisons between experimental and control areas in the future (i.e. differences between sites 1 and 2 (designated to be experimental and control sites respectively in future) varied among variables and Areas). There were fewer differences between Areas.

The kelp biotope sampled is common around the coast of Ireland. All of the species recorded among the kelp are common in infralittoral kelp biotopes in Ireland and no rare or unusual species were recorded. All of the algal species associated with the kelp stipes, or forming the understory on the rock surface, are common species associated with this biotope. Few birds were observed in the study sites.

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Appendix 1

Agreed Monitoring Programme as required by licence

(a) Introduction:

BioAtlantis Aquamarine Ltd. has been licensed to sustainably harvest *Laminaria* sp. in 750 Ha's of Bantry Bay. This is split into a number of different areas, A, B, C, D and E as outlined in the attached map. As part of the licensing agreement, BioAtlantis Aquamarine Ltd. has agreed with the Department of the Environment, Community and Local Government that a baseline study of the area will be conducted prior to commencing harvest. The aim of the survey is to assess the potential environmental effects of mechanical harvesting in areas populated by *Laminaria* over a 3 to 5 year period within the licensed area. Test and control areas, harvested and non-harvested respectively, will be selected and assessed as summarised in Section B below. Table 1 and Figure 1 provide further details relating to the selection of appropriate sites. Table 2 summarises the sampling plan, detailing species/taxa assessed, methodologies employed and years and locations in which assessments will take place.

(b)Summary of survey plan

1. **Selection of representative areas:**

The initial step will involve selection of suitable tracts within allocated harvest (test) and unharvested (control) areas. Areas will be chosen on the basis that they provide a good overall representation of the 750 Ha licence area, in terms of depth, substrate, aspect, exposure and natural variations. The tracts will also be representative of the areas where harvesting is likely to occur. Tracts will be relatively homogeneous on the basis of height and density of *Laminaria* Sp.

2. **Selection of control tracts (unharvested):**
   - A total of 5 tracts (10 * 100 meters each) will be identified in areas A, B, C, D and E. The coordinates will be recorded by GPS and the transects will be allocated as areas that will not be harvested during the 5 year period of the study.
   - In year 1 (2016), a single $10M^2$ sub-site will be marked within each of the 5 control tracts, with the coordinates recorded by GPS. While a 10m width is proposed for the subsites, this will be increased if necessary. Sufficient buffer zones will be allocated in order to remove "edge" effects. Quantitative measurements of flora and fauna as described in Table 2, will be taken from $n=15x1m^2$ quadrants located within each of the sub-sites. Fish and bird species will be assessed separately as described in Section C of this document (see 'Methodology employed').
   - In years 3 and 5, *Laminaria* sp. density and canopy height will be measured within each of the 5 control tracts. Measurements will be taken from $n=15x1m^2$ quadrants located within each of the $10m^2$ sub-sites. This ensures that natural variations in *Laminaria* sp. over time are measured.

3. **Selection of test tracts (harvested):**
   - A total of 5 tracts (10 * 100 meters each) will be identified in areas A, B, C, D and E. The coordinates will be recorded by GPS.
   - Year 1: Before harvesting takes place (2016), a full assessment of flora and fauna at 5 test tracts will be undertaken, as described above for the control. Once the harvesting device has been commissioned and working correctly in year 1, the 10x100m tracts will be cut soon after.
   - In years 3 and year 5, a sub-site ($10M^2$) will be marked within each of the 5 test tracts which were cut in 2016. Quantitative measurements of flora and fauna, including *Laminaria* sp. will be taken from $n=15x1m^2$ quadrants located within each of the $10m^2$ sub-sites. Fish and bird species will be assessed separately as described in Section C ('Methodology employed').

4. **Statistical analysis:** The potential differences between the control data from year 1 and test data generated in years 3 and 5, will be compared statistically using PRIMER or other appropriate statistical methods or software. Potential differences in *Laminaria* sp. density and canopy height over time will be assessed in the control areas. The full analysis of flora and fauna in test areas in year 1, prior to harvest, will facilitate a Before, After, Control, Impact assessment.

Site Name	Licensed area (Ha)	Control (unharvested)			Test (harvested)		
		Tracts † (Number x Area, m^2)	No. Subsites‡	No. Quadrants*	Tracts † (Number x Area, m^2)	No. Subsites‡	No. Quadrants*
A	35	1 x 1000	1	15	1 x 1000	1	15
B	64	1 x 1000	1	15	1 x 1000	1	15
C	100	1 x 1000	1	15	1 x 1000	1	15
D	183	1 x 1000	1	15	1 x 1000	1	15
E	368	1 x 1000	1	15	1 x 1000	1	15
Total	750	5 x 1000	5	75	5 x 1000	5	75

Table 1: Selection of control and test tracts

This table outlines the planned distribution of tracts within the licensed areas. In the case of the control category, harvesting within the tracts will not occur. Depending on site suitability, the control tracts will be located inside the licensed area. In the case of the test category, harvesting will take place within the tracts. At year 1, flora and fauna (inc. *Laminaria* sp.), will be measured quantitatively within a single subsite selected from each of the 5 control tracts. In years 1 (pre-harvest) and 3 and 5 (post-harvest), flora and fauna (including *Laminaria* sp.) will be measured quantitatively within a single subsite of each of the 5 harvested test tracts. This will facilitate statistical comparison between both test and control. In years 3 and 5, *Laminaria* density alone will be assessed in the control subsites, to ensure that natural variations in density over time are measured (see Table 2 for more details).

