Plymouth Sound and Estuaries SAC: Kelp Forest Condition Assessment 2012. Final report

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1 EXECUTIVE SUMMARY

The Plymouth Sound and estuaries SAC has a rich diversity of fauna and flora that is protected by European Law. Natural England has a statutory duty to periodically assess the condition status of the SAC and since kelp forests are a sub-feature of the SAC these must be incorporated into this process.

Based on methodology used in previous monitoring surveys for this site, Ecospan Environmental Ltd has developed what is intended to be a highly cost efficient method for surveying the kelp forest and red algal understory communities. The methodology for determining the abundance of the kelp species was identical to that used in previous years. However, the sampling strategy differed to improve the degree in which the results were representative of each site as a whole and to provide a statistically robust design within the required budgetary constraints (as determined by Natural England's suggested length of the survey period for this project). The method for assessing the red algal community structure differed from that used previously in that photo-quadrats and a reference collection of pressed plants were used to identify the species present and their percentage cover in each transect rather than this being carried out underwater.

Ecospan Environmental Ltd conclude that the methodology used in this survey should be very effective in meeting the aims of the long term monitoring as determined by Natural England. The use of photo-quadrats requires a high standard of digital photographic equipment and surveyors who are capable of using it; as well as the services of a skilled taxonomist to undertake the species identification. After the initial survey period, a consistent structure for taking the photographs at each quadrat was developed which markedly increased the quality of the data.

The condition of the kelp forest and under storey red algae were assessed at 5 locations within Plymouth Sound using 3 transects of 10 quadrats (for the kelp, 5 for the red algae) at each location (except Duke Rock where 4 transects were surveyed). The surveys were undertaken in mid-August and early September 2012. As well as using 0.25 m^2 photo-quadrats for assessing red algal community structure, the abundance of kelp species was assessed in 1 m^2 quadrats. The abundances of the colonial sea-squirt *Distomus variolosus* and the sea urchin *Echinus esculentus* were also measured, as was the presence of the non-native species: *Undaria pinnatifida (*Wakame*)*, *Sargassum muticum* (Wire weed) and the pacific oyster *Crassostrea gigas.* None of these non-native species were observed in 2012.

The most common species of kelp within the areas surveyed was *Laminari. hyperborea* which was the dominant kelp species on all transects except those at Duke Rock and one at the Mewstone where it was completely absent. The southern species of kelp *Laminaria ochroleuca* has now replaced *L hyperborea* at transects on Duke Rock However, on transects outside the Sound only a single *L. ochroleuca* plant was found despite this species having dominated the transect at Penlee Point in 2003. Furbellows (*Saccorhiza polyschides*) was present at low densities at most sites with the exception of one transect at the Mewstone on which it was the only species found. Sugar kelp (*S. latissima*) was found at moderate densities on transects at Duke Rock. The overall density of plants (all species combined) remained the same or slightly higher on all transects for which previous data was available.

A highly diverse community of under-storey red algae was encountered throughout the survey area with a surprisingly similar community structure between all transects (given the variation in exposure, tidal streams, suspended solids and geographical separation). An analysis of transects on which there existed baseline data from previous years, suggested that although the community structure varied significantly from year to year, this was primarily due to a change in the relative proportions of the species present rather than different species being observed in different years. The overall % coverage at most sites remained within the range previously encountered and the diversity at each site was found to be almost identical.

The colonial sea-squirt *Distomus variolosus* was not widely found throughout the survey area with the exception of two transects at Cavehole point on which it was found in approximately 60% of the quadrats surveyed. Since no baseline data exists for this attribute, it could not be determined whether this attribute was in a favourable condition.

In terms of the condition assessment of the kelp forest sub-feature of the SAC, the evidence obtained within the report suggest that attributes on which there were previous data are likley to be in favourable condition.

2 INTRODUCTION

Plymouth Sound and its associated tributaries hold a number of national and international designations. The areas within European Sites (Special Area of Conservation (SAC) and Special Protection Area (SPA), which are covered by tidal waters at any time are collectively referred to as a European Marine Site (EMS) and protected by national and international legislation.

The Plymouth Sound and Estuaries SAC has a rich diversity of southern flora and fauna and a variety of different habitats due to the variations in wave exposure, water depth, rock and sediment types, salinity and tidal streams. Plymouth Sound and Estuaries qualifies as a SAC for the following Annex 1 habitats as listed in the EU Habitats Directive:

- Large shallow inlets and bays
- Estuaries
- Sandbanks which are slightly covered by seawater all the time.
- Inter-tidal mud and sandflats
- Reefs
- Atlantic Salt Meadows

One feature of the SAC is 'Large shallow inlets and bays' of which 'kelp forests' are a sub-feature. The dominant species is *L. hyperborea* with other kelp species such as the southern species *L. ochroleuca* in places, and a wide variety of often dense red algae and sponges.

Kelp forests are considered to be of conservation for the following reasons:

- Kelp plants are major primary producers in the UK marine coastal habitat.
- Kelp often dominates communities in the infralittoral zone.
- Kelp detritus and dissolved organic matter are exported from kelp beds and support ecosystems on soft bottoms.
- Kelp plants structurally support a diverse epiflora and epifauna.
- Kelp beds are dynamic ecosystems where competition for light, space and food result in the species-rich, but patchy, distribution patterns of flora and fauna on infralittoral reefs.

Natural England has a statutory duty to periodically assess the condition of the SAC and consequently, since the kelp forests are an important sub-feature, these are incorporated within the process. The relevant part of Natural England's advice under Regulation 33 (1) that relates to the kelp forest is shown in the Favourable Condition Table (Table 1).

TABLE 1

Plymouth SAC Kelp forest favourable condition table

Sub-feature	Attribute	Measure
Kelp forest communities	Algal species composition	Presence and abundance of composite of algal species from kelp zone. Measured during summer, twice during reporting cycle.
	Characteristic species - *Laminaria hyperborea* & *L. ochroleuca* - population size	Relative proportions and density of each species in kelp forests at representative series of sites. Measured during summer, twice per reporting cycle.
	Characteristic species *Distomus variolosus* population size	Average abundance on kelp stipes (percentage of stipe length over which present and density of cover (measured twice during reporting cycle)

The kelp forest sub-feature last underwent condition assessment in 2003 (2). For this reason, Natural England commissioned Ecospan Environmental Ltd to undertake a condition assessment of the kelp forest within the SAC in the summer of 2012. The overarching aim of this project was to obtain standardised biological information for the kelp forest habitats and communities of the Plymouth Sound and Estuaries EMS and to assess the condition of the kelp forest sub-feature of the SAC against previous survey data.

3 OBJECTIVES

The objectives of this assessment were:

- To develop a cost effective sampling strategy to allow the condition of the kelp forests to be assessed against the relevant attributes (shown in Table 1) using Common Standards Monitoring Guidance which also allows for a comparison with previous survey data.
- To provide an ecological baseline of attribute condition (from which to assess future change) where this does not exist.
- Where possible, to provide an assessment of the direction of ecological change by the integration of previously obtained relevant data.
- To develop a statistically robust survey design to enable quantitative long term trend analysis within the required budget.
- To allow anthropogenic influences, impacting on the ability of the sub-feature to achieve Favourable Condition, to be identified and where possible quantified.
- To record the presence and abundances of any non-native species such as *Undaria pinnatifida*, *Sargassum muticum* and *Crassostrea gigas* across the survey area.

4 SAMPLING STRATEGY

The sampling effort and methodology is based on the Plymouth Sound and Estuaries European marine site diving survey undertaken in 2003[2]. In 2003, a variable number of randomly allocated quadrats were taken from a single 10 m long transect in each of three sites (Duke Rock, Penlee Point and the Mewstone) to assess the kelp and red algal abundance and distribution in each area,. A further transect at Duke Rock was also surveyed. The total sampling effort for the SAC was fifty four 0.25 m^2 quadrats for red algal abundance and identification and sixty two 1.0 m^2 quadrats for the kelp determination. This enabled a precise (high number of replicates within each transect) but inaccurate (low replication with only three sites surveyed, only one of which had more than one transect within it) determination of the kelp feature within the SAC as a whole.

The sampling strategy and results from the previous surveys of the SAC were reviewed by Ecospan Environmental Ltd prior to the submission of the tender for the work. A statistical comparison of previous results (data was only available for red algae) at each site between years consistently showed a highly significant difference between data from different years. Obviously, this could be due to a significant change in the flora community structure between years. However, it was considered that it was probable that, at least in part, the reason for the statistical differences observed was the high degree of precision and low accuracy of the sampling strategy previously employed.

This is particularly pertinent in view of the patchy distribution of kelp and red algal communities that is commonly exhibited within an area (e.g. Penlee Point). This means that each quadrat is not independent of each other if considered at the area level (although they will be at the transect level). In layman's terms, having up to 25 quadrats within a 10m by 2m transect was not considered a very accurate estimation of the community structure of, for example, red algae at the Mewstone (an area well in excess of 450,000 m^2). For these reasons, the statistical comparison between data from Duke Rock and the Mewstone is limited to a comparison between the transects rather than the kelp abundances in the areas (i.e. kelp at Duke Rock compared to kelp at the Mewstone).

Due to the patchy distribution of algal species within an area, the quadrats are dependent on the location of the transect and therefore the transect will need to be in exactly the same place in future years for any valid comparison to be made. Prior to 2000, the accuracy of a GPS position was poor (c.50m) unless a differential signal was received from a land based beacon, since selective availability was not turned off until this year. Since 2000, the accuracy has improved from +/- 20 m to +/- 5m today. Consequently prior to 2000 the transects could have been up to 100m away from each other and, even today, using a standard DGPS set, could be the length of a transect (10 m) apart (this is assuming that the skipper drops the shot exactly on the marked position). The validity of previous transect comparisons, is therefore highly questionable. If multiple transects had been made on each area, the validity would be higher since the number of replicates per area would be increased and the accuracy of the data improved.

Natural England had already understood the importance of sampling more areas within the SAC and had suggested this in the tender document. For all these reasons, Ecospan Environmental Ltd proposed that the number of sites surveyed was increased to 5 and that 3 transects of 5 quadrats were placed on each (5 quadrats for the kelp and 5 for the red algae). This compares to a single transect at all sites other than Duke Rock with a variable number of quadrats on each in previous surveys. The differences in sampling strategies are shown in Table 2.

TABLE 2

Sampling effort/strategy comparison 2003 v 2012

		2003 Survey		2012 Survey	
		Red algae	Kelp	Red algae	Kelp
No. of sites within the SAC		3	3	5	5
No of transects within a site		1*	1*	3**	3**
No of quadrats on each transect	Duke Rock	16 and 14	20 and 7	5	5
	Mewstone	12	25	5	5
	Penlee Point	12	10	5	5
	Tinker Shoal	0	0	5	5
	Cavehole Point	0	0	5	5
No of quadrats per site	Duke Rock	30	27	15	15
	Mewstone	12	25	15	15
	Penlee Point	12	10	15	15
	Tinker Shoal	0	0	15	15
	Cavehole Point	0	0	15	15
Total sampling effort (number of quadrats for the SAC)		54	62	75	75

* except Duke Rock which had two transects

** except Duke Rock which had 4 transects

It would clearly have been beneficial to increase the degree of replication still further (especially to increase the number of transects from 3 to 5 at each site to facilitate statistical comparisons between areas and years), but this would have substantially increased the survey time to well above that suggested in the tender document (it was already one day longer prior to the number of transects being increased from 2 to 3). The strategy employed during 2012 still enables comparisons between transects to be statistically analysed as in previous years (subject to the same constraints mentioned in the paragraphs above, although a survey standard DGPS was employed in 2012 with a sub-metre horizontal accuracy). However, by having multiple transects, an anlaysis of the data at one site between years can be made with more confidence. Since the number of replicates (transects) is below 5, the data cannot be tested using ANOSIM, but it can be visualised and analysed using other multi-variate techniques and over time any change in a particular director should become apparent.

5 METHODS

5.1 Overview

All fieldwork was undertaken by Ecospan Environmental surveyors and two divers from Natural England in two periods of diving which totalled 7 days. The first period of diving was from 11th– 14th August 2012 and the second from 4th-6th September. This was consistent with the sampling period in 2003 (4th – 15th August) and in the previous surveys (July – September). Diving operations were undertaken from Ecospan Environmental's MCA Cat 3 coded catamaran *Coastal Surveyor.* Positioning was provided by a survey quality DGPS (Hemisphere R320) which provides sub-metre accuracy and was linked to *Seapro* navigational software.

Three 10 m transects were laid at each of five sites within the kelp biotope within the Plymouth Sound and Estuaries SAC. To minimise the effects of pseudo-replication, each transect was separated by at least 100m except for those at Duke Rock (due to the small size of this site). Three of the sites to be surveyed (Duke Rock, Mewstone and Penlee point) had previously been surveyed by Howson *et al* in 2003 (2), whereas the remaining two (Tinker Shoal and Cavehole Point) had not previously been surveyed. The transect positions at Duke Rock 1 and Penlee Point 1 were within 1 m of the previous transect positions, whereas the one at the Mewstone was not as no kelp was encountered at the recoreded site position. Due to concern regarding the relatively sparse kelp cover experienced at one transect at Duke Rock, a fourth transect was undertaken at this site. The location of each site is shown in Fig. 1.

On each transect the following tasks were undertaken:

- Diver operated video recording of the entire transect. This was to provide an overview of the transect as a whole for reference in future years and to enable the presence or absence of less common or notable/invasive species to be determined.

- The relative proportions and densities of kelp species (*L. hyperborea*, *L. ochroleuca*, *S. latissima* and *S polyschides*) were determined using 1 m^2 stainless steel quadrats at 5 predetermined locations along each quadrat. Each quadrat was uniquely labelled and a digital photograph of each quadrat taken using a high quality digital stills camera.

- The abundance of the lesser gooseberry sea squirt *Distomus variolosus*, was determined whilst undertaking the 1 m^2 quadrats. The metric used was percentage cover of the first 50 cm of the stipe.

