Natural England Commissioned Report NECR042

Monitoring intertidal sandflats of the Isles of Scilly Special Area of Conservation

Survey of the infaunal organisms of St. Martin's sedimentary shore, September 2009

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Introduction

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Background

Special Areas of Conservation are established under the European Union's Habitats Directive 1992 as the best examples in Europe of a suite of listed habitats.

One of the features for which the Isles of Scilly were selected as a Special Area of Conservation (SAC) are their rich infaunal communities of intertidal and subtidal marine sediment.

The Directive requires a SAC to be monitored at least every six years to ensure that the features for which it was selected are being conserved.

The objectives of this study carried out in September 2009 were to repeat the surveys of the sites sampled in 2000 and 2004 using the same methodology and to highlight differences and offer possible explanations and recommendations.

The results will inform the site managers as to any changes that may need to be made to the future management of the SAC.

This report is being published to inform managers and to allow others to review the work as well as to develop and adapt monitoring programmes for this and other SACs.

© Richard M. Warwick
Characteristic cast of the Lug worm (Arenicola marina)

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The Sand Mason worm (Lanice conchilega)

Natural England Project Manager - Sangeeta McNair, Pydar House, Pydar Street, Truro, Cornwall, TR1 1XU
Sangeeta.McNair@naturalengland.org.uk

Contractor - Richard M. Warwick, Plymouth Marine Laboratory

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Further information
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Summary

This report presents an investigation into the fauna of three biotopes that fall within the 'intertidal mud and sandflats' biotope complex on St Martin's Flats, Isles of Scilly: the *"Lanice/Echinocardium*", "*Ensis*" and "*Arenicola*" biotopes.

The objectives of this study were to repeat the surveys of the sites sampled in 2000 and 2004 in September 2009 using the same methodology, to analyse the granulometry of the sediments and the biological samples to the lowest practical taxonomic level, to analyse the resulting data to determine similarities and differences between surveys and to suggest reasons and explanations for any differences.

Sediment granulometry fell within the range of values recorded in previous years.

Only minor changes in faunal diverstity had occurred in the *"Lanice/Echinocardium*" and "*Arenicola*" biotopes. However, in the "Ensis" biotope there has been a dramatic drop in total numbers of species, the number of individuals per sample and in all species diversity measures between 2000 and 2009. However, this was not the case for average taxonomic distinctness (Δ^*).

AMBI (AZTI's Marine Biotic Index) scores indicated the "Undisturbed" ecological condition for all three biotopes, although the "Slightly Disturbed" condition had been indicated for the "*Ensis*" and "*Arenicola*" biotopes in some previous years.

Multivariate analysis showed that the species compositions of the three biotopes remained completely distinct as in previous years. There were clear differences between years for each biotope, but the differences were not so clearly marked as those between the different biotopes in each year. Differences between years were greatest in the *"Ensis"* biotope, and possible reasons for this are discussed.

The original definitions of the three biotopes are no longer considered tenable. It is suggested that the original *"Ensis"* biotope be redefined as the *Dosinia exoleta* assemblage, the *"Arenicola"* biotope as the *"Arenicola/Scoloplos"* assemblage and the *"Lanice/Echinocardium"* biotope as the *"Echinocardium/*Opheliid polychates*"* assemblage. It is further suggested that the degree to which they are representative of the fauna of St Martin's Flats as a whole might be assessed.

The problems of distinguishing between natural and anthropogenic change are discussed. Two possible indicators of environmental deterioration are suggested, a worsening of the ecological condition indicated by AMBI scores in comparison to previous years, and a significant reduction in average taxonomic distinctness (Δ^+) compared with expectation. The determination of species biomasses as well as abundances might also open more possibilities for assessment.

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1 Introduction

1.1 The European Union's Habitats Directive was adopted in 1992 and transposed into UK law by the Habitats Regulations 1994. A primary requirement of the habitats directive is the selection of a series of sites known as Special Areas of Conservation, which are the best examples in Europe of a suite of habitats listed in the Directive. The Isles of Scilly were selected as a Special Area of Conservation (SAC) due to their rich infaunal communities of intertidal and subtidal marine sediments.

1.2 In order to ensure that the features for which the SAC was selected are being conserved, there is a requirement to undertake monitoring of the site at least every six years. The results of monitoring will then be used to inform managers of the site as to any changes that may need to be made.

1.3 This report presents an investigation into the fauna of three biotopes that fall within the 'intertidal mud and sandflats' biotope complex. The three biotopes were defined on the basis of an initial monitoring survey of St Martin's Flats, Isles of Scilly, that was conducted on the 2nd and 3rd August 2000 (Plymouth Marine Laboratory, 2000), and were based largely on physical and biogenic sediment surface features:

1) "*Lanice/Echinocardium*" Biotope
Ripple-marked sand with sparse *Lanice* tubes (fans apparently rather degraded) and *Echinocardium* burrow openings present.