†Distribution of tracts within licensed areas may be subject to change, depending on suitability of individual areas.

‡There will be one subsite per tract. The area of each subsite will be $10m^2$.

*There will be 15 quadrants per subsite. The area of each quadrant will be $1m^2$.

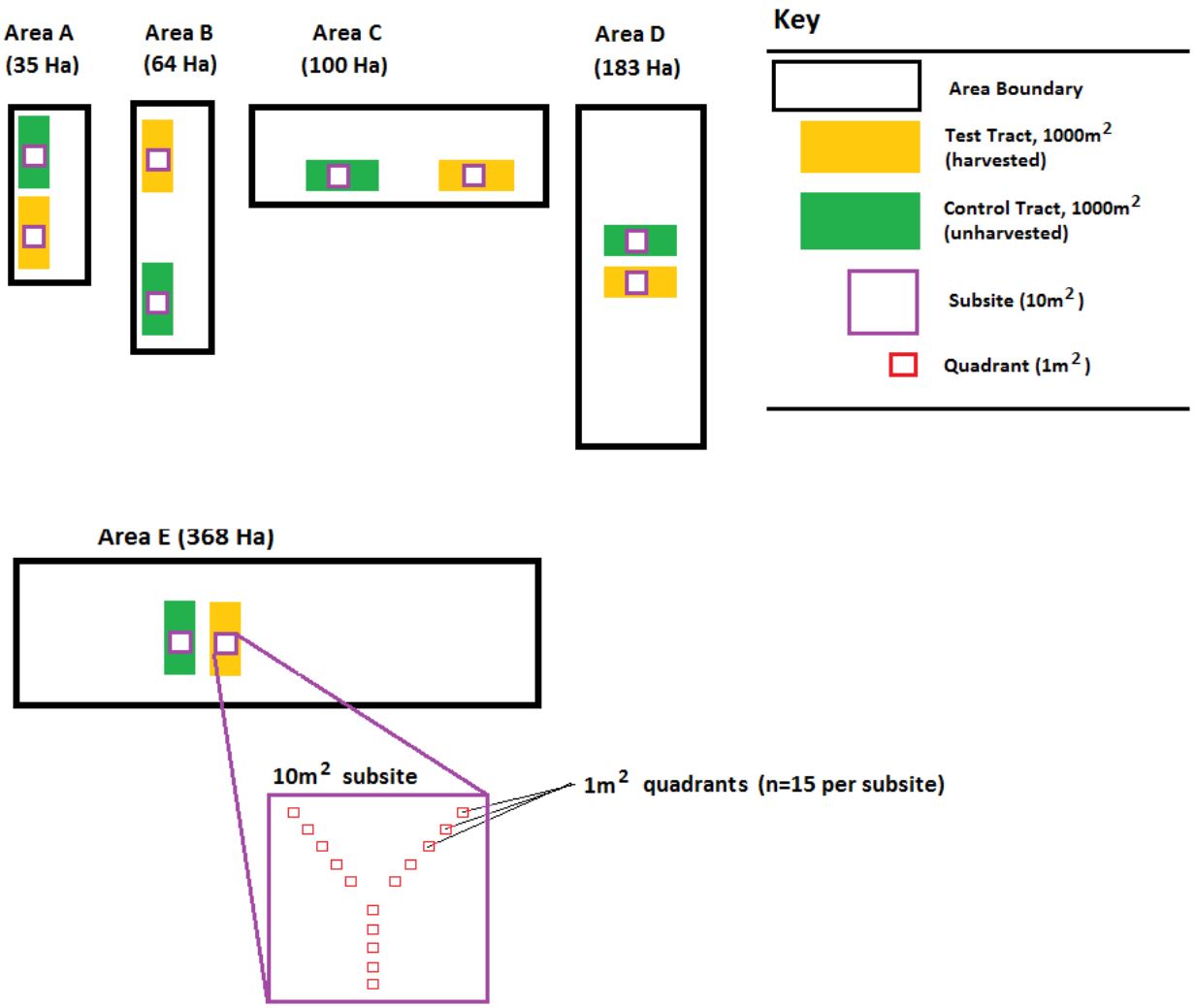

Figure 1: Planned distribution of test and control tracts and allocation of subs-sites and quadrants This figure illustrates the proposed distribution of test and control tracts, along with assigned subsites and quadrants therein. Please note, the figure is not to scale and allocation of control and test tracts may be subject to change, depending on the suitability of individual areas.