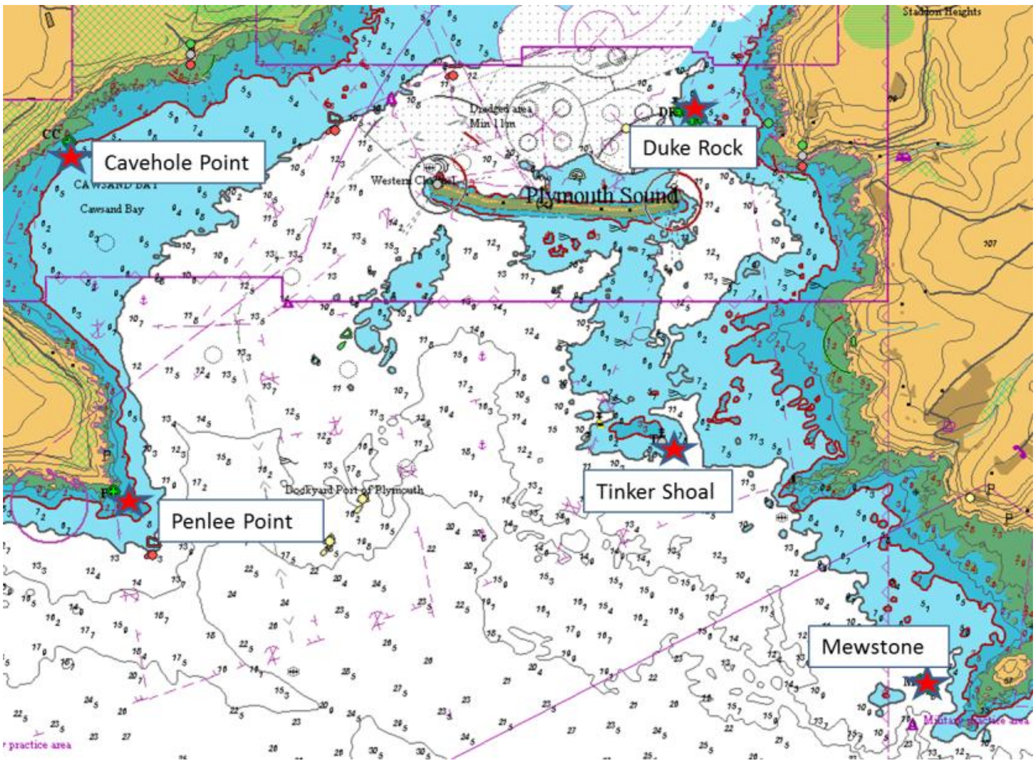
- The presence and abundance of red algal species within the kelp zone was assessed using five 0.25 m^2 quadrats per transect. The species composition and abundance (% cover) was determined from a combination of photo-quadrats and the collection of voucher specimens for pressing. These were analysed by an expert in marine algal identification and biology.

- The water depth (and time to enable the depths to be converted to depths relative to chart datum), average underwater visibility and current were also recorded on each transect.

- From 14^{th} August onwards (after 8 transects), it was decided that the abundance of the sea urchin *Echinus esculentus* would also be assessed. This was due to the well-known potential impact of this species on kelp (particularly recruitement[(3)]). This was determined by counting the number of individuals present in an area one metre either side of the 10 m transect (20 m^2).

FIGURE 1

Kelp assessment sites within the Plymouth Sound and Estuaries SAC



5.2 Diving Practices

All diving was carried out under the HSE's Scientific and Archaeological Approved Codes Of Practice (ACOP)[4]. All divers wore positive pressure AGA masks equipped with through water voice communications and were commercially trained (HSE part IV or Professional SCUBA). This was primarily for safety reasons (and to fully comply with the ACOP), but also reduces the burden on the diver and improves the quality of the data produced. A project plan and risk assessment was produced in advance of the survey and issued to Natural England as well as to all divers. All diving also followed Ecospan Environmental Ltd.'s generic risk assessment for diving operations (RA-DS-01). Two pairs of divers were used at for each transect. The first pair laid the transect out along the depth contour and undertook the kelp and video survey, whilst the second pair undertook the survey of under-storey red algal communities on the same transect.

5.3 Quality Assurance

Ecospan Environmental Ltd Ecospan has an ISO9001 accredited management system to ensure that we work to the high standards expected by our customers. We undertake all work in accordance with standard operating procedures (SOPs) and recognised national/international guidelines. Ecospan is also UVDB verified under Achilles services who regularly audit management systems for health, safety, environment, quality and best practices. Identification of preserved samples of marine organisms is carried out in house by Ecospan Environmental Ltd which is an NMBAQS accredited laboratory.

All divers used on this project were qualified and experienced marine biologists although none specialise in marine macroalgae. A project plan detailing the methodology to be used during the project was issued to all divers in advance of the first day's diving. This ensured that all of the survey team understood the aims of the survey and the methods that were going to be employed. Prior to the first dive, all divers were asked if they understood what they were supposed to be doing and any queries were discussed. The tasks assigned to each pair of divers were also made clear. A detailed pro-forma project notebook had also been prepared in advance of the survey to act as an aid memoir and also to record the data from the dive and more general information as required by Ecospan's SOPs and international guidelines. All divers were made familiar with this project notebook to ensure that it was filled in satisfactorily. The project notebook was reviewed by the project manager after every dive and any points of interest or omissions raised and rectified.

Both digital still and video photography were used on this project. Whilst Ecospan's divers were familiar with these, Natural England's divers had not used the same models of camera before. To overcome this, all divers were briefed on the use of the cameras and the cameras were set to what was expected to be an appropriate setting prior to the dive. All stills and video footage were reviewed by the project manager every evening for quality control purposes and changes made if thought appropriate (this lead to the most experienced operator of the stills camera being responsible for the red algae photo-quadrats after the second days diving). Additionally, after the first diving period, the stills for the photo-quadrats were reviewed by Dr Wells (the person responsible for the identification and enumeration of the red algae). At this stage any transects with photographs that were considered too poor were noted and repeated during the subsequent diving period.

A reference collection of pressed red algae was also produced during this project and sent to Dr Wells with the photographic stills to aid identification. Representative specimens were taken from each quadrat, given a unique identifier and then pressed. Only those specimens that had not been encountered previously were pressed, but the quadrats in which each reference specimen was found were noted (so that one specimen would usually have several numbers attached to it).

5.4 Transect (station) location

There was some confusion over the exact co-ordinates of those transects that had been previously surveyed in 2003 (2). This was due to an inconsistent method of recording the co-ordinates and the lack of a stated datum (OSGB or WGS 1984). In Plymouth Sound, the difference between these two datums is over 100 m. For this reason, both potential points were investigated prior to diving using an echo-sounder and local knowledge. The site that most accurately reflected the previous description was then selected. For transect DR1 and PP1 these positions were taken as the WGS 1984 positions, for DR2 this was the OSGB position and for the Mewstone neither position seemed to have kelp . All positions during the 2012 survey were recorded in WGS 84. The starting co-ordinates of each transect are shown in Table 3. The transect start positions are also shown in a chart format in Fig. 2.

TABLE 3

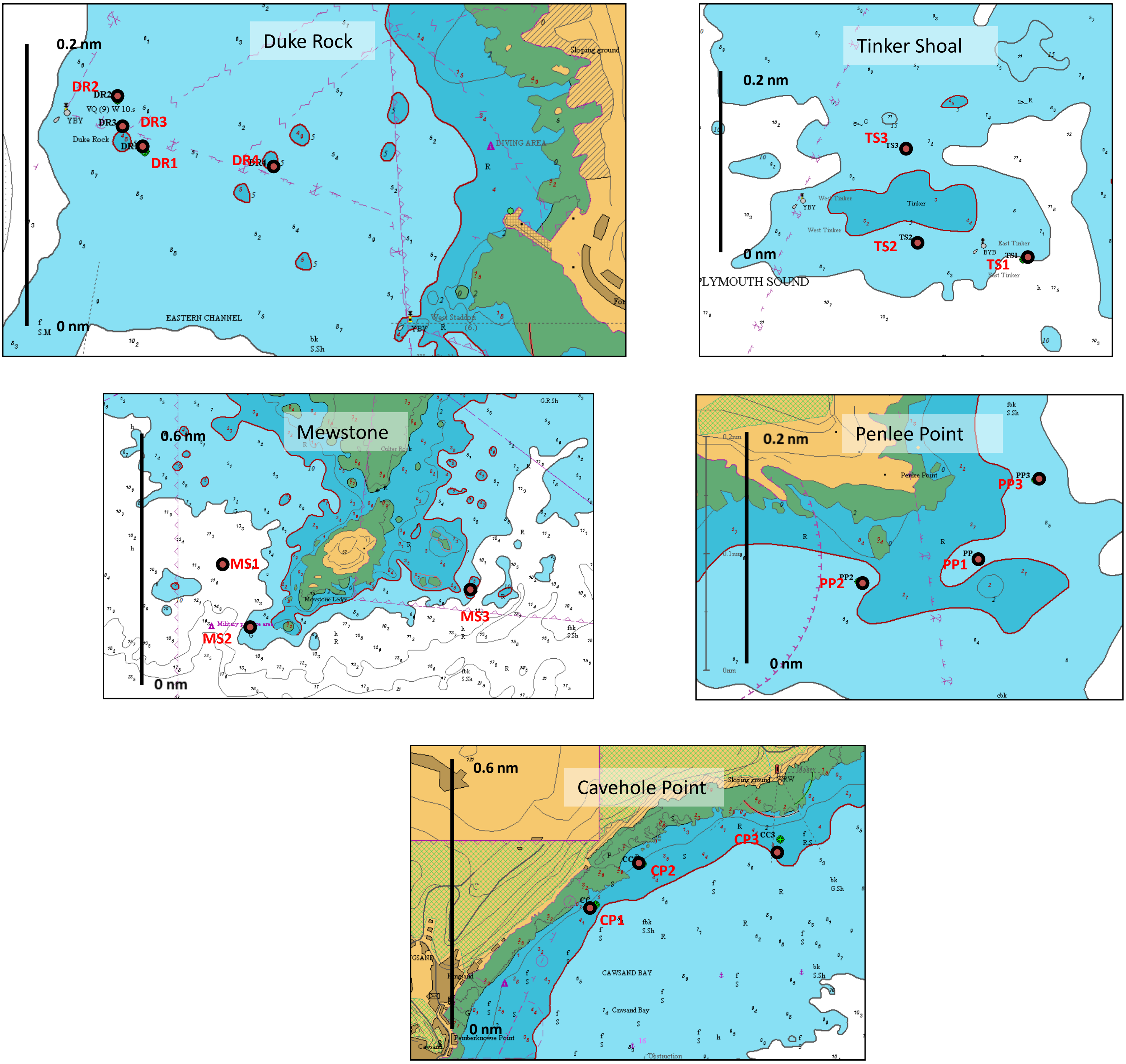
Transect starting positions at each site 2012

Kelp assessment site	2012 Transect Number	2003 transect name	Lat	Long	Depth (m) below CD 2003	Depth (m) below CD 2012
Duke Rock	DR1	Duke Rock	50.3382	-4.1356	4.0 - 7.5*	6.9
	DR2	Duke Rock South	50.3388	-4.1362	5.3	8.6
	DR3		50.3385	-4.1361		7.0
	DR4		50.3380	-4.1332		5.6
Tinker Shoal	TS1		50.3198	-4.1372		12.3
	TS2		50.3201	-4.1405		9.0
	TS3		50.3219	-4.1409		12.0
Mewstone	MS1	Mewstone	50.3066	-4.1150	12 - 15.5	14.1
	MS2		50.3041	-4.1131		7.4
	MS3		50.3055	-4.0986		11.8
Penlee Point	PP1		50.3167	-4.1869	7.5	5.9
	PP2	Penlee Point	50.3163	-4.1897		5.5
	PP3		50.3178	-4.1856		8.9
Cavehole Point	CP1		50.3369	-4.1920		4.9
	CP2		50.3385	-4.1892		3.8
	CP3		50.3394	-4.1809		5.1

* Two transects carried out on the same position one 4.0 - 4.5 m below CD and the other 6.0 - 7.5 m below CD

FIGURE 2

Chartlets showing the starting positions of each transect



5.5 Video Transects

Following their decent down the shot line, the divers positioned the transect line along a depth contour and pulled it tight. The whole transect area was then recorded on high quality digital video (JVC Everio in Seapro housing lit with a Fisheye 500 LED video light). The approximate abundance of large macro-algal species was noted using the SACFOR scale. In particular the presence and abundance of less common algal species and notable species (e.g. *Undaria pinnatifida*, *Sargassum muticum*, *Crassostrea gigas* was recorded where encountered). Relevant information was relayed to the surface via the voice communications. The focus of this assessment was species that were not going to be assessed during the quadrat phases of the work (i.e. this did not include red algae).

5.6 Kelp Species Composition

Five 1 m^2 quadrats, allocated on randomly assigned pre-determined positions along a marked transect line, were assessed for the relative abundances of the four kelp species likely to be encountered (*L. hyperborea*, *L. ochroleuca*, *L. saccharina*, *Saccorhiza polyschides*). The quadrats were randomly assigned using the same method as that used in 2003. The transect was marked at 1m intervals and random numbers generated from 0 – 21. Numbers from 0 - 10 corresponded to locations at metre intervals on the left side of the transect and 11 – 21 corresponded to those on the right side of the transect (e.g 2 would be 2 m along the left hand side and 12 would be 1 m along the right hand side). The kelp plants observed were grouped into mature plants, under-storey plants and sporelings for each species. Mature and medium sized plants were counted, whereas sporelings were recorded as percentage cover. Under-storey plants were defined as those where the frond, when held up, did not exceed the length of the stipe of the main canopy adults. Sporelings were categorised as the small plants that lay flat on the seabed.

FIGURE 3

Photograph of a 1 m^2 quadrat showing the quadrat number and density of the kelp

Non-gridded quadrats were used with one open side that allowed the quadrat to be fitted around the kelp plants. This was considered important due to the size and density of the kelp plants on many quadrats. Quadrats were placed, as far as was practical, on level rock. Where this was not possible, the quadrat was moved to the next random position. Each quadrat was uniquely labelled and a digital photograph of each quadrat taken using a digital stills camera (Sea and Sea 2G with external YS50 TTL flash). This is illustrated in Fig 3 which shows the quadrat (just visible on the centre right bottom margin), the unique number (16) and a high density of mature kelp (*L. hyperborea*) plants (in this instance at transect MS2).

5.7 Abundance of *Distomus variolosus*

Although often considered a southern species [(4)], *Distomus variolosus* has been recorded in west Sussex, south Devon and Cornwall, Lundy, Wales, Ireland, the Isle of Man and in the Outer Hebrides [(5)]. The reason for this species' inclusion as an attribute to be assessed as one of the parameters determining favourable condition of the kelp forest is because it is indicative of the supporting processes as it is sensitive to deviations in salinity and siltation.

The abundance of this sea squirt was relatively low. For this reason, following the first day's diving, it was decided that the abundance of *D. variolosus*, should be determined whilst undertaking the 1 m^2 quadrats. The metric used was the percentage cover of the first 50 cm of the stipe as this was the part of the stipe on which it was observed during this survey (see Fig 4).