2) "*Ensis*" Biotope
Smoother, more waterlogged sand with evidence of live *Ensis* plus large numbers of empty *Ensis* shells on sediment surface.

3) "*Arenicola*" Biotope
Fine sand with blackening close to the surface. Abundant *Arenicola* holes and casts on sediment surface.

1.4 The 2000 study showed that diversity was higher in samples from the "*Ensis*" biotope than in those from either the "*Arenicola*" or "*Lanice/Echinocardium*" biotopes. Measures of eveness demonstrated that the "*Arenicola*" biotope was heavily dominated by a few species. This was not the case for the "*Ensis*" and "*Lanice/Echinocardium*" biotopes, where individuals were more evenly distributed between the species present. Infaunal organisms were less abundant in the "*Lanice/Echinocardium*" biotope than in either of the other two biotopes. Multivariate analysis showed that the infaunal community comprised three distinct assemblages, associated with the three biotopes, and there was no overlap between samples from the different biotopes. Replicates from each biotope were more similar to each other than to replicates of other biotopes, although the variation in species composition within biotopes was quite high. Each biotope had a characteristic set of species which were absent or had low abundance in each of the other two biotopes.

1.5 The survey was repeated on 15-17 October 2004. The initial intention was to sample exactly the same sites as were sampled in 2000. However, the original "*Ensis*" site sampled in 2000 was situated at Extreme Low Water of Spring Tides and was not uncovered by the tide during that visit, despite this being the period of the lowest predicted tides for the latter part of 2004. Accordingly an alternative site was selected which appeared to have similar surface features to the original site, and five trial samples were collected here for comparison. Four samples had been collected at the original "*Ensis*" location in April 2001 using identical methodology but for a different study, and these samples were also used in the analysis of change.

1.6 Analysis of these samples showed that, although the species composition of each biotope had changed significantly, the biotopes had retained their integrity between 2000 and 2004. Each biotope in 2004 was closer in composition to that same biotope in 2000 than to any other biotope, and diversity profiles (particularly in terms of species accumulation plots) were unchanged.

1.7 The definition of each biotope was questionable. None of the biotopes corresponded exactly with any of those currently classified by the JNCC (Connor et al., 2004).

1.8 The "*Lanice/Echinocardium*" biotope had some species in common with "Polychaetes in littoral fine sand" (LS.LSa.FiSa.Po) and "Polychaete / amphipod dominated fine sand shores" (LS.LSa.FiSa), although none of the characterising species in the St Martin's assemblage were recorded from these two previously described biotopes, and the sediment on St Martin's flats was in the Wentworth grade "coarse sand". The St Martin's assemblage did not correspond with "*Lanice conchilega* in littoral sand" (LS.LSa.MuSa.Lan) because *Lanice* was not present in "densities of common and above". Some of the rarer species in the St Martin's "*Ensis*" biotope are also found in "Polychaetes in littoral fine sand" (LS.LSa.FiSa.Po), but none of the characterising species corresponded and again the sand at St Martin's was coarse.

1.9 The "*Arenicola*" biotope on St Martin's had some of the same characterising species as "Polychaetes in littoral fine sand" (*Scoloplos armiger, Spio filicornis*), and *Arenicola marina* is often recorded from this latter biotope. *Arenicola marina* is a characterising species of "Polychaetes, including *Paraonis fulgens*, in littoral fine sand" (LS.LSa.FiSa.Po.Pful), but *Paraonis fulgens* was not found in this survey. Neverthless, the "*Arenicola*" biotope on St Martin's is probably the closest in composition and habitat type to a previously recorded biotope ("Polychaetes in littoral fine sand").

1.10 The objectives of this study were to repeat the surveys of the sites sampled in earlier years using the same methodology, to analyse the biological samples to the lowest practical taxonomic level, to analyse the resulting data to determine similarities and differences between surveys and to suggest reasons and explanations for any differences.

2 Methods

Field sampling

2.1 Samples were collected on 18-20 September 2009, with predicted low water heights of 0.7, 0.5 and 0.5 m respectively. The original "*Ensis*" site sampled in 2000 was exposed on the 0.5 m tides, and was chosen for the 2009 study. Samples were collected haphazardly within a 20 m radius of a central point: *Lanice/Echinocardium* 49°57'40.0"N 6°17'17.0"W; *Ensis* 49°57'33.78"N 6°17'34.1"W; *Arenicola* 49°57'58.6"N 6°17'35.3"W. The sampling locations are shown in Figure 1.