No.	Taxa/species†	Functional group/ characteristics	Justification/ requirement	Assessment Method (e.g. Semi-quantitative, Presence/absence, etc.)	No. subsites and quadrants	Schedule
	Flora					
1	*Laminaria* sp.	Target species for harvesting	Assessment required by Dept. of Environment (licence No- FS 6061).	• Quantitative measurement of: ➢ Number of *Laminaria* plants ➢ Density of *Laminaria* plants. ➢ Height of canopy	• Control (unharvested): ➢ Measurements taken in n=5 subsites: 15 x 1m^2 quadrants per subsite, i.e. 75 quadrants total. • Test (harvested): ➢ Post harvest measurements taken in n=5 subsites: 15 x 1m^2 quadrants per subsite, i.e. 75 quadrants total.	• Control (unharvested): ➢ Year 1 prior to harvest (date: Mar-Apr 2016) ➢ Year 3 post harvest (date: Mar-Apr 2019) ➢ Year 5 post harvest (date: Mar-Apr 2021) • Test (harvested): ➢ Year 1 prior to harvest (date: Mar-Apr 2016) ➢ Year 3 post harvest (date: Mar-Apr 2019) ➢ Year 5 post harvest (date: Mar-Apr 2021)
2	*Saccorhiza*	Opportunistic species	Opportunistic species which may occur where *Laminaria* stypes are lost.	Quantitative measurement of: • Number of *Saccorhiza* plants	As per point 1 above	As per point 1 above
3	Epiphytic flora (e.g. red algal species, *Polysiphonia, Ceramium, Lithothamnion*)	Species that grow on *Laminaria* holdfast, stipe and/or blade	Assessment of epiphytes required by Dept. of Environment (licence No- FS 6061).	Semi-quantitative measurements of presence of epiphytes on *Laminaria* holdfast, stipe and blade.	As per point 1 above	As per point 1 above
	Fauna (Invertebrates)					
4	**Sponges** (e.g. *Pachymatisma, Cliona)*	• Epifaunal • Filter feeders	Potential candidates for long term monitoring. Assessment required by Dept. of Environment (licence No- FS 6061).	• Quantitative measurement: ➢ Inventory ➢ Relative Abundance	As per point 1 above	• Control (unharvested): ➢ Year 1 prior to harvest (date: Mar-Apr 2016) • Test (harvested): ➢ Year 1 prior to harvest (date: Mar-Apr 2016) ➢ Year 3 post harvest (date: Mar-Apr 2019) ➢ Year 5 post harvest (date: Mar-Apr 2021)
5	**Decapods** (e.g. *Cancer)*	• Mobile • Predatory or scavenging	Potential candidates for long term monitoring. Assessment required by Dept. of Environment (licence No- FS 6061).	As per point 4 above	As per point 4 above	As per point 4 above

No.	Taxa/species†	Functional group/ characteristics	Justification/ requirement	Assessment Method (e.g. Semi-quantitative, Presence/absence, etc.)	No. subsites and quadrants	Schedule
6	**Echinoderms** (e.g. *Echinus, Asterias* and *Holothuria)*	• Epifaunal • Sessile or limited mobility • Grazers, predatory or detritivorous	Potential candidates for long term monitoring. Assessment required by Dept. of Environment (licence No- FS 6061).	As per point 4 above	As per point 4 above	As per point 4 above
	Fauna (Fish)					
7	Under Canopy species (e.g. Gobies, *Gobiusculus flavescens).*	• Mobile • Permanent	Assessment required by Dept. of Environment (licence No- FS 6061).	• Quantitative measurement: ➢ Inventory ➢ Relative Abundance	• Control (unharvested): ➢ Kelp area: Measurements taken from two strings of fyke nets (gangs of 3 nets) per n=4 control sites. Fyke nets will be placed on seabed for 48hours. Species will be identified, enuemrated and measured prior to release. ➢ Non-kelp area: as above • Test site (harvested): ➢ Kelp area: The same procedure will be followed at 4 test site locations, post harvest.	• Control site (unharvested): ➢ Year 1 prior to harvest (date: Mar-Apr 2016) • Test site (harvested): ➢ Year 3 post harvest (date: Mar-Apr 2019) ➢ Year 5 post harvest (date: Mar-Apr 2021)
8	Over-canopy species within the pelagic zone.	• Mobile • Transient	Assessment required by Dept. of Environment (licence No- FS 6061).	As per point 7 above	• Control (unharvested): ➢ Kelp area: Trawl above kelp canopy in the pelagic zone (10mm net mesh). Four hauls will be made in 4 control locations. Species will be identified, enumerated and measured. ➢ Non-kelp area: as above • Test site (harvested): ➢ Kelp area: The same procedure will be followed at 4 test site locations, post harvest.	As per point 7 above
	Fauna (Birds)					
9	Various species	• Mobile • Transient	Assessment required by Dept. of Environment (licence No- FS 6061).	Semi-quantitative records of seabird species occurrence will be made from the survey vessel during the underwater surveys.	• Control (unharvested): ➢ Species will be identified and enumerated from the survey boat while survey is underway. • Test site (harvested): ➢ The same procedure will be followed at test locations, post harvest.	As per point 7 above

Table 2: Sampling plan, methodology, timing and duration involved.