FIGURE 4

Photograph of a typical colony of *D. variolosus* growing on the lower portion of a *L. hyperborea* stipe

5.8 Abundance of *Echinus esculentus*

From the 14th August onwards, it was decided to record the number of *Echinus* present on each transect. Due to the relatively large size of this organism, it is not usually found in large densities. For this reason its abundance was determined in a 20 m^2 area. This was achieved by counting the number of individuals 1 m either side of each 10 m transect. Assessments were made at all transects at Penlee Point, Cavehole Point and Tinker Shoal.

5.9 Algal species composition

The presence and abundance of red algal species within the kelp zone was assessed using five 0.25 m^2 photo-quadrats per transect. As for the kelp monitoring, the quadrat positions were pre-determined using random number tables. The photo-quadrat technique was thought to provide accurate and robust data. It has the potential advantage of reducing the specialist knowledge required by the diver surveyors and the elimination of inter-diver variability. It also has the advantage of generally having more accurate (and certainly more consistent) estimations of percentage cover although it may be that some smaller or under-storey species abundance estimates are under-recorded compared to other methods. It is obviously highly reliant on the quality of the photography.

Although this technique has not been widely used for this purpose in the UK, it is used by NMBAQCS for the quality control element of inter-tidal algae under the Water Framework Directive. It is also widely used in the field of coral biology. The prevalence of high quality (the camera used had a resolution of 12 megapixels) digital cameras has now greatly improved this technique as it is possible to electronically magnify any part of the picture several fold before the image pixelates. Indeed, it is possible to identify features that would not be readily visible to the naked eye. These advances greatly enhance the ability of the operator to identify small specimens compared to what was possible prior to the advent of digital photography or when cameras with a lower resolution are used.

After the first survey period, the technique was to take at least one vertical shot of the whole quadrat and then a vertical shot of each quarter working from top left to bottom left. Close up photographs of plants were also taken to aid identification and shots taken at an angle where plants were obscured by large individuals or by kelp.

Each quadrat was uniquely labelled and at least one photograph of the entire quadrat taken. Where required, multiple digital stills were taken. The information gathered from the photo-quadrats was supplemented by the taking of representative samples of seaweed from each quadrat. Representative samples from each quadrat were put into a uniquely labelled self-sealing plastic bag (see Fig 5). These samples were sorted on the surface and good specimens preserved by pressing within 48 hrs to provide a voucher specimen collection and to aid the identification in the photo-quadrats. Once pressed, the quadrat number was marked on the card together with the number of any other quadrats that contained the same species of algae. Due to variations in form, this resulted often resulted in multiple pressings for each species. To prevent deterioration, all algal samples were kept with a small amount of seawater in a zip lock bag and chilled (in a coolbox on the boat prior to being transferred to a refrigerator every evening) prior to processing. All samples were judged to be in as good a condition as when they were removed from the sea when processed.

FIGURE 5

Photograph of a diver taking red algal samples from a 0.25 m^2 quadrat

All photo-quadrats, along with the pressed algal specimens, were sent to Dr Emma Wells of Wells Marine Surveys who undertook the specialist algal identification required and also the determination of % cover for each of the species present.

6 RESULTS AND DISCUSSION

6.1 Weather, underwater visibility and working conditions

Unfortunately, in 2012 Plymouth experienced unseasonably adverse weather for most of the spring and summer with high winds heavy rain and the worst underwater visibility that the author has experienced in over twenty years of diving in Plymouth Sound. Strong ESE winds were experienced at the beginning of the first period of diving followed by light SW winds on the second and fourth day and strong southerly on the third day. This resulted in poorer visibility than is usually encountered at this time of year coupled with silty conditions on the bottom. A significant swell was also experienced at Tinker Shoal and on the Mewstone. The weather experienced during the second three days of diving was much more clement with light winds, sun and reasonably good visibility. A total of 37 dives were made during this survey

6.2 Kelp species composition

The species composition on each transect at each of the five sites surveyed is summarised in Table 4. The raw data for each quadrat is shown in Table 1 in the Appendix.

TABLE 4

Mean kelp abundance and standard error per m² by species at each transect

Taxon	DR1		DR2		DR3		DR4		TS1		TS1b		TS2		TS3	
	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
L. hyperborea (M)							1.2	1.0	4.8	1.4	7.6	0.7	7.8	1.6	2.4	1.1
L. hyperborea (US)							1.6	0.5	3.2	0.9	1.8	0.7	5.8	2.2	2.6	1.1
L. ochroleuca (M)	3.4	0.5	1.6	0.7	4.0	0.9	3.2	0.7								
L. ochroleuca (US)	1.8	0.9	1.4	0.6	1.6	0.7	1.4	0.2								
S. latissima (M)	0.2	0.2	3.2	2.3	0.6	0.4									0.2	0.2
S. latissima (US)	0.4	0.2					0.2	0.2								
S. polyschides (M)																
S. polyschides (US)									0.2	0.2						
% Sporlings per m^2			0.6	0.6			4.0	1.0	1.0	0.6	15.0	4.2	4.0	1.6	4.0	1.6

Taxon	MS1		MS2		MS3		PP1		PP2		PP3		CP1		CP2		CP3	
	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
L. hyperborea (M)	4.8	0.9	7.8	0.8			5.8	0.4	6.4	1.0	5.0	1.4	10.4	2.8	7.6	0.7	7.6	1.6
L. hyperborea (US)	3.2	1.2	5.4	0.9			1.8	0.7	3.8	1.2	0.2	0.2	1.8	0.5	1.0	0.3	1.6	0.7
L. ochroleuca (M)		0.2											1.2	0.5	0.4	0.2		
L. ochroleuca (US)									0.2	0.2			1.0	0.8	0.4	0.2		
S. latissima (M)													0.2	0.2				
S. latissima (US)																		
S. polyschides (M)					1.4	0.5	0.2	0.2										
S. polyschides (US)	0.2				8.0	0.5												
% Sporlings per m^2	1.0		0.1	0.1			2.0	0.9	2.2	1.2	0.4	0.2			1.2	1.0	11.0	4.3

M = Mature plants. US = Understorey plants
N.B Transect TS1 and TS1b are the same transect but visited on two occasions.

It can be seen from this table that the most common kelp species observed was *L. hyperborea* which was found at all of the sites surveyed and on the majority of the transects. It was not observed at 3 of the 4 transects on Duke Rock where *L. ochroleuca* was the dominant species, or on one of the Mewstone transects (MS3) where *S. polyschides* was the only species observed.

The southern species of kelp: *L. ochroleuca* was encountered at all sites except Tinker Shoal, but was more abundant at those sites inside of the breakwater (Duke Rock and Cavehole Point). Whether this is due to potentially warmer waters within this area, more shelter or some other factor is not known.

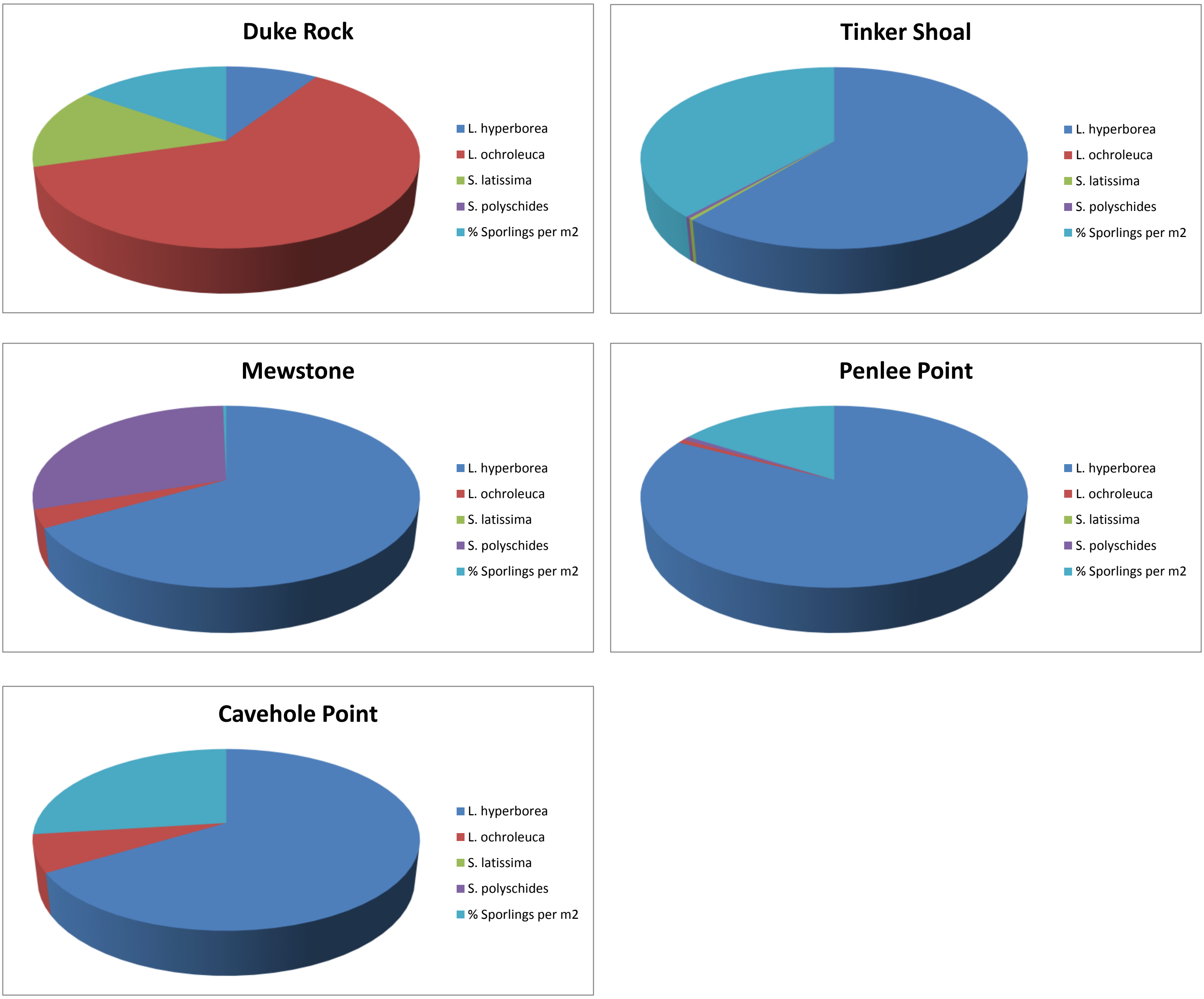
Sugar Kelp (*S. latissima*) was primarily found at transects on Duke Rock. This may be due to the more mixed nature of the substratum that occurs at this site.

S. polyschides was only commonly observed on transect MS3 which is located to the east of the Mewstone and is marginally more sheltered than the other two transects at this site. It was absent from the other two transects at this site which serves to underline the heterogeneous nature of kelp species present within a fairly small geographical area.

To illustrate the similarities and differences between the various sites, the data for each transect within a site has been combined to give the mean proportions of each of the species at that site. This is shown graphically in Fig. 6.

FIGURE 6

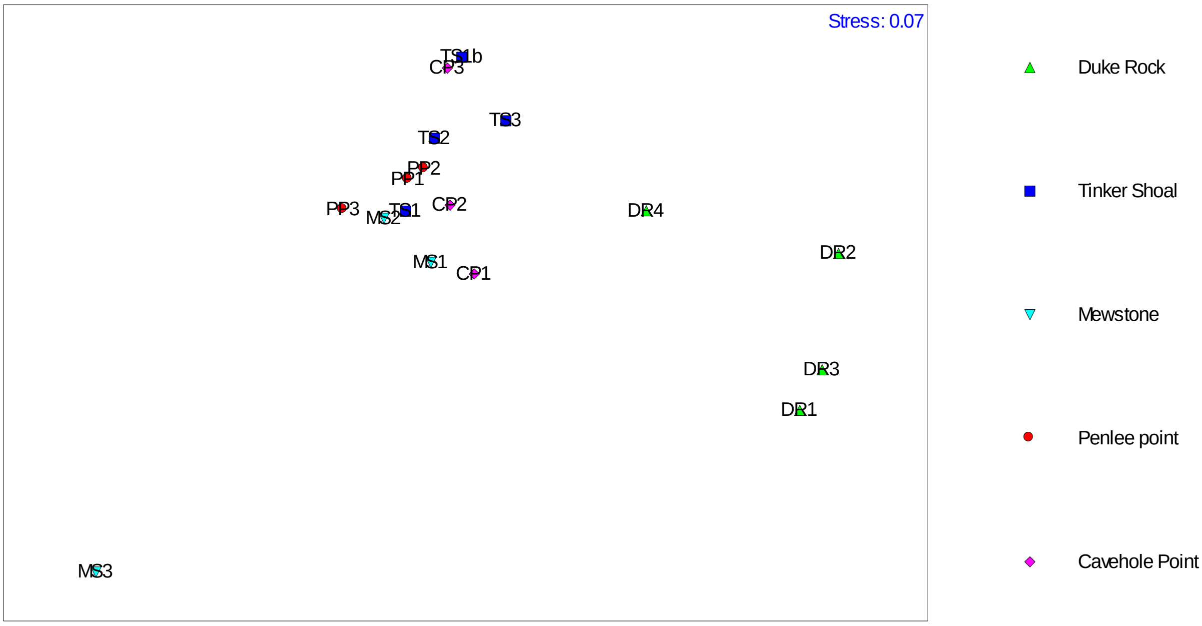
Mean proportion of kelp species observed at each site in 2012



The data has also been analysed using PRIMER(7). The similarity between transects was determined using a Bray-Curtis similarity matrix(8) and this information used to plot an MDS. The data was not transformed and was not aggregated in any way (i.e. each species of kelp was separated into mature and understorey). The resulting MDS plot visually depicts these similarities in such a way that the closer together two transects are on the plot, the greater their similarity to each other. The MDS plot for the 1 m^2 quadrats is shown in Fig. 7.

FIGURE 7

MDS plot of similarities between kelp abundances on each transect: 2012



It can be seen from this figure, that transect MS3 was the most dissimilar to all the others for the reasons discussed above. Also, transects from Duke Rock were distinctly different from other transects. Although the transects at the other sites tended to be fairly similar to other transects at that particular location (with the exception of MS3), it can be seen from Fig 7 that the differences amongst transects from the same site were occasionally more than that observed between transects from different locations.

To investigate the significance of the similarities between the transects, the data were statistically tested using ANOSIM(7). Since it is the relative proportions of the four species of kelp which are the metric by which the condition status is to be measured, the data from mature plants was aggregated with that from under storey plants and the % coverage of sporelings ignored during this analysis. The results of each of the tests are shown in Table 5.