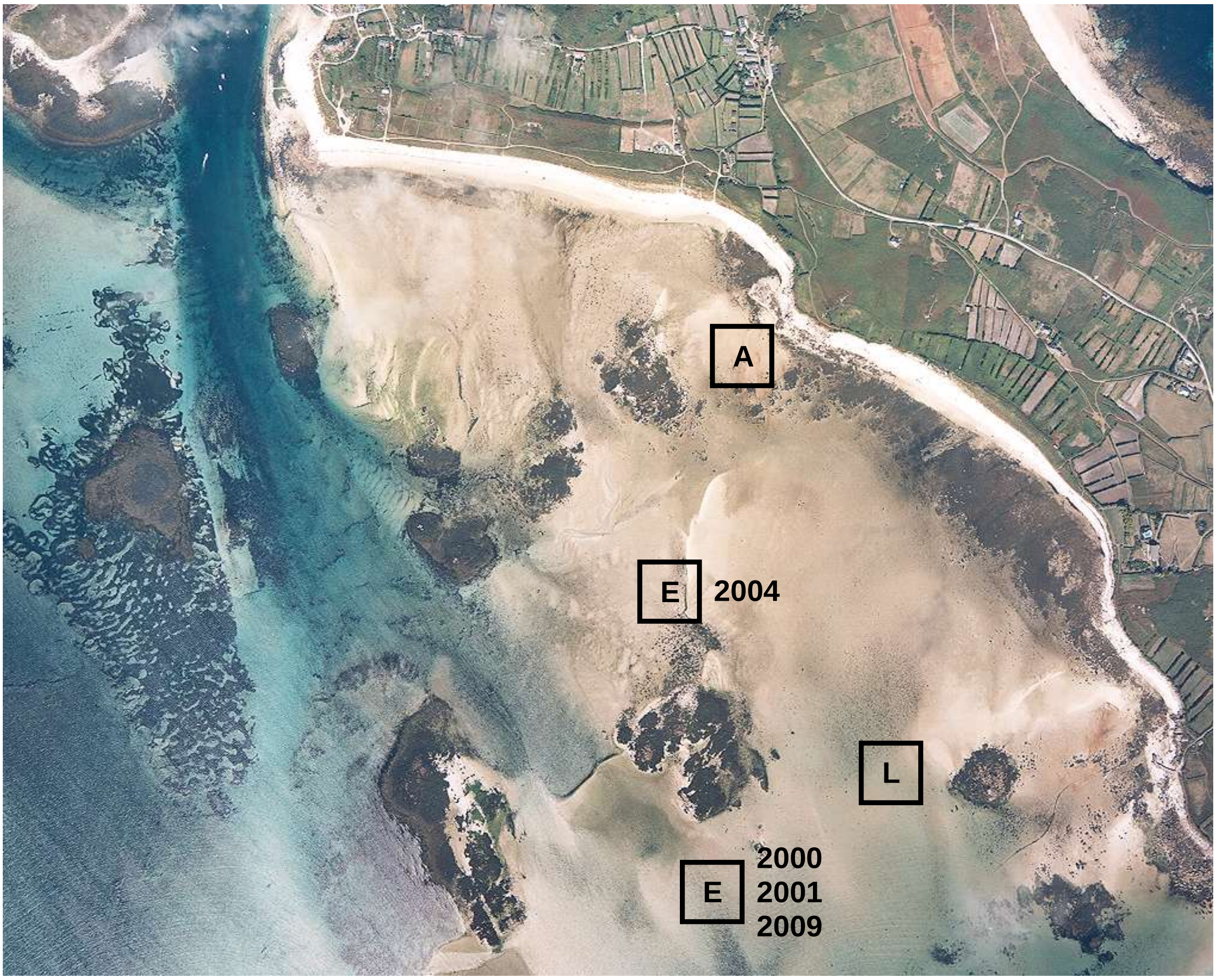

Figure 1 Aerial photograph of the St Martin's sedimentary shore indicating the areas sampled for each of the 3 biotopes: L = *Lanice/Echinocardium*, E = *Ensis* and A = *Arenicola*

2.2 Within each of these sites, 10 replicate core samples, haphazardly distributed throughout the extent of the site, were collected. For each sample, a 0.1m² stainless steel square corer was pushed into the sediment to a depth of 30cm. The sediment within the core was then removed and gently sieved (puddled) over a 1mm mesh. The residue on the sieve was then elutriated by resuspending the sediment in a bucket of seawater that had been pre-filtered through a 0.5 mm sieve, and decanting onto a 1mm-mesh sieve. After 3 elutriations, the residue remaining in the bucket was carefully hand-sorted and all organisms extracted and added to the elutriate. The sample was preserved in 10% formalin. From each of the 3 sites, 2 samples were taken for sediment granulometry.