† See section C (ii) 'Flora and Fauna' for details how species and taxa will be selected.

(c) Methodology Employed:

(i). Survey areas

Mar-Apr 2016 (Year 1): Assessment of the control and test areas.
In Mar-Apr 2016, ecologists will determine the most appropriate locations in which to assign control and tests tracts. Ecologists will take quantitative measurements of flora and fauna from the control tracts and test tracts (prior to harvest) in year 1. Ecologists will begin at the centre of each subsite ($10m^2$) assigned within each tract, laying down a $1m^2$ quadrant marker, approximately 2 meters from the central point. Direct measures relevant to the survey, as described in the next section, will be taken from this quadrant (i.e. quadrant 1). When complete, the ecologists will proceed in a sequential manner, taking quantitative measurements from quadrants 2, 3, 4 and 5, etc. For each dive, GPS will be used to log diver entry and exit points. The procedure for measuring fish and bird species is described separately in sections (iv) and (vii).

Mar-Apr 2019 and 2021 (Year 3 & 5 post-harvest): Assessment of the test areas
Quantitative assessments of flora and fauna will take place in the test areas in 2019 and 2021, in a similar manner as described above in 2016. In 2019 and 2021, assessments in the controls areas will be limited to assessment of *Laminaria* sp., in order to assess the potential for natural variations in density or canopy height over time, in non-harvested areas.

(ii). Measurement of *Laminaria* density and recovery

Mar-Apr 2016 (Year 1): Assessment of the control and test areas.
Surveys will take place in the control and test sections prior to harvest in Mar-Apr 2016 (i.e. year 1). Assessment of *Laminaria* forest structure will involve the following measurements:

- *Laminaria* plant height: young and adult sporophytes at different stages of growth.
- *Laminaria* canopy height.
- Density: number of *Laminaria* plants per quadrant.

Frond length will not be measured.

Mar-Apr 2019 and 2021 (Year 3 & 5 post-harvest): Assessment of the test area
The same assessment above will be performed on both control and test areas in year 3 and 5 post-harvest. This will allow for statistical comparisons to be made between unharvested control sites and test sites, 3 and 5 years post harvest. It will also allow for assessment of *Laminaria* sp. parameters in the undisturbed control site between 1-5 years.

(iii). Fauna and Flora assessed

The presence of ~10 sentinel taxa (fauna and flora) will be measured in each quadrant, selected on the basis of their suitability as markers of change within the ecosystem. Suitability will be determined via desk study on the basis of range of parameters, including:

- Presence of Taxa/species within the *Laminaria* biotope,
- Importance of the *Laminaria* biotope to life cycle requirements of the Taxa/species,
- Sensitivity to alterations of disturbance to *Laminaria* sp.,
- Duration of life cycle,
- Overall importance within the *Laminaria* biotope.

Presence of the Taxa/species within Bantry Bay will be determined during a number of preliminary dives, prior to beginning the survey. Additionally, standard MNCR phase 2 survey techniques will be carried out. Digital photographic and video records will be taken at each site during the survey.

(iv). Birds

A semi-quantitative assessment of seabird occurrence will be undertaken from the survey vessel while dives and survey is being carried out (seabird identification and enumeration).

(v). Statistical analysis

Statistical analyses will be carried out using appropriate statistical software such as Primer which will be used to analyse community structure as well as to describe species assemblages and biotopes at control and harvest sites. Statistical comparisons will be made between the control (unharvested) and data generated in year 1 with data from the harvested areas generated in year 3 and 5 post harvest. The statistical analysis will include tests such as analysis of variance (ANOVA), univariate, multivariate analysis or other statistical methods deemed appropriate when assessing and comparing species abundance/relative abundance in test versus control. In addition, potential natural variations in *Laminaria* density and canopy height over time will be assessed in the control sites. Comparisons will be made between the test areas pre harvest (year 1) and post harvest (years 3 and 5).

(vi). Survey Schedule

Mar-Apr 2016 (pre-harvest):
Day 0: Organization and travel to site.
Day 1: preliminary assessment of site suitability
Days 2-4: Survey; Assessment of flora and fauna (inc. *Laminaria* sp.) – **Control & test (unharvested)**
Days 1-4: transfer of raw datasets and creation of database.