Due to the number of different transects compared, the results are not easily interpreted at first glance. It can be seen from this Table, that transects within each site were not significantly different either at Penlee Point or Tinker Shoal. At Duke Rock DR4 was significantly different from the other transects at that site and at Cavehole Point CP1 was significantly different to CP2. At the Mewstone, all transects were statistically different although the difference between MS1 and MS2 was only just significant.

It can also be seen from Table 5 that transects at Duke Rock were significantly different from all other transects whereas, with the exception of TS2 and PP3, there were no significant differences between transects at Penlee Point and Tinker Shoal. Similarly, transects at Cavehole Point are generally similar to those at Tinker Shoal (with the exception that CP2 is significantly different from TS2 and CP1 is significantly different from TS3) and those at Penlee Point (with only CP1 being significantly different from PP1 and PP3). Transect MS3 was significantly different to all other transects, whereas transects MS1 and MS2 were not significantly different to some of the transects at Cavehole Point, Penlee Point or Tinker Shoal.

TABLE 5

Statistical analysis of transect similarities: 2012.

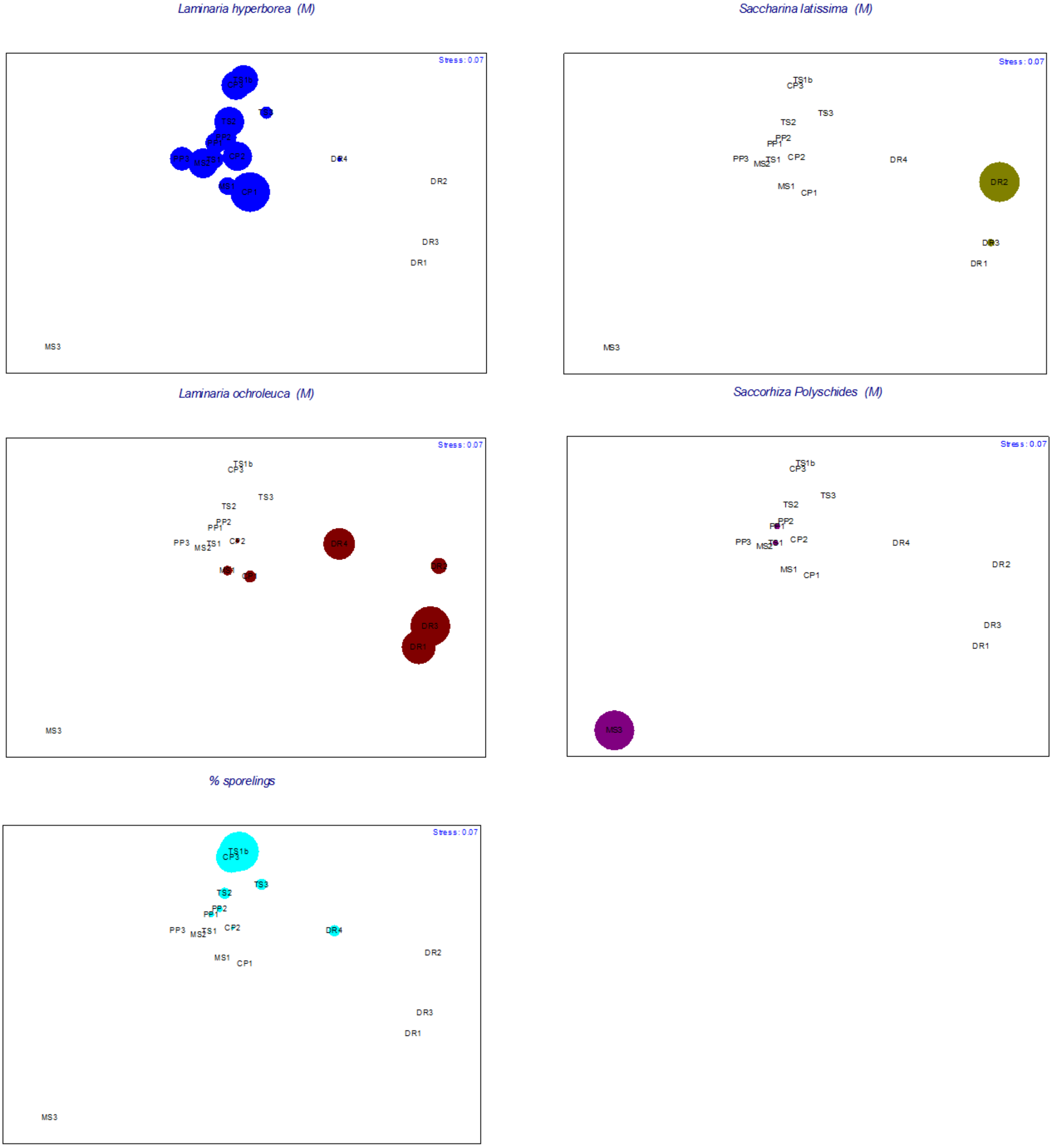
Transects		Sig. Level %	Transects		Sig. Level %	Transects		Sig. Level %	Transects		Sig. Level %
	DR2 2012	31		TS2 2012	0.8	TS1 2012,	CP2 2012	31		PP1 2012	74.6
	DR3 2012	96.8		TS3 2012	0.8		CP3 2012	96		PP2 2012	57.9
	DR4 2012	0.8		MS1 2012	0.8		TS2 2012	13.5		PP3 2012	70.6
	TS1 2012	0.8		MS2 2012	0.8		TS3 2012	7.1	MS1 2012,	CP1 2012	2.4
	TS1b 2012	0.8		MS3 2012	0.8		MS1 2012	22.2		CP2 2012	19
	TS2 2012	0.8	DR3 2012,	PP1 2012	0.8		MS2 2012	9.5		CP3 2012	81
	TS3 2012	0.8		PP2 2012	0.8		MS3 2012	0.8		MS3 2012	0.8
DR1 2012,	MS1 2012	0.8		PP3 2012	0.8	TS1b 2012	PP1 2012	57.1		PP1 2012	0.8
	MS2 2012	0.8		CP1 2012	0.8		PP2 2012	65.1		PP2 2012	41.3
	MS3 2012	0.8		CP2 2012	0.8		PP3 2012	7.9	MS2 2012,	PP3 2012	0.8
	PP1 2012	0.8		CP3 2012	0.8		CP1 2012	0.8		CP1 2012	4
	PP2 2012	0.8		TS1 2012	0.8		CP2 2012	47.6		CP2 2012	0.8
	PP3 2012	0.8		TS1b 2012	0.8		CP3 2012	81		CP3 2012	15.9
	CP1 2012	0.8		TS2 2012	0.8		TS3 2012	2.4		PP1 2012	0.8
	CP2 2012	0.8		TS3 2012	0.8		MS1 2012	11.9		PP2 2012	0.8
	CP3 2012	0.8		MS1 2012	0.8		MS2 2012	58.7	MS3 2012,	PP3 2012	0.8
	DR3 2012	48.4		MS2 2012	0.8		MS3 2012	0.8		CP1 2012	0.8
	DR4 2012	0.8	DR4 2012,	MS3 2012	0.8	TS2 2012,	PP1 2012	5.6		CP2 2012	0.8
	TS1 2012	0.8		PP1 2012	0.8		PP2 2012	49.2		CP3 2012	0.8
	TS1b 2012	0.8		PP2 2012	0.8		PP3 2012	2.4		PP2 2012	38.1
	TS2 2012	0.8		PP3 2012	0.8		CP1 2012	11.1		PP3 2012	59.5
	TS3 2012	0.8		CP1 2012	1.6		CP2 2012	4	PP1 2012,	CP1 2012	0.8
	MS1 2012	0.8		CP2 2012	0.8		CP3 2012	28.6		CP2 2012	44.4
DR2 2012,	MS2 2012	0.8		CP3 2012	0.8		MS1 2012	57.9		CP3 2012	67.5
	MS3 2012	0.8		TS1b 2012	51.6		MS2 2012	0.8		PP3 2012	16.7
	PP1 2012	0.8		TS2 2012	19		MS3 2012	0.8	PP2 2012,	CP1 2012	12.7
	PP2 2012	0.8		TS3 2012	35.7		PP1 2012	19.8		CP2 2012	33.3
	PP3 2012	0.8		MS1 2012	88.1	TS3 2012,	PP2 2012	11.1		CP3 2012	95.2
	CP1 2012	0.8	TS1 2012,	MS2 2012	9.5		PP3 2012	28.6		CP1 2012	0.8
	CP2 2012	0.8		MS3 2012	0.8		CP1 2012	1.6	PP3 2012,	CP2 2012	7.9
	CP3 2012	0.8		PP1 2012	83.3		CP2 2012	7.1		CP3 2012	27.8
	DR4 2012	0.8		PP2 2012	84.9		CP3 2012	35.7	CP1 2012,	CP2 2012	1.6
DR3 2012,	TS1 2012	0.8		PP3 2012	33.3	MS1 2012,	MS2 2012	4.8		CP3 2012	5.6
	TS1b 2012	0.8		CP1 2012	6.3		MS3 2012	0.8	CP2 2012,	CP3 2012	27.8

(yellow) statistically different (P<0.05)

To illustrate how the proportions of the various kelp species influence the MDS, bubble plots of the mature plants of each species and the sporelings are shown in Fig. 8.

FIGURE 8

MDS plots of transects similarities with the proportion of the different mature kelp plants of each species and sporelings superimposed



It can be seen from the tables and plots presented in this section, that although more than one species of kelp were observed on several transects, each one tended to be dominated by one species.

6.2.1 Potential influence of physical factors on species abundances

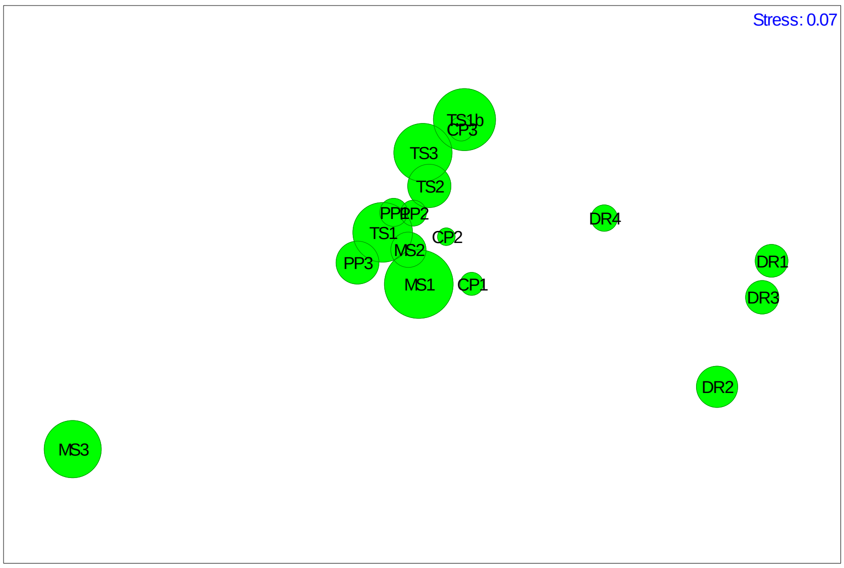
There are a number of abiotic factors that are known to affect kelp distribution. These include wave exposure, depth, turbidity, temperature and substrate. How these factors affect the relative proportions of the kelp species is less well researched. However, kelps do not tolerate wide fluctuations in salinity or temperature and it is considered that temperature in particular is the major factor influencing the geographical limits of each species[9]. It would therefore be expected that elevated temperatures would favour the southern species of kelp *L. ochrolueca.*

Of the sites surveyed, Duke Rock is probably the most sheltered and turbid location with Cavehole Point also facing away from the predominant wind and swell. The transects at Tinker Shoal, Penlee Point and the Mewstone are all exposed. However, transect MS3 was located on the eastern side of the Mewstone which is considerably less exposed than those transects on the southern or south eastern sides.

Although the depth range for each species of kelp are similar[9], it was thought that the depth of each transect might have had a significant bearing on the proportions of the kelp species at each site. Indeed Howson *et al* (2003) [2] had drawn attention to the fact that the outlying data occurred at a different depth to the majority. For this reason, the depth relative to chart datum has been super-imposed on the MDS for each transect as a bubble plot (Fig. 9).

FIGURE 9

MDS bubble plot showing the influence of depth on transect similarities: 2012



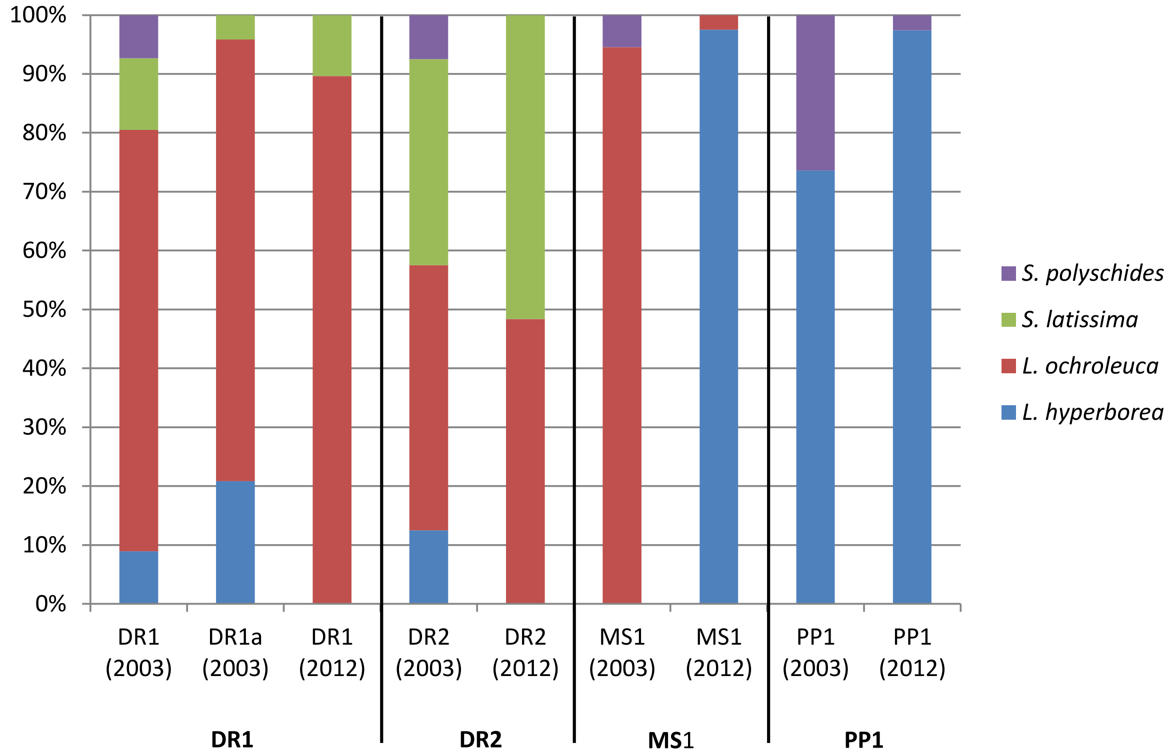
It can be seen from this plot that the depth of each transect did not seem to correlate with similarities in the species distribution. This is confirmed when the data is analysed using BIOENV[7] which gives a Spearman's Rank correlation of -0.1 for this variable. However, it should be noted that there is a possibility that this is be because the mean depths of all but 4 transects quite similar (6.5 m with a range of only 2.75m above this and 3.5 below).