Mar-Apr 2019:
Day 0: Organization and travel to site.
Day 1: Survey; Assessment of flora and fauna (inc. *Laminaria* sp.) – **test (post harvest)**
Day 2: Survey; Assessment of flora and fauna (inc. *Laminaria* sp.) – **test (post harvest)**
Day 3: Survey; Assessment of *Laminaria* sp. density and canopy height – **Control (unharvested)**
Days 1-3: transfer of raw datasets and creation of database.

Mar-Apr 2021:
Day 0: Organization and travel to site.
Day 1: Survey; Assessment of flora and fauna – **test (post harvest)**
Day 2: Survey; Assessment of flora and fauna – **test (post harvest)**
Day 3: Survey; Assessment of *Laminaria* density and canopy height – **Control (unharvested)**
Days 1-3: transfer of raw datasets and creation of database.

(vii). Reporting Schedule

Analysis of data: 0-4 weeks post survey. Writing
and submitting report: 4 weeks.

(viii). Fish species:

Objectives:

Specific sampling work objectives of fish community studies are to:

1. Year 1 (control):
   - Kelp area: generate baseline data for under canopy and over canopy areas. This will include identification of species, enumeration and determination of size frequency.
   - Non-kelp area: repeat the above.
2. Year 3 and 5 (test):
   - Kelp area: as above.

Sampling design will aim to collect data in relation to:

- Under canopy species (e.g. Gobies, *Gobiusculus flavescens).*
- Over canopy species within the pelagic zone.

Timing of sampling:

Sampling of fish will take place once in Mar-Apr of year 1 (control - forested, unharvested), once in Mar-Apr of year 3 (test - forested, harvested) and once Mar-Apr of year 5 (test - forested, harvested). Statistical comparisons will be made to assess the potential for changes in fish numbers over a 5 year period.

Methodology:

Sampling of fish will take place in clearly defined harvested and non-harvested areas, using non-destructive methodologies where possible/feasible. Sufficient buffer zones will be applied between harvested and non-harvested areas (e.g. ≥30meters). Where necessary, test and control tracts may be increased in size to ensure that the distance to be travelled for each trawl is sufficient to ensure that trawls operate effectively. Additionally, sampling may take place within larger representative harvested and unharvested zones if deemed necessary.

Under Canopy species

In year 1, under canopy species (e.g. Gobies, *Gobiusculus flavescens)* will be assessed. The sampling method will involve fyke sets positioned on the seabed for 48 hours at a total of 4 control locations. Species will be taken from the nets identified and enumerated before release. In year 3 and 5, this assessment will also be carried out in the post harvested test area.

Over Canopy species

The following procedures and equipment to be employed may be subject to change if deemed necessary in the course of the survey:

- Over kelp canopy species will be assessed by trawling fish nets (~10mm mesh) above the kelp canopy, within the pelagic zone.
- Trawl net length: 1.0-5.0 meters.
- Trawl mouth width: 1.0-5.0 meters.
- Trawl duration: 4-20 minutes
- Distance travelled for each trawl: 50-200m.
- The trawling period will be long enough and at appropriate speed to capture fish.
- In year 1, there will be 4 hauls in each of the n=4 control areas. On retrieval of nets, specimens will identified, measured and enumerated. In year 3 and 5, this procedure will also be carried out in the n=4 post-harvested test areas.

Replicate numbers:

The protocol includes n=4 control sites and n=4 test sites:

- Control site 1 (forested, unharvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 1.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).
- Control site 2 (forested, unharvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 1.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).
- Control site 3 (forested, unharvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 1.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).
- Control site 4 (forested, unharvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 1.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).
- Test site 1 (forested, harvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 3 and 5.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).
- Test site 2 (forested, harvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 3 and 5.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).
- Test site 3 (forested, harvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 3 and 5.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).
- Test site 4 (forested, harvested):
  - Located in a single subsite selected from Area A, B, C, D or E.
  - Assessed in year 3 and 5.
  - Under canopy species: two strings of fyke nets (gangs of 3 nets)
  - Over Canopy species: n=4 hauls of pelagic trawl (~10mm mesh).

Data analysis and reporting

Parameters to be analyzed will include species type, abundance, size and catch per unit effort. Control and harvest areas will be compared statistically using methods such as multivariate analysis. The results of the analysis will be provided with the overall report.

Appendix 3 – complete lists of species and their occurrences in the licensed Areas

Table A 3.1. Summary of mean percentage cover of algal species found on rocks in each of five licenced areas in Bantry Bay (*n* =30), also shown are the calculated overall means and standard errors across all licensed areas (*n* = 150).

Algal species on rock	Taxon	Mean A	Mean B	Mean C	Mean D	Mean E	Overall Mean	Std Err.
Delesseria sanguinea	Rhodophyta	9.7	5.517	0.733	3	0.517	3.893	0.212
Phycodrys rubens	Rhodophyta	0.6	11.5	0.5	3.117	0.1	3.163	0.211
Plocamium cartilagium	Rhodophyta	0	1.15	0.467	0.767	0.717	0.62	0.037
Dictyota dichotoma	Phaeophyceae	1.567	3.4	3.217	2.317	1.8	2.46	0.120
Dictyopteris membranacea	Phaeophyceae	2.3	2.65	0.767	1.483	3.75	2.195	0.100
Cryptopleura ramosa	Rhodophyta	29.383	16.733	7.567	5.233	6.783	13.14	0.466
Hypoglossum hypoglosoides	Rhodophyta	0.167	0.417	0.050	0.117	0	0.15	0.022
Dilsea carnosa	Rhodophyta	0.1	1.683	0.033	0	0.183	0.4	0.041
Heterosiphonia plumosa	Rhodophyta	0.05	0	0	0.25	0	0.06	0.011
Laminaria sporelings	Phaeophyceae	0.25	0	0	0	0.067	0.063	0.013
Acrosorium venulosum	Rhodophyta	0	0.6	0	0.083	0	0.137	0.021
Pterothamnion sp	Rhodophyta	0	0	0	0.05	0.183	0.047	0.004
Brogniartella byssoides	Rhodophyta	0.017	0.033	0.233	0.183	0.183	0.13	0.012
Callophyllis laciniata	Rhodophyta	2.267	2.217	0.367	1.768	0	1.318	0.058
Trailliella intricata	Rhodophyta	0.333	0	3.817	3.6	0.25	1.6	0.102
Desmarestia ligulata	Phaeophyceae	0.383	0.017	0	0	0.733	0.227	0.032
Desmarestia aculeata	Phaeophyceae	1.567	5.55	0	0	0.083	1.44	0.172
Saccharina latisima	Phaeophyceae	0	1.583	0	0	0	0.317	0.045
Kallymenia reniformis	Rhodophyta	0.217	0.2	0	0.083	0	0.1	0.013
Polyneura	Rhodophyta	0.133	0	0	0	0.033	0.033	0.005
Alaria esculenta	Phaeophyceae	0.167	0	0	0	0.033	0.04	0.011
Saccharina polyschides	Phaeophyceae	0.05	0	0	0	0	0.01	0.002
Rhodophyllis divaricata	Rhodophyta	0.35	0	0	0	0	0.07	0.015
Kelp sporelings	Phaeophyceae	0.5	0	0.183	0	0.483	0.233	0.023
Halidrys siliquosa	Phaeophyceae	0.333	0.3	0	0	0	0.127	0.025
Phyllophora pseudoceranoides	Rhodophyta	0.05	0	0.05	0.533	0	0.127	0.016
Nitophyllum punctatum	Rhodophyta	0	0.117	0	0	0	0.023	0.005
Caliblepharis ciliata	Rhodophyta	0	0.3	0	0	0	0.06	0.013
Rhodomenia pseudopalmata	Rhodophyta	0	0	0.033	0	0.033	0.013	0.002
Rhodomenia sp.	Rhodophyta	0	0	0	0.133	0	0.027	0.004
Red sporelings	Rhodophyta	0	0	0	0.1	0	0.020	0.003

Table A3.2 Summary of mean percentage cover of faunal species/groups on rock surfaces recorded in quadrats in each of five licenced areas in Bantry Bay (*n* =30), also shown are the calculated overall means and standard errors across all licensed areas (*n* = 150).

Faunal species (covering rock surfaces)	**Mean A**	**Mean B**	**Mean C**	**Mean D**	**Mean E**	**Overall Mean**	**Std Err.**
% *Spirobranchus* spp.	1.617	3.567	2.05	0.85	1.266	1.87	0.132
% Orange sponge	0.133	0.083	0.033	0.216	0.166	0.126	0.008
% White sponge	0	0	0.1	0	0.133	0.046	0.004
% *Cliona cellata*	0.067	0.2	0.333	1.689	1.25	0.701	0.044

Table A3.3 Summary of mean percentage cover of algal species/groups recorded on stipes in quadrats in each of five licenced areas in Bantry Bay (*n* =60), also shown are the calculated overall means and standard errors across all licensed areas (*n* = 300).

Species on stipes	**Taxa**	**Mean A**	**Mean B**	**Mean C**	**Mean D**	**Mean E**	**Overall Mean**	**Std Err.**
Sporelings	Phaeophyceae	0.21	0	0	0	0	0.042	0.0335
Phycodrys rubens	Rhodophyta	27.42	28.78	19.17	42.55	20.17	30.20	1.4348
Membranoptera alata	Rhodophyta	1.18	1.79	1.53	2.35	1.54	1.85	0.2069
Cryptopleura ramosa	Rhodophyta	1.84	1.73	1.45	0.91	3.03	1.70	0.2775
Rhodymenia pseudopalmata	Rhodophyta	0.03	0.42	0	0.47	0.24	0.23	0.0744
Hypoglossum hypoglossoides	Rhodophyta	0	0.08	0	0.34	0	0.08	0.0300
Desmarestia aculeata	Phaeophyceae	0.08	1.17	0	0	0	0.25	0.1797
Brogniartella byssoides	Rhodophyta	0	0	0	0	0.008	0.002	0.0017
Palmaria palmata	Rhodophyta	0.22	0.08	0	0	0.08	0.14	0.0548
Delesseria sanguinea	Rhodophyta	0	0.51	0	0	0	0.10	0.0998
Plocamium cartilagium	Rhodophyta	0	0.32	0.08	0	0.23	0.49	0.1396
Callophyllis laciniata	Rhodophyta	0.80	0.74	0	0	0	0.31	0.0768
Phylophora pseudoceronoides	Rhodophyta	1.07	1.10	1	0.48	1.87	1.007	0.1842
Phyllophora crispa	Rhodophyta	0	0.19	0	0	0.07	0.05	0.0232
Desmerestia ligulata	Phaeophyceae	0	0.008	0	0	0	0.002	0.0017
Lomentaria articulata	Rhodophyta	0	0	0	0.05	0	0.01	0.0040