6.2.2 Comparison with historical data.

Transects DR1, DR2, MS1 and PP1 were repeats of transects sampled in 2003. The proportion of each of the kelp species present at each transect in each year is shown in Fig. 10. (Transect DR1 was sampled twice in 2003 although the depths were different on each occasion).

FIGURE 10

Proportion of kelp species present at transects sampled in 2003 and 2012

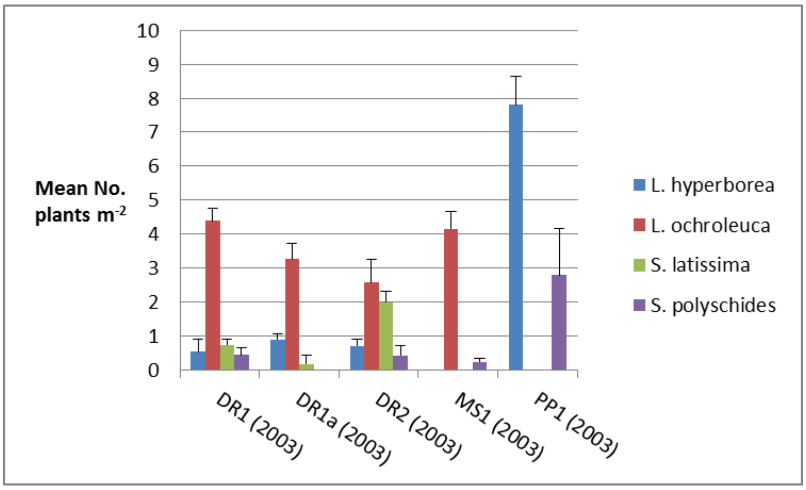


It can be seen from this figure that whereas the proportion of plants at PP1, DR1 and to a lesser extent DR2 were similar in 2012 to those found in 2003, the transect at the Mewstone (MS1) was completely different. Assuming that these two transects were actually sampled in the same position (see section 5.4), it can be seen that there has been a complete change in the species composition found there; from one dominated by *L. ochroleuca* to one dominated by *L. hyperborea.* It can also be seen from Fig. 10 that *L. hyperborea* is now completely absent from transects DR1 and DR2 (although it is still present in low proportions at DR4) being replaced by *L. ochroleuca* in DR1 and *S. latissima* in DR2. The increase in the proportion of *L. hyperborea* at PP1 is not due to an increase in the abundance of that species, but rather a slight reduction in the abundance of *S. polyschides* on that transect. It might be expected that the abundance of *S. polyschides* might exhibit considerably more variation in abundance from year to year as, unlike the other species of kelp present in the study area, this an annual plant rather than a perennial. The mean abundances and standard error of the data for those transects surveyed in both 2003 and 2012 is shown in Fig.11.

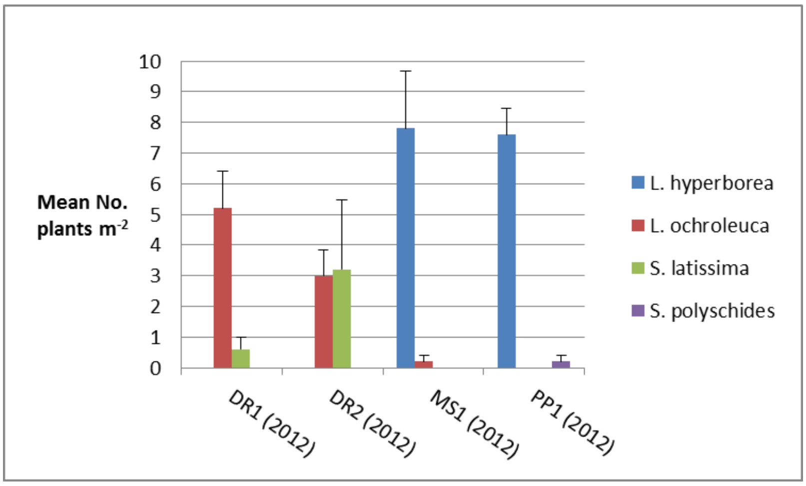
FIGURE 11

Mean number of plants per m^2 of each species present at transects sampled in 2003 and 2012

2003



2012



The community composition of each transect has been compared between 2003 and 2012 using ANOSIM (as previously this used combined data for mature and under storey plants). This revealed that there was no significant difference between DR1 in 2012 compared with either DR1 or DR1a in 2003 or at PP1. However, there was a significant difference at DR2 between 2003 and 2012 (p=0.035). As expected, the complete change in the kelp composition at MS1 was highly significant. In terms of the specific objectives of the survey, statistical analysis using a two tailed t-test showed a significant difference (p< 0.05) in the density of *L. hyperborea* at DR1 between 2003 and 2012 and also significantly different densities of both *L. hyperborea* and *L. ochroleuca* on transect MS1 beween the two years.

6.3 Abundance of Distomus variolosus

The gooseberry seasquirt *Distomus variolosus* was not found to be widely distributed across all sites. It was observed on *L. hyperborea* plants in two 1 m^2 quadrats on transects at Penlee Point and in approximately 60% of quadrats at Cavehole Point. The percentage cover of the first 50 cm of stipe was usually below 10% but was up to 50% on one plant. A typical colony on a kelp stipe from Cavehole Point is shown in Fig. 4.

6.4 Abundance of Echinus esculentus

Since it was only decided to record the abundance of the sea urchin *Echinus esculentus* half way through the survey, it is difficult to gain an overall impression of its abundance throughout the survey area. However, at those sites surveyed for this species (Tinker Shoal, Cavehole Point and Penlee Point), it was only found on two transects at Tinker shoal (TS1b and TS3) at relatively low densities (0.5-1 per 10 m^2). Although not specifically recorded at sites on the Mewstone, it was observed to be much more common here.

6.5 Presence and abundance of non-native species

During the survey no specimens of *Undaria pinnatifida*, *Sargassum muticum* or *Crassostrea gigas* were encountered on any of the transects surveyed.

6.6 Red algae species composition

Conditions were quite challenging during some dives due to poor visibility (caused by overlying silt being stirred up) and a significant swell. After reviewing the data with the algal expert following the first survey period, it was decided to re-visit the two sites at the Mewstone due to the data being of insufficient quality. This was due to a combination of technical problems with the camera, the use of a novel technique (to the survey team) and some operators not being sufficiently familiar with the camera. The protocol was revised after the review and then used for all subsequent photo-quadrats. Consequently, the data was of lower quality on some of the early transects than on later ones. The confidence in the data from transects DR1-3 and MS1 was considered relatively low, whereas it was high in all other transects. The full species list and percentage cover for each quadrat is shown in Table 2 in the Appendix.

The under storey algal cover was diverse over the entire study area with 44 taxa being observed. Over the entire survey area in 2012, the species that were responsible for principle similarities between quadrats were: *Rhodophyllis divaricata, Delesseria sanguinea Kallymenia reniformis, Cryptopleura ramosa, Dilsea carnosa and Callophyllis lacinata.* Photographs of these species taken from the photo-quadrats are shown in Fig. 12.

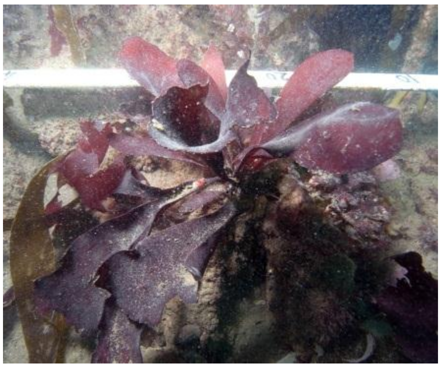
FIGURE 12

Photographs of six of the most common species of red algae over the survey area.

Rhodophlllis divaricata

Kallymenia reniformis

Dilsea carnosa



Delesseria sanguinea

Cryptopleura ramosa

Callophyllis laciniata

The similarities in red algal communities at each quadrat and between transects was statistically investigated using PRIMER. A Bray Curtis similarity matrix was calculated using a square root transformation of the raw data (to reduce the influence of more abundant species). Following this manipulation, an MDS plot was produced. The MDS plot of community similarities for each quadrat is shown in Fig. 13.

It can be seen from Fig. 13 that generally quadrats from each transect are fairly similar to each other although there is considerable overlap between quadrats from the different transects and some quadrats within the same transect show considerable variations. The average similarities at quadrats within each transect ranges from 27% (at DR1) to 64% at (CP1) and with a mean value of 42%.

The quadrat data has also been combined by transect and the mean data illustrated on an MDS plot (Fig. 14).

FIGURE 13

MDS plot of red algae community structure at each quadrat: 2012

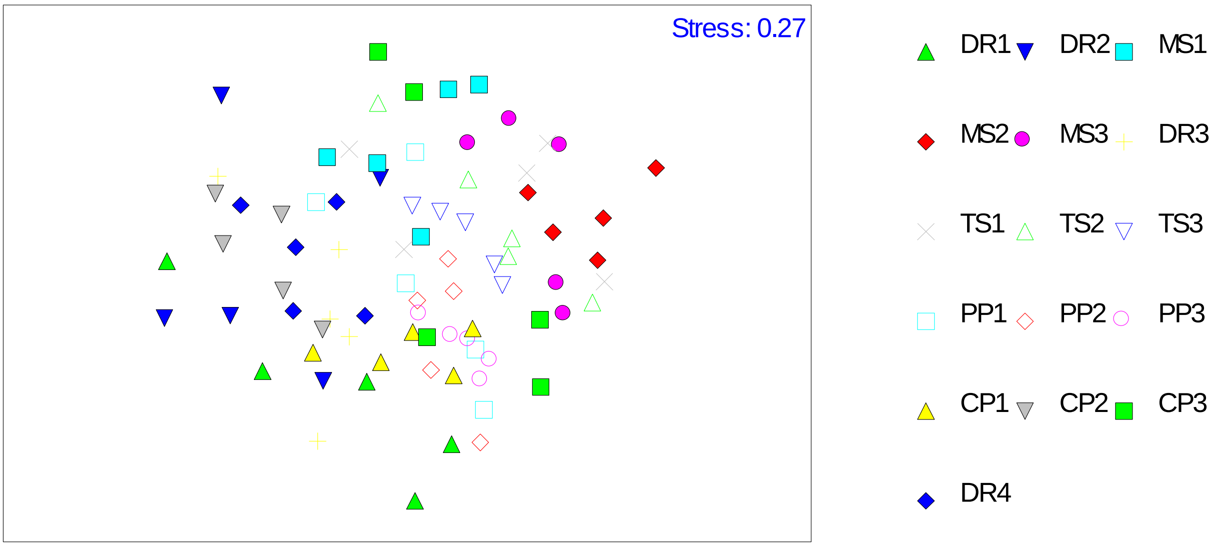
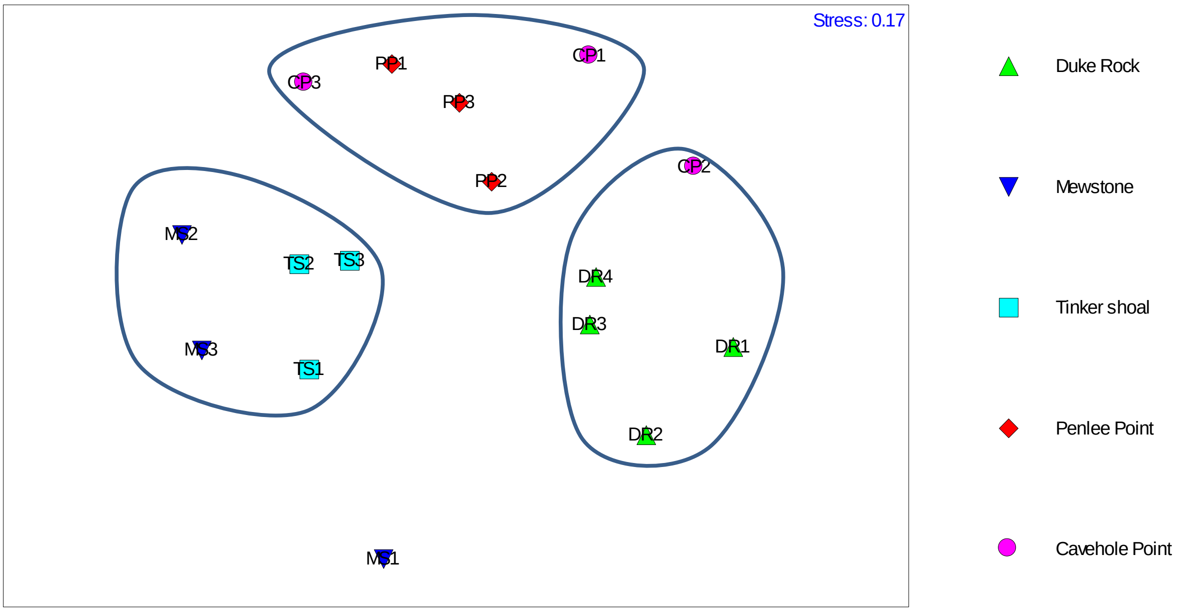


FIGURE 14

MDS plot of red algae community by transect: 2012



It can be seen from this MDS plot that transects within each area are quite similar to each other. The similarities have also been plotted on to a cluster diagram (Fig. 15). It is evident from this that, although the red algae community varies from area to area, it is surprisingly consistent over the survey area given the differences in depth, turbidity and exposure. The similarity between any given two transects is at least 50% with many transects in different areas being considerably more similar. It can also be seen from this that the transects cluster into 3 groups (above 60% similarity) plus MS1 which is isolated. These are delineated in Fig.14 by the spherical lines.