Table A3.4 Summary of mean percentage cover of covering species (algal & faunal) recorded on holdfasts of *Laminaria* in quadrats in each of five licenced areas in Bantry Bay (*n* =30), also shown are the calculated overall means and standard errors across all licensed areas (*n* = 150).

Species on holdfasts	**Mean A**	**Mean B**	**Mean C**	**Mean D**	**Mean E**	**Overall Mean**	**Std Err.**
% Bare holdfast	47.33	0	16	11.80	12.37	17.62	0.564
% Bryozoans Enc.	10.20	5.77	6.72	15.20	7.80	9.14	0.212
% Crisiids	14.48	21.87	48.67	37.17	38.53	32.14	0.636
% Coralline crusts	14.47	9.57	13.58	13.67	16.57	13.57	0.266
% Sponges	0	0.05	0	0	0	0.01	0.002
% Ascidians	0	0.02	4.03	5	0	1.81	0.116
% Other algae	9.25	8.30	5.47	6.50	13.77	8.66	0.303

Table A3.5 Summary of count data of all faunal species recorded in quadrats in each of five licenced areas in Bantry Bay (*n* =30), also shown are the calculated overall means and standard errors across all licensed areas (*n* = 150).

Faunal species on benthos (Counts of individuals)	**Taxa**	**Mean A**	**Mean B**	**Mean C**	**Mean D**	**Mean E**	**Overall Mean**	**Std Err.**
Cancer pagurus	Arthropoda	0	0	0	0	0.033	0.007	0.002
Palaemon serratus	Arthropoda	0	0	0	0.233	0.233	0.093	0.011
Necor puber	Arthropoda	0	0	0.033	0.033	0	0.013	0.003
Liocarcinus depurator	Arthropoda	0	0	0	0.067	0	0.013	0.003
Botryllus schlosseri	Ascidiacea	0	0	0	0.017	0	0.003	0.001
Haliclystus auricula	Bryozoa	0.033	0	0	0	0	0.007	0.002
Taurulus bubalis	Chordata	0	0	0	0.1	0.033	0.027	0.004
Symphodus melops	Chordata	0.467	0	0	0.033	0	0.1	0.021
Chirolophis ascanii	Chordata	0	0	0	0.033	0	0.007	0.002
Ctenolabrus rupestris	Chordata	0.167	0	0	0.033	0	0.04	0.005
Gobiusculus flavescens	Chordata	0	0	3.567	0.033	0.133	0.747	0.073
Labrus mixtus	Chordata	0.033	0	0.067	0	0	0.02	0.004
Labrus bergylta	Chordata	0.067	0	0	0	0	0.013	0.003
Parablennius gattorugine	Chordata	0.033	0.133	0	0	0	0.033	0.005
Parablennius gattorugine	Chordata	0.133	0.067	0	0	0	0.04	0.006
Gadus morhua	Chordata	0	0	0.067	0	0	0.013	0.003
Caryophyllia smithii	Cnidaria	0.083	0.017	0.033	0.217	0.45	0.16	0.011
Corynactis viridis	Cnidaria	0.2	0	0.533	0	3.05	0.757	0.069
Anemone viridis	Cnidaria	0	0	0.3	0	0.333	0.127	0.011
Asterina sp.	Cnidaria	0.033	0	0	0	0	0.007	0.002
Henrica sanguinolenta	Cnidaria	0.233	0	0	0	0	0.047	0.007
Urticina felina	Cnidaria	0	0	0.033	0	0	0.007	0.002
Sagartia elegans	Cnidaria	0	0	0	0	0.033	0.007	0.002
Aglaophenia tubulifera	Cnidaria	0	0	0	0	0.017	0.003	0.001
Asterias rubens	Echinodermata	5.5	1.7	4.867	5.067	4.467	4.32	0.142
Marthasterias glacialis	Echinodermata	0.333	0.1	0.5	0.2	0.333	0.293	0.013
Echinus esculentus	Echinodermata	0.633	0.133	1.033	0.633	0.833	0.653	0.022
Luidia ciliaris	Echinodermata	0	0	0.067	0	0	0.013	0.003
Holothuria forskali	Echinodermata	0	0	0.033	0	0	0.007	0.002
Antedon bifida	Echinodermata	0	0	0	0	2.633	0.527	0.064
Calliostoma ziziphinum	Mollusca	0.033	0.067	0.067	0.1	1	0.253	0.017
Gibbula cineraria	Mollusca	0	0.467	0	0.2	0	0.133	0.014
Gibbula tumida	Mollusca	0	0.033	0	0	0	0.007	0.002