Unfortunately, it is not possible to statistically test whether the differences observed between sites are significant as there are only 3 transects at each site (except Duke Rock) and 5 would be required. (It is not possible to use each quadrat as a replicate as these are actually pseudo-replicates at this level of analysis). However, it is possible to test whether each transect is statistically different from the next using ANOSIM. The results of this are shown in Table 6.

FIGURE 15

Cluster analysis plot of red algae community by transect: 2012

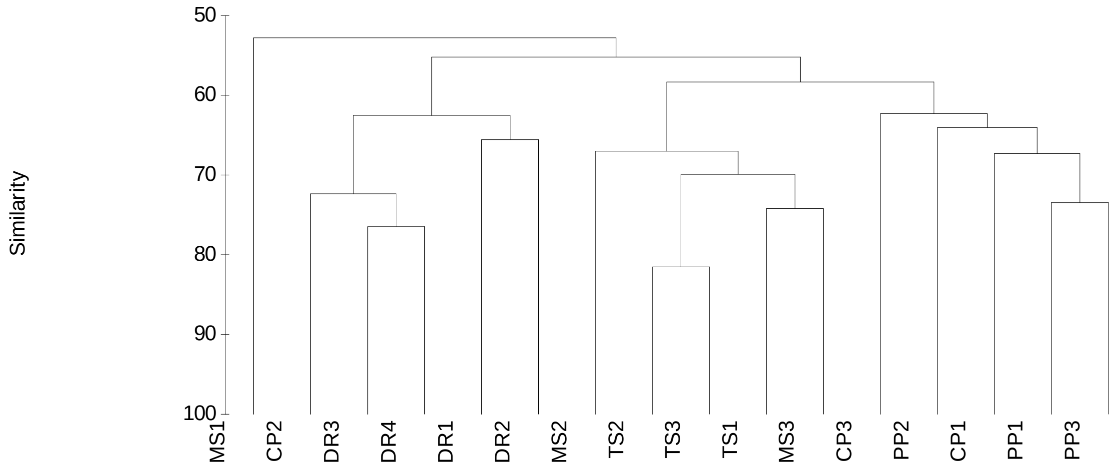


TABLE 6

ANOSIM analysis of red algae community structure between transects: 2012

Transect		Sig. level (%)	Transect		Sig. level (%)	Transect		Sig. level (%)	Transect		Sig. level (%)
DR1	DR2	29.4	MS1	MS3	1.6	MS3	PP3	0.8	TS2	CP3	13.5
	MS1	0.8		DR3	0.8		CP1	0.8		DR4	1.6
	MS2	0.8		TS1	0.8		CP2	0.8	TS3	PP1	3.2
	MS3	0.8		TS2	1.6		CP3	2.4		PP2	0.8
	DR3	16.7		TS3	0.8		DR4	0.8		PP3	0.8
	TS1	0.8		PP1	0.8	DR3	TS1	0.8		CP1	0.8
	TS2	0.8		PP2	0.8		TS2	1.6		CP2	0.8
	TS3	0.8		PP3	0.8		TS3	0.8		CP3	1.6
	PP1	4.8		CP1	0.8		PP1	0.8		DR4	0.8
	PP2	0.8		CP2	0.8		PP2	0.8	PP1	PP2	2.4
	PP3	0.8		CP3	0.8		PP3	0.8		PP3	14.3
	CP1	0.8		DR4	0.8		CP1	0.8		CP1	4
	CP2	2.4	MS2	MS3	11.9		CP2	4		CP2	0.8
	CP3	1.6		DR3	0.8		CP3	0.8		CP3	38.1
	DR4	5.6		TS1	8.7		DR4	31		DR4	4
DR2	MS1	0.8		TS2	11.1		TS2	40.5	PP2	PP3	0.8
	MS2	0.8		TS3	1.6	TS1	TS3	4		CP1	1.6
	MS3	0.8		PP1	0.8		PP1	0.8		CP2	0.8
	DR3	44.4		PP2	0.8		PP2	0.8		CP3	0.8
	TS1	0.8		PP3	0.8		PP3	0.8		DR4	0.8
	TS2	1.6		CP1	0.8		CP1	0.8	PP3	CP1	0.8
	TS3	0.8		CP2	0.8		CP2	0.8		CP2	0.8
	PP1	0.8		CP3	4.8		CP3	5.6		CP3	0.8
	PP2	0.8		DR4	0.8		DR4	1.6		DR4	0.8
	PP3	0.8	MS3	DR3	0.8	TS2	TS3	36.5	CP1	CP2	0.8
	CP1	0.8		TS1	54		PP1	7.1		CP3	0.8
	CP2	4		TS2	19.8		PP2	2.4		DR4	0.8
	CP3	0.8		TS3	19		PP3	0.8		CP3	0.8
	DR4	22.2		PP1	1.6		CP1	0.8		DR4	49.2
MS1	MS2	0.8		PP2	0.8		CP2	0.8		DR4	2.4

(highlighted) Significantly different (p<0.05)

It can be seen from Table 6, that although the community structure is similar on many of the transects (as can be seen in Fig. 14), there are significant differences between the majority of transects. These are most apparent at transects from different clusters.

The species contributions that are responsible for the similarities and the differences between the clusters shown in Figs 13 and 14 have been investigated using SIMPER[7]. The results are shown in Tables 7 and 8.

TABLE 7

SIMPER analysis of species contributing most to the similarities in quadrats from each cluster of transects: 2012

Cluster 1 (DR1-4 and CP2)			
	Average similarity: 42%		
Species	Av.Abund	Contrib%	Cum.%
Kallymenia reniformis	22.75	16.66	39.8
Rhodophyllis divaricata	8.55	10.22	64.21
Delesseria sanguinea	11.75	3.53	72.65
Cryptopleura ramosa	5.3	2.33	78.22
Calcareous encrusters	1.35	1.88	82.71
Rhodymenia holmesii	2.1	1.59	86.53

Cluster 2 (PP1-3 , CP1 and CP3)			
	Average similarity: 47%		
Species	Av.Abund	Contrib%	Cum.%
Rhodophyllis divaricata	5.43	23.03	23.03
Delesseria sanguinea	7.73	17.7	40.73
Cryptopleura ramosa	4.93	14.57	55.3
Dilsea carnosa	6.17	13.14	68.44
Callophyllis laciniata	3.3	8.63	77.07
Calcareous encrusters	1.37	6.83	83.9

Cluster 3 (MS2, MS3, TS1-TS3)			
	Average similarity: 46%		
Species	Av.Abund	Contrib%	Cum.%
Calcareous encrusters	3.72	7.54	16.39
Heterosiphonia plumosa	6.48	7	31.6
Delesseria sanguinea	6.6	6.17	45.01
Non Calcareous encrusters	6.6	5.82	57.66
Rhodophyllis divaricata	2.2	4.05	66.45
Cryptopleura ramosa	2.32	3.16	73.31
Callophyllis laciniata	2.68	2.85	79.51
Dilsea carnosa	3.12	2.01	83.87
Phycodrys rubens	3.64	1.95	88.1

Cluster 4 (MS1)			
	Average similarity: 56%		
Species	Av.Abund	Contrib%	Cum.%
Heterosiphonia plumosa	21.2	18.4	32.64
Rhodophyllis divaricata	8.4	12.73	55.22
Cryptopleura ramosa	3.6	5.38	64.77
Phyllophora crispa	3.6	5.08	73.78
Calcareous encrusters	1.8	4.81	82.32
Jania rubens/ Ceramium?	1.8	3.51	88.54

TABLE 8

SIMPER analysis of species contributing most to the differences in quadrats from each cluster of transects: 2012

Clusters 1 & 2 Average dissimilarity 63%				
Species	Cluster 1 Av.Abund	Cluster 2 Av.Abund	Contrib%	Cum.%
Kallymenia reniformis	22.75	4.7	16.31	16.31
Delesseria sanguinea	11.75	7.73	11.42	27.73
Dilsea carnosa	4.7	6.17	8.5	36.23
Cryptopleura ramosa	5.3	4.93	7.87	44.1
Callophyllis laciniata	2.2	3.3	6.07	50.16
Rhodophyllis divaricata	8.55	5.43	5.46	55.62
Phycodrys rubens	2.55	2.17	5.23	60.85
Calliblepharis ciliata	4.75	0	4.35	65.2

Clusters 2 and 3 Average dissimilarity 61%				
Species	Cluster 3 Av.Abund	Cluster 2 Av.Abund	Contrib%	Cum.%
Heterosiphonia plumosa	6.48	0.37	9.05	9.05
Non Calcareous encrusters	6.6	0.13	8.95	17.99
Delesseria sanguinea	6.6	7.73	8.4	26.4
Dilsea carnosa	3.12	6.17	7.98	34.38
Phycodrys rubens	3.64	2.17	6.4	40.78
Kallymenia reniformis	1.36	4.7	6.25	47.03
Cryptopleura ramosa	2.32	4.93	6.19	53.22
Callophyllis laciniata	2.68	3.3	5.98	59.2

Clusters 1 and 3 Average dissimilarity 70%				
Species	Cluster 1 Av.Abund	Cluster 3 Av.Abund	Contrib%	Cum.%
Kallymenia reniformis	22.75	1.36	14.6	14.6
Delesseria sanguinea	11.75	6.6	9.7	24.3
Non Calcareous encrusters	0.15	6.6	7.64	31.94
Heterosiphonia plumosa	1.1	6.48	7.2	39.14
Rhodophyllis divaricata	8.55	2.2	6.71	45.85
Cryptopleura ramosa	5.3	2.32	6.06	51.91
Dilsea carnosa	4.7	3.12	6.06	57.97

Clusters 2 and 4 Average dissimilarity 74%				
Species	Cluster 4 Av.Abund	Cluster 2 Av.Abund	Contrib%	Cum.%
Heterosiphonia plumosa	21.2	0.37	17.95	17.95
Delesseria sanguinea	1.4	7.73	9.38	27.33
Dilsea carnosa	0	6.17	8.47	35.8
Kallymenia reniformis	3.2	4.7	7	42.8
Phyllophora crispa	3.6	1.03	5.81	48.61
Callophyllis laciniata	2.2	3.3	5.34	53.95
Cryptopleura ramosa	3.6	4.93	5.27	59.22

Clusters 1 and 4 Average dissimilarity 66%				
Species	Cluster 1 Av.Abund	Cluster 4 Av.Abund	Contrib%	Cum.%
Delesseria sanguinea	22.75	3.2	22.24	22.24
Heterosiphonia plumosa	1.1	21.2	20.35	42.59
Delesseria sanguinea	11.75	1.4	11.95	54.53
Rhodophyllis divaricata	8.55	8.4	6.85	61.38
Cryptopleura ramosa	5.3	3.6	6.12	67.5
Calliblepharis ciliata	4.75	0	4.7	72.19

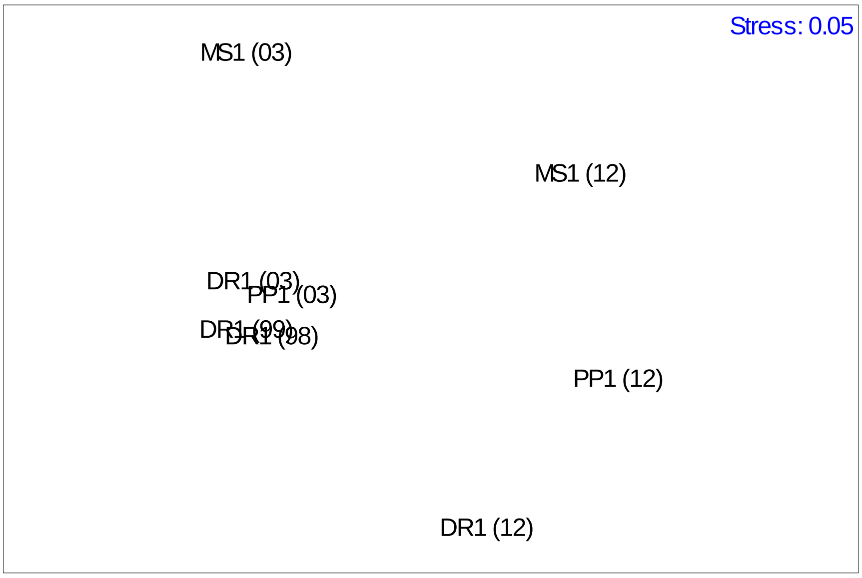
Clusters 3 and 4 Average dissimilarity 59%				
Species	Cluster 4 Av.Abund	Cluster 3 Av.Abund	Contrib%	Cum.%
Heterosiphonia plumosa	21.2	6.48	11.74	11.74
Non Calcareous encrusters	0.2	6.6	8.82	20.57
Delesseria sanguinea	1.4	6.6	8.76	29.32
Rhodophyllis divaricata	8.4	2.2	7.59	36.92
Phyllophora crispa	3.6	1.04	6.34	43.26
Kallymenia reniformis	3.2	1.36	5.82	49.08
Cryptopleura ramosa	3.6	2.32	5.46	54.54
Callophyllis laciniata	2.2	2.68	5.4	59.93

6.6.1 Comparison with historical data

The available data from monitoring carried out by Moore (1998)(10), Moore *et al* (1999)(11) at Duke Rock and algal data from Howson *et al*(2)in 2003 on transects at Duke Rock, Penlee Point and the Mewstone were used to compare the 2012 data with the historical data. Of these three surveys, the methods from Howson *et al* most closely matched the current methodology although crucially in 2012 the identification was carried out using photo-quadrats. The raw data from these previous studies was inputted into PRIMER for subsequent analysis. Unfortunately, the sampling effort used in the surveys (and within the same surveys) was markedly different, with some areas having up to 5 times the number of quadrats as were used on a single transect in 2012. It should be noted that for the reasons mentioned in section 5.3, it is likely that the samples were not taken at exactly the same location on each survey. For these reasons, it should be noted that the surveys cannot be directly compared and caution should be taken when interpreting the following analyses. However, if the existing methodology is used in subsequent studies, it will be possible to statistically compare each transect between the years and, with future surveys, the direction of any potential change will become apparent. As for the 2012 survey, all data was subject to a square root transformation prior to being further analysed by muliti-variate techniques. The resulting MDS plot of site similarities is shown in Fig. 16.

FIGURE 16

MDS plot of site similarities in red algae community structure: 1998 - 2003.



It can be seen from this MDS plot that the community structure at sites in 2012 grouped separately from those at Duke Rock and Penlee Point in 1998-2003. The data for the Mewstone in 2003 groups separately from all other sites surveyed in 2003, although it should be noted that the red algae community structure at this transect (MS1) was also very different in 2012.

The data has been statistically analysed in previous years using ANOSIM with the conclusion that the sites are statistically different in each year. However, due to the high number of replicate quadrats over a very small area, the patchy distribution of algae species and the probability that the sampling transects were not actually sampled in the same position, it is likely that at least some of these differences were due to a difference in transect location rather than any real change over time. Therefore extreme caution should be applied when interpreting these analyses. However, for completeness, those transects that had been sampled in previous years were statistically compared with the time series data using ANOSIM. As expected, all transects were statistically different ($p<0.05$) from each other.

To try and minimise the effect of the variation in sampling effort on the data, three transects of the 2012 data were combined (15 quadrats in total) to give a more uniform sampling effort to enable an assessment of overall species composition. (This is not strictly speaking valid as quadrats on each transect in 2012 are pseudo-replicates, however it does reduce the effect of vastly different sampling effort on species composition). The red algal community structure has been analysed at each site using SIMPER to show the species that are responsible for the differences between each site in each year.

TABLE 9

SIMPER analysis of species contributing most to dissimilarities in quadrats from each site 2003 v 2012

DR (03) & DR (12)	Average dissimilarity = 76.47			
Species	DR (03) Av.Abund	DR (12) Av.Abund	Contrib%	Cum.%
Heterosiphonia plumosa	20.63	1.16	8.38	8.38
Cryptonemia hibernica	18.06	0	8.28	16.65
Dictyota dichotoma	13.38	0	7.66	24.32
Delesseria sanguinea	15.25	12.15	6.91	31.23
Kallymenia reniformis	3.75	17.7	6.75	37.98
Rhodophyllis divaricata	0.13	8.9	6.21	44.19
Rhodymenia pseudopalmata	7.78	0.11	5.62	49.81
Dilsea carnosa	10.81	5.11	5.43	55.25
Polyneura bonnemaisonii	6.72	1.25	5.29	60.54
Cryptopleura ramosa	6.31	5.4	4.51	65.05
Calliblepharis ciliata	3.31	4.75	3.79	68.84

MS (03) & MS (12)	*Average dissimilarity = 76.61*			
Species	MS (03) Av.Abund	MS (12) Av.Abund	Contrib%	Cum.%
Calliblepharis ciliata	32.25	0.2	13.34	13.34
Cryptopleura ramosa	11.98	2.07	5.74	19.08
Halopteris filicina	5.67	0	5.41	24.48
Non Calcareous encrusters	0	7.6	5.26	29.75
Delesseria sanguinea	5	6.12	4.74	34.48
Phyllophora crispa	7.33	2	4.7	39.18
Dictyopteris membranacea	6.88	0	4.54	43.72
Rhodophyllis divaricata	0	4.47	4.46	48.18
Heterosiphonia plumosa	11.58	11.27	4.45	52.63
Calcareous encrusters	0	3.87	4.41	57.05
Dictyota dichotoma	3.58	0	4.26	61.31
Pterosiphonia complanata	4.79	0.53	4.01	65.32
Callophyllis laciniata	3.98	3.07	3.34	68.66

PP (03) & PP (12)	Average dissimilarity = 57.43			
Species	PP (03) Av.Abund	PP (12) Av.Abund	Av.Diss	Cum.%
Cryptopleura ramosa	23.79	5.93	6.44	11.21
Rhodophyllis divaricata	0	4.87	5.22	20.29
Dilsea carnosa	13.92	7.68	4.74	28.54
Kallymenia reniformis	5.58	0.62	4.49	36.37
Delesseria sanguinea	11.92	9.87	4.15	43.61
Phyllophora crispa	5.1	1.15	3.62	49.91
Callophyllis laciniata	3.54	4.6	2.75	54.7
Dictyota dichotoma	3.42	0	2.51	59.07
Polyneura bonnemaisonii	1.83	0.55	2.28	63.05
Heterosiphonia plumosa	1.33	0.53	1.92	66.38
Phycodrys rubens	0.17	2.48	1.9	69.68

The average dissimilarity at Duke Rock for 1998, 1999 and 2003 was 56% whereas the 2012 data was on average 76 % dissimilar to the previous years. There are a number of possible reasons for this increase including methodology etc, but it is thought very likely this is in part due to the fact that it is 9 years since Duke Rock was last surveyed compared to the maximum of 5 in previous years. The results from 2003 and 2012 are shown in Table 7. It can be seen from this that, as discussed by Howson[2] *et al*, the species present in each year are similar, but their relative abundances vary considerably. This is probably a reflection of the fact that the many of these algae are ephemeral in nature and that recruitment can be highly variable.

It can also be seen from this table that some species that had been relatively abundant were absent in 2012. This included the *Cryptonemia hibernica* which appears to have completely disappeared from the survey area following its appearance at Duke Rock in 1999. However, due to the fact this species is very easily confused with *Kallymenia reniformis* the photoquadrats were rechecked. The conclusion was that this species may have been present in two quadrats from DR3, one from TS2 and all those from CP2, but it was not possible to be definitive.

It is common for a number of large flat red species to be confused during identification whether in the field or through images taken of field specimens. The Seasearch Guide to Seaweeds of Britain and Ireland highlights identity confusions between a number of red species including*, Kallymenia reniformis* and *Crytonemia hibernica.* Information on the *C. hibernica* is extremely limited with the only available image being an illustration by Irvine (1983)[12]. The differences between these species are difficult to pick up during both *in-situ* subtidal identification and subsequent identification through detailed in-situ photographs. Many of the differential characteristics may also be considered subjective and based on personal perception of what may be considered 'more oval', 'more fleshy', 'more tapered' or 'more pointed' all of which are difficult to determine regardless of survey method. In some instances, individuals of *K. reniformis* may have a split frond therefore appear pointed and in most instances the thickened base cannot be seen, or is not obvious enough for it to be accurately identified as such. Despite its consideration as an introduced species it has not been suggested that *C. hibernica* is an invasive species [13] so its presence may hold little significance in the overall species assemblage of subtidal algal communities. If it is considered by Natural England that the abundance of this species is of sufficient nature conservation importance to merit the extra effort, the methodology could be fine-tuned to accommodate this by taking representative samples (e.g. one out of every five quadrats) and/or by taking close up photographs of the base and tips.

The variability shown in the percentage cover of each species from year to year suggests that it may not be appropriate to use this metric in isolation. Another measure of a community's health is often considered to be its diversity. For this reason, the mean diversity statistics for each of the sites have been calculated for each year. The results are shown in Table 10. It can be seen from this table that the number of taxa at each site has remained very similar between years as have most of the diversity indices. It can therefore be concluded that although the abundances of individual species vary from year to year, the overall diversity at each site remains more or less constant.

TABLE 10

Taxa diversity statistics for each site 1998 -2003

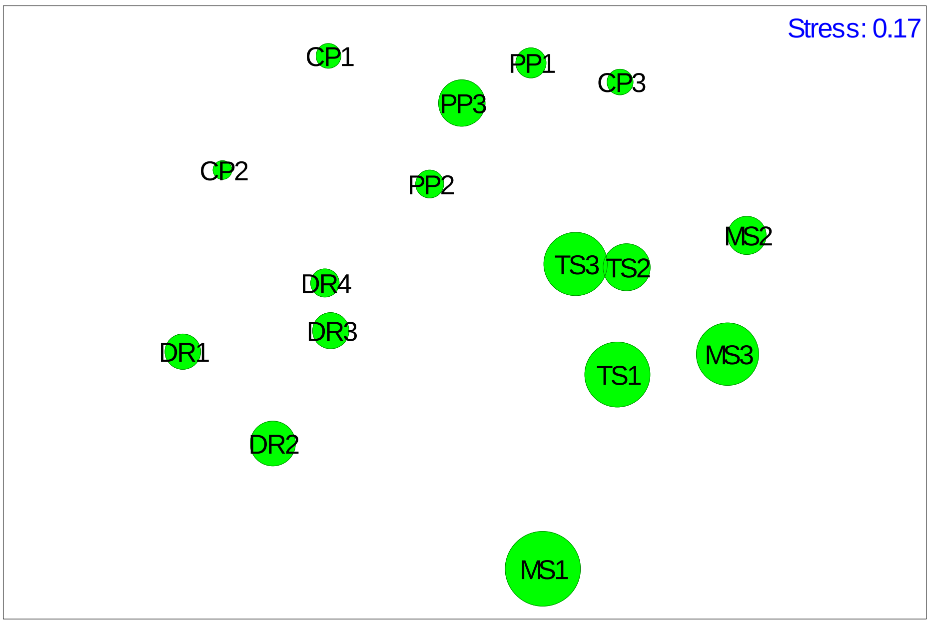
Site	Year	No. Taxa at site S	Mean % cover per quadrat N	Margalef's species richness d	Pielou's eveness J'	Shannon's diversity H'(log10)
Duke Rock	1998	33	64.14	7.69	0.74	1.12
	1999	30	85.77	6.51	0.68	1.00
	2003	35	129.80	6.99	0.74	1.14
	2012	29	67.49	6.65	0.69	1.00
Mewstone	2003	33	109.02	6.82	0.72	1.10
	2012	29	52.07	7.08	0.74	1.09
Penlee Point	2003	26	78.00	5.74	0.66	0.94
	2012	30	43.25	7.70	0.69	1.03

Interestingly, this table also suggests that there was an overall increase in the percentage cover of red algae in 2003 (almost double that of other years). However, for both Duke Rock and the Mewstone, the average % cover per quadrat was over 100% in 2003 which indicates that there may have been a significant difference in the way it was estimated in that year.

The relationship between red algal community structure and depth has been examined using BIOENV. A relatively weak Spearmans rank correlation of 0.28 was calculated. This is illustrated in the bubble plot (Fig. 17).

FIGURE 17

MDS bubble plot of site similarities in red algae community with depth (size of bubble is proportional to the depth).



7 CONCLUSIONS

7.1 Sampling strategy

It is concluded that the current sampling strategy which was based primarily on the work of Howson *et al* (2) and Moore (10, 11) is a highly cost efficient methodology for assessing the condition of the kelp forest against its attributes. The increase in cost efficiency has largely been gained by the use of photo-quadrats for the identification and estimation of the percentage coverage of red algae. Since the photographs are analysed in the comfort of the laboratory with reference material to hand and with the pressings gathered during the survey, it is also thought that this may be more accurate and robust than data gathered in the field in many instances. However, it is dependent on high quality photography and it is still paramount that the taxonomy is undertaken by someone with the necessary skills. It is also possible that the % cover of smaller understory plants might be underestimated using this technique (although this is also possible with *in situ* estimates).

The survey made use of both stills and video recording at each site. The quality of the video recordings and 1 m^2 quadrats are of less importance than that of the 0.25 m^2 quadrats as they are providing supplementary information in the form of a visual record should they be required to be viewed in future. However, the quality of the 0.25 m^2 photo-quadrats is of critical importance. For this reason it should be undertaken using a high quality digital stills camera using a wide angle lens and external flash lighting. This is particularly important in poor visibility or silty conditions. It also provides a sharp image so that the taxonomist can zoom in on small features. The ability to control the aperture and shutter speed to get a good depth of field can also be important and might be difficult with a standard compact type digital camera. It is also very important that the diver using the camera has adequate experience to be able to adjust the settings manually when conditions require and obtain high quality stills.

This survey also differed from previous surveys in that three times the number of transects were surveyed per site and a standard number of quadrats was taken on each. This was often substantially fewer than taken on some transects by previous workers. However, it is known that the abundance of kelp is highly patchy (9). The use of short transects on which multiple quadrats are taken therefore is likely to result in pseudo-replication, reducing the degree in which the data represents a site as a whole and a reduction in the statistical power of the subsequent statistical analysis. For this reason, it is thought that the current approach gives a better estimate of the species composition as a whole. Although the best approach would be to randomly distribute the same number of quadrats across each site, this would be extremely expensive due to the number of individual dives that would be required.

The use of three transects at each site is also a trade off between cost and statistical power. Although the current strategy allows statistical testing of the significance of any differences between any of the transects undertaken in any year, if 5 transects were used at each site, sites could be statistically compared within and between years. By examining the data for a particular transect or site over time using a combination of multi-variate statistical techniques such as MDS plots and ANOSIM, it will be possible to detect the direction of any change from the baseline and determine whether these changes are significant. It is therefore concluded that this is a good methodology for long term monitoring.

7.2 Determination of the abundance of keystone speceies

During the course of this survey, it was decided to assess the abundance of the sea urchin *Echinus esculentus* due to its well-known potential impacts on kelp forests and parks. Since this can be achieved at no significant extra cost, it is concluded that this should be continued for future surveys. Although it would probably result in a cost increase, it may also be appropriate to determine the abundance of the blue rayed limpet *Patella pellucida* as this can also negatively impact kelp by grazing and destroying their holdfasts. Both these species are sometimes considered keystone species within the kelp forest [9].

Although the abundance of *Distomus variolosus* is sensitive to changes in salinity and siltation, given budgetary constraints, it is thought that monitoring effort might be better spent on assessing the two keystone species mentioned above in the Plymouth Sound and Estuaries SAC.

7.3 Determination of attribute condition status

7.3.1 Algal species composition

The target for this attribute is that the presence and abundance of algal species should not deviate from an established baseline subject to natural change[1]. Red algae are thought to act as indicators of a reduction or increase in the entire algal population.

For those sites where there was existing baseline information, the results of this survey show that there has been a change in the community structure at the sites assessed previously. In common with previous years, it is the relative abundance of the major species that is principally responsible for this, rather than a change in the identity of the species present which is almost certainly a result of natural fluctuations. When the species diversity is examined from year to year, the results are almost identical. It can therefore be concluded that there has been no reduction in the diversity of the algal species present. The mean algal abundance (as measured by % cover) at Duke Rock was less than that observed in 2003, but within the range previously encountered. The overall densities at the Mewstone and Penlee Point were also less than that observed in 2003, but it is thought that this is probably due to a difference in the way densities were estimated.

Overall, it is concluded that this attribute is in **Favourable condition**.

7.3.2 Characteristic species: *L. hyperborea* and *L. ochroleuca* population size

The measure of this attribute is the proportion and density of these species measured at a number of sites within the SAC (5 during this survey). The target is that the average ratio and density of these two species of kelp should not deviate significantly from the established baseline subject to natural change.

It can be seen from Fig. 11 that the overall density of plants (irrespective of species) at each site remained the same or higher to that in previous years. However, the proportion of these two species had varied from the baseline set in 2003 at Duke Rock and the Mewstone, although no difference was observed at Penlee Point. At Duke Rock *L. ochroleuca* has now been completely replaced by *L. hyperborea*. However, at the Mewstone, whereas in 2003 the kelp was predominantly *L. ochroleuca*, it is now *L. hyperborea*. In 2003 it was concluded that the southern species *L. ochroleuca* was extending its distribution out of Plymouth Sound. However, the results from this year indicate that although its abundance within the Sound has increased, it has decreased in abundance at sites outside the Sound. The variations observed are almost certainly natural changes.