Appendix 4 – Supplementary data on kelp lengths and age (June 2017)

In June 2017, an additional trip was made to Bantry Bay to estimate for each of the five licensed areas, the average total lengths of kelp plants and the lengths of their stipes and fronds. The ages of a sample kelp plants in each of the five licensed areas were also assessed. The methodology employed and results of the assessment are described below.

Methodology:

a) In each licensed area, randomly select 30 kelp plants from the combined areas of the experimental and control tracts.
b) Detach these plants (including as much of the holdfast as possible to facilitate age estimation) and bring them to the surface.
c) For each plant, use a tape measure to measure the total length and the length of the stipe and of the fronds.
d) Take the lower stipe and holdfast of each plant so that it can be brought back to the laboratory in UCD for processing to estimate age following the methodology of Kain JM (1963) Aspects of the biology of *Laminaria hyperborea*. II Age, weight and length. *J Mar Biol Ass UK* 43: 129-151.

Results:

1. Lengths of kelp plants

Canopy heights in the licensed area were estimated in the original survey (September 2016) and data are provided in the main report. Average total lengths of kelp plants varied from 130 cm to 175 cm in the different licensed areas, with the minimum and maximum values arising in Areas A and E respectively (Table 1). The longest individual plant was 250 cm long and the shortest was 57 cm. On average, the ratio of stipe to frond was 0.66, ranging from 0.23 to 1.69. The average length of stipes was 55 cm and the average length of fronds was 90 cm. There was some variation in the relative lengths of stipes and fronds among areas (Table 1).

2. Age of kelp plants

In applying the methodology described by Kain (1963), 70% of individuals could be aged to the nearest year without any uncertainty. In the other 30%, there was some doubt because one of the growth lines was unclear. In those cases, the highest possible number of years was used in summary data. For example, if it was unclear whether a plant was two years old or three, it was taken to be three years old in calculating the average age for the Area. Quality control was undertaken by obtaining two independent estimates of age for a subset of 10 individuals. There was agreement in each case.

The average age of kelp in the Areas sampled was 3.4 years. There was some variation among Areas, with the average age varying from 2.97 (Area D) to 3.80 (Area E). In each of the Areas, only a few individuals were 5 years old (6 in Area A, 4 in Area D, 2 in Area E and

1 in Area C). In each of Areas C and E, a single individual was found that was 6 years old. All other individuals (89%) were 4 years old or less.

Table 1. Summary of data on length and age of 30 individual kelp plants sampled randomly in each licensed Area in June 2017.

Area		Length of stipe (cm)	Length of frond (cm)	Total length (cm)	Ratio of stipe to frond	Age (years)
A	**Average**	**52.83**	**77.07**	**129.91**	**0.70**	**3.44**
	Min	21.00	36.00	57.00	0.37	1.00
	Max	85.50	134.00	185.00	1.08	5.00
	Stdev	20.28	23.21	36.80	0.24	1.19
B	**Average**	**50.22**	**92.09**	**142.30**	**0.55**	**3.61**
	Min	18.00	60.00	92.00	0.23	2.00
	Max	92.00	129.00	194.00	0.90	6.00
	Stdev	19.45	16.67	29.74	0.20	0.85
C	**Average**	**57.47**	**84.87**	**142.33**	**0.69**	**3.20**
	Min	17.00	33.00	76.00	0.24	1.00
	Max	90.00	120.00	203.00	1.30	5.00
	Stdev	21.42	20.84	36.52	0.26	0.89
D	**Average**	**46.57**	**97.17**	**143.73**	**0.48**	**2.97**
	Min	25.00	62.00	105.00	0.31	2.00
	Max	72.00	142.00	214.00	0.77	5.00
	Stdev	11.24	19.80	28.77	0.10	0.93
E	**Average**	**79.53**	**95.63**	**175.17**	**0.85**	**3.80**
	Min	25.00	61.00	105.00	0.31	2.00
	Max	130.00	128.00	250.00	1.69	6.00
	Stdev	25.21	17.80	34.05	0.30	1.00
Overall	**Average**	**57.41**	**89.62**	**147.03**	**0.66**	**3.39**
	Min	17.00	33.00	57.00	0.23	1.00
	Max	130.00	142.00	250.00	1.69	6.00
	Stdev	23.02	20.79	36.12	0.26	1.01