Overall, it is concluded that this attribute is in **Favourable condition.**

7.3.3 Characteristic species: *Distomus variolosus* – population size

The target is that the average percentage cover and density on the kelp stipes should not deviate significantly from an established baseline. This species was not very abundant over the survey area. No baseline information existed for this attribute in this area, therefore no conclusions can be drawn on its condition status.

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APPENDIX

TABLE 1

Raw data of kelp abundances and the % cover of sporelings at each transect.

Species	DR1					DR2					DR3					DR4				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
L. hyperborea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	5	2
L. ochroleuca	4	7	3	3	9	3	6	3	2	1	5	2	3	11	7	4	5	3	5	6
S. latissima	1	0	0	2	0	1	3	12	0	0	1	2	0	0	0	1	0	0	0	0
S. polyschides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Sporelings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	5	0

Species	TS1					TS1b					TS2					TS3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
L. hyperborea	2	7	6	14	10	11	12	9	6	9	14	18	7	17	12	4	8	4	9	4
L. ochroleuca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. latissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
S. polyschides	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Sporelings	3	0	0	2	0	10	25	10	25	5	2	2	1	10	5	2	1	10	2	5

Species	MS1					MS2					MS3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
L. hyperborea	15	4	7	7	6	10	18	12	13	13	0	0	0	0	0
L. ochroleuca	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
S. latissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. polyschides	0	0	0	0	0	0	0	0	0	0	11	12	6	9	9
% Sporelings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	PP1					PP2					PP3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
L. hyperborea	7	9	7	10	5	16	7	5	11	12	6	8	8	5	5
L. ochroleuca	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
S. latissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. polyschides	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
% Sporelings	0	2	0	5	3	0	5	1	0	5	1	0	0	1	0

Species	CP1					CP2					CP3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
L. hyperborea	16	11	20	1	13	10	10	8	6	9	9	4	6	16	11
L. ochroleuca	2	2	2	1	4	1	2	1	0	0	0	0	0	0	0
S. latissima	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. polyschides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Sporelings	0	0	0	0	0	0	0	0	5	1	10	5	0	15	25

TABLE 2

Percent cover by species for each quadrat.

Taxon	Duke Rock DR1					Duke Rock DR2					Duke Rock DR3					Duke Rock DR4				
	1	2	3	4	5	1	2	3	4	5	29	26	27	28	30	90	89	88	86	87
Pterosiphonia complanata																				
Sphondylothamnion multifidum			10																	
Plocamium cartilaginuem																				<1
Bonnemaisonia asparagoides							<1													
Heterosiphonia plumosa	1	1			5			7				3		2	3		<1	1		
Delesseria sanguinea	40	35			60					20		40	10	20			10		8	
Stenogramme interupta										<1										
Phyllophora pseudoceranoides		<1		<1					<1			4				2		<1	1	1
Phycodrys rubens				15							1					8		7	<1	3
Acrosorium venulosum				3														<1	<1	
Hypoglossum hypoglosoides							<1													
Callophyllis laciniata		8				5	3						5		5				8	3
Gelidium latifolium						10												<1		
Rhodymenia holmesii			6			3		6		10		4	1	5	5				6	1
Calliblepharis ciliata	35		10				25	15							10					
Rhodophyllis divaricata	12	20	15	15	10	5		3	25	10	2		5	7	15	6	10	5	8	5
Cryptopleura ramosa			5				30	12		10					25	7		12	5	2
Kallymenia reniformis			10	35	15	8	10	4	25	10	50	12	25	28	8	15	45	30	20	4
Drachiella spectabilis		<1																		
Schottera nicaeensis																				
Phyllophora crispa							10				2			5	5	5	2			1
Rhodymenia pseudopalmata																2				<1
Palmaria palmata																				
Dilsea carnosa		30	25		7			5		<1				15	5			5	10	
Meredithia microphylla																		<1		
Cordylecladia erecta																				
Chondrus crispus																				
Polyneura bonnemaisonii				15			10													
Polysiphonia sp.																	<1			
Halurus flosculosa																<1				
Calcareous encrusters			1		1	1		2			10	2	2	2	2		2	2	1	2
Non Calcareous encrusters								3												
Membranoptera alata																				
Radicilingua thysanorhizans/ Rhodophysema																				
Corallina officinalis				1													1			
Brogniartella byssoides																				
Jania rubens/ Ceramium?																				
Rhodothamniella floridula																				
Nitophyllum punctatum																				
Rhodomela confervoides																				
Asparagopsis armata																		1		
unknown thick filiform red																				
Lomentaria articulata																				
Gelidium sesquipedale																				
Total % cover of reds	88	94	82	84	98	32	88	57	50	60	65	65	48	84	83	45	70	63	67	22

N.B. Species in red are species where the identity is not certain.

TABLE 2 (CTD)

Percent cover by species for each quadrat.

Taxon	Tinker Shoal TS1					Tinker Shoal TS2					Tinker Shoal TS3				
	33	31	32	34	35	36	37	39	40	38	45	44	41	42	43
Pterosiphonia complanata													1	1	2
Sphondylothamnion multifidum															1
Plocamium cartilaginuem						1									1
Bonnemaisonia asparagoides															
Heterosiphonia plumosa	8	2	12	12	12	10		1	3	18	6	2	8	5	
Delesseria sanguinea		18		10	20	2		3	3	8	4	2	3	3	2
Stenogramme interupta															
Phyllophora pseudoceranoides					1			6		3		2			
Phycodrys rubens			2	12				5	2	4	7				
Acrosorium venulosum		2?		1	2								<1		
Hypoglossum hypoglosoides							1							1	
Callophyllis laciniata	4				3	7		3	2		6		2	3	2
Gelidium latifolium														1	
Rhodymenia holmesii															
Calliblepharis ciliata	10			1											
Rhodophyllis divaricata	1	1		3	2		2	2		1	2	5	6	3	2
Cryptopleura ramosa			10		2	8	1	2		2	4	6	5	3	2
Kallymenia reniformis	2	1	8		5	2	4				3	2		1	1
Drachiella spectabilis															
Schottera nicaeensis												1			
Phyllophora crispa				1	3		1				3	3	3		
Rhodymenia pseudopalmata						1									
Palmaria palmata															
Dilsea carnosa	4		5					6	4	6				12	9
Meredithia microphylla															
Cordylecladia erecta	<1														
Chondrus crispus															
Polyneura bonnemaisonii						2					1		1	2	
Polysiphonia sp.															
Halurus flosculosa															
Calcareous encrusters	2	5	2	2		3	4	4	2	2	1	3	2	8	4
Non Calcareous encrusters	17	18		3			2	3			2	2	1	2	2
Membranoptera alata															
Radicilingua thysanorhizans/ Rhodophysema							1	1	1				1	1	1
Corallina officinalis															
Brogniartella byssoides															
Jania rubens/ Ceramium?				2	2		1	1		1	2			1	
Rhodothamniella floridula															
Nitophyllum punctatum															
Rhodomela confervoides															
Asparagopsis armata															
unknown thick filiform red															
Lomentaria articulata															
Gelidium sesquipedale														1	
Total % cover of reds	48	45	39	47	52	36	17	37	17	45	41	28	33	48	29

N.B. Species in red are species where the identity is not certain.

TABLE 2 (CTD)

Percent cover by species for each quadrat.

Taxon	Mewstone MS1					Mewstone MS2					Mewstone MS3				
	14	11	12	13	15	71	75	72	74	73	79	78	76	80	77
Pterosiphonia complanata				3	2								2	1	
Sphondylothamnion multifidum												<1			
Plocamium cartilaginuem		1				<1	<1			1	1	2	1	2	
Bonnemaisonia asparagoides															
Heterosiphonia plumosa	7	7	30	27	35			6	3		3	2	22	15	12
Delesseria sanguinea					7	5	3		3	8	<1	30	<1	<1	35
Stenogramme interupta															
Phyllophora pseudoceranoides															
Phycodrys rubens							25	12	3	4				15	
Acrosorium venulosum	1									1					
Hypoglossum hypoglosoides			<1									1			
Callophyllis laciniata			5	3	3		7	10	8		3	7			
Gelidium latifolium															
Rhodymenia holmesii			2												
Calliblepharis ciliata											3				
Rhodophyllis divaricata	17	5	5	10	5	5	1			2		5	4	5	3
Cryptopleura ramosa	2	3		5	8		2			5	2		1	3	
Kallymenia reniformis	5			7	4									2	3
Drachiella spectabilis															
Schottera nicaeensis													1		
Phyllophora crispa	1	3	7	7						3	4	5			
Rhodymenia pseudopalmata															
Palmaria palmata															
Dilsea carnosa							2	8	20			2			
Meredithia microphylla		6													
Cordylecladia erecta		1												<1	
Chondrus crispus															
Polyneura bonnemaisonii											2				1
Polysiphonia sp.															
Halurus flosculosa															
Calcareous encrusters	3	2	2		2	10	6		5	6	2	8	5	5	2
Non Calcareous encrusters	1					15	5	30	10	15		15	8	8	7
Membranoptera alata															
Radicilingua thysanorhizans/ Rhodophysema							2								2
Corallina officinalis										1					
Brogniartella byssoides		1													
Jania rubens/ Ceramium?	1		4	3	1	2				3				1	
Rhodothamniella floridula												3			
Nitophyllum punctatum															1
Rhodomela confervoides															
Asparagopsis armata															
unknown thick filiform red															1
Lomentaria articulata															
Gelidium sesquipedale															
Total % cover of reds	38	29	55	65	67	37	53	66	52	49	20	80	44	57	67

N.B. Species in red are species where the identity is not certain.

TABLE 2 (CTD)

Percent cover by species for each quadrat

Taxon	Penlee Point PP1					Penlee Point PP2					Penlee Point PP3				
	47	50	49	46	48	51	55	54	53	52	60	59	57	58	56
Pterosiphonia complanata		1								1					
Sphondylothamnion multifidum	<1														
Plocamium cartilaginuem						1	1								
Bonnemaisonia asparagoides															
Heterosiphonia plumosa									3	1	1	2			1
Delesseria sanguinea	15	22		2	30	2	4	8	4	8	6	20	5	12	10
Stenogramme interupta															
Phyllophora pseudoceranoides										1					<1
Phycodrys rubens		<1	20	15											2
Acrosorium venulosum							1			<1					
Hypoglossum hypoglosoides	<1														
Callophyllis laciniata	5	10	5		5	3	6	2	3		8	5	6	3	8
Gelidium latifolium															
Rhodymenia holmesii									2					1	
Calliblepharis ciliata															
Rhodophyllis divaricata	2	3	10	6	2	12	6	2	3	4	2	9	3	3	6
Cryptopleura ramosa	5	3		2	4	5	20	17	10	6	4	5	2	4	2
Kallymenia reniformis		2	3					<1	1			3			
Drachiella spectabilis															
Schottera nicaeensis													1		
Phyllophora crispa		5	5	1			3		<1				1		2
Rhodymenia pseudopalmata										1					
Palmaria palmata			7	1							<1				
Dilsea carnosa	10		5		4	5	1	<1	5	35	7	12	15	4	12
Meredithia microphylla		2					3	1	1	8					
Cordylecladia erecta														<1	
Chondrus crispus					2									1	
Polyneura bonnemaisonii	<1		1			1	2					2	1	1	
Polysiphonia sp.															
Halurus flosculosa															
Calcareous encrusters	2	1	1	2			3	3				2		2	
Non Calcareous encrusters								1							
Membranoptera alata							1			1					
Radicilingua thysanorhizans/ Rhodophysema					3						1		2	1	1
Corallina officinalis							1					1	1		
Brogniartella byssoides															
Jania rubens/ Ceramium?							1			2					
Rhodothamniella floridula															
Nitophyllum punctatum															
Rhodomela confervoides															
Asparagopsis armata															
unknown thick filiform red															
Lomentaria articulata							1		1	1					
Gelidium sesquipedale															
Total % cover of reds	39	49	57	29	50	29	54	34	33	69	29	61	37	32	44

N.B. Species in red are species where the identity is not certain.

TABLE 2 (CTD)

Percent cover by species for each quadrat

Taxon	Cavehole Point CP1					Cavehole point CP2					Cavehole Point CP3				
	65	64	63	62	61	66	70	69	68	67	82	81	83	85	84
Pterosiphonia complanata															
Sphondylothamnion multifidum															
Plocamium cartilaginuem								2	2		1			1	
Bonnemaisonia asparagoides															
Heterosiphonia plumosa											1				
Delesseria sanguinea	8	13		5	6	8				2	17		10		7
Stenogramme interupta															
Phyllophora pseudoceranoides										2			0	3	1
Phycodrys rubens							8		7	20		6			2
Acrosorium venulosum												1			1
Hypoglossum hypoglosoides													1		
Callophyllis laciniata		10	6		2	13			5			<1			
Gelidium latifolium															
Rhodymenia holmesii										2					
Calliblepharis ciliata															
Rhodophyllis divaricata	6	5	4	10	12	8	7	4	3	5	1	1	6	3	8
Cryptopleura ramosa	8	15	3	2		5	7		7	5	2			1	2
Kallymenia reniformis	4	3		8		28	40	60	55	32		2			
Drachiella spectabilis			1												
Schottera nicaeensis															
Phyllophora crispa			0				0	2			1		1	2	1
Rhodymenia pseudopalmata															
Palmaria palmata												2		4	
Dilsea carnosa	9	17	8		6					6	<1	6			7
Meredithia microphylla															
Cordylecladia erecta												<1			
Chondrus crispus		<1							<1			1			
Polyneura bonnemaisonii	8	5	3	2	6									3	
Polysiphonia sp.											<1				
Halurus flosculosa															
Calcareous encrusters		2	3		3			2	2		2	4	1	2	1
Non Calcareous encrusters											1	1	1		
Membranoptera alata															
Radicilingua thysanorhizans/ Rhodophysema															
Corallina officinalis															
Brogniartella byssoides															
Jania rubens/ Ceramium?															
Rhodothamniella floridula															
Nitophyllum punctatum															
Rhodomela confervoides											1				
Asparagopsis armata															
unknown thick filiform red															
Lomentaria articulata															
Gelidium sesquipedale															
Total % cover of reds	43	70	28	27	35	62	62	70	81	74	27	24	20	19	30

N.B. Species in red are species where the identity is not certain.

Further information

Natural England evidence can be downloaded from our **Access to Evidence Catalogue**. For more information about Natural England and our work see **Gov.UK**. For any queries contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk** .

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