Laboratory procedures

Sediment granulometry

2.3 Sediment samples were oven dried and sieved through a sieve stack consisting of 7 grades of mesh (4mm, 2mm, 1mm, 0.5mm, 250µm, 125µm and 63µm) on a mechanical sieve shaker. Each sediment fraction was weighed to the nearest milligram on a top-loading balance and cumulative frequency curves were constructed.

Faunal analysis

2.4 Samples were washed free of formalin on a 0.5 mm mesh sieve and the animals picked out under a binocular microscope. Individuals were identified to the lowest practical taxonomic level using the most recent peer approved keys and literature available. On St Martin's flats four species of the amphipod genenus *Urothoe* have been recorded in previous studies. The positive identification of these species requires dissection and can be very time-consuming, since several hundred specimens are present in the samples. There is also some uncertainty regarding specific identification between different sample analysts (even experts sometimes disagree!). Identification to genus level is less of a problem (dissection is not necessary) and, following the recommendation in the 2004 Report, this group of species has been identified to genus level only. Species nomenclature follows Howson & Picton (1997).

Data analysis

2.5 For comparison with earlier years, the same methods of data analysis were used as in the 2004 Report. Univariate measures of community structure and diversity [number of species, number of individuals, Margalef species richness (d), Shannon-Wiener diversity (H'), Pielou's eveness (J'), estimated number of species for 50 individuals (ES(50)) and Simpson's Index were calculated for each sample. Diversity profiles were also visualised by plotting *k*-dominance curves, and species accumulation plots were constructed based on the means of up to 999 permutations of the sample ordering. Multivariate data analyses followed the methods described by Clarke (1993) using the PRIMER (<u>P</u>lymouth <u>R</u>outines <u>I</u>n <u>M</u>ultivariate <u>E</u>cological <u>R</u>esearch) software package (Clarke & Warwick, 2001), using the Bray-Curtis similarity measure on square root transformed species abundance data.

2.6 In addition, two other types of univariate measures were determined, and applied to the whole time-series of data. AMBI (AZTI's Marine Biotic Index) was designed to analyse the response of macrobenthic assemblages in European coastal waters to changes in environmental quality (Borja et al., 2000, 2003). The species are classified into five ecological groups depending on their sensitivity to environmental stress, and the index is based on the relative abundances of species in each group. The index has become one of the mainstays for the assessment of ecological status under the European Water Framework Directive, and it was therefore considered appropriate to assess the ecological status of the St Martin's Flats assemblages on these terms.

2.7 Another biodiversity measure that is independent of species richness and is responsive to anthropogenic disturbance concerns the taxonomic relatedness of species in the assemblage. It is well known that in impacted assemblages of organisms the taxonomic spread of species is reduced, and in extreme cases they may be sibling species belonging to the same genus, or at least very closely related. Unimpacted assemblages, on the other hand, have a wider taxonomic spread and the species belong to many different genera, families, orders, classes and phyla. The methods are based on tracing the average path length or taxonomic distance between every pair of individuals or species in a taxonomic classification tree, or measuring the variability in these path lengths. The measures are independent of sample size or sampling effort, and are little affected by small variations in habitat type. They can be used for data consisting simply of species lists and arising from unknown or uncontrolled sampling effort, which usually renders it impossible to read anything into the relative size of these lists. There are possible permutation tests for the significance of departure from expectation. The methods are fully described in the

PRIMER (Plymouth Routines In Multivariate Ecological Research) software package (Clarke & Warwick, 2001).

3 Results

Sediment granulometry

3.1 The sediments within the "*Ensis*" biotope predominantly consisted of coarse sand, whilst the sediments of the and "*Lanice/Echinocardium*" and "*Arenicola*" biotopes were finer and were predominantly medium sand (Table 1).

Table 1 Weights of sediment fractions (grams) for duplicate samples from each of the three biotopes (L = "*Lanice/Echinocardium*", E = "*Ensis*", A = "*Arenicola*")

Wentworth grade	Size fraction	L1	L2	E1	E2	A1	A2
Small pebble (gravel)	4-8mm	0.533	1.052	0	0	0	0.166
Granule	2-4mm	1.116	1.139	0.125	1.792	0.79	0.596
Sand - very coarse	1-2mm	1.641	1.771	5.013	11.617	2.073	2.763
Sand - coarse	0.5-1mm	17.838	17.944	23.773	19.945	3.03	3.179
Sand - medium	250-500μm	23.758	21.246	15.051	10.621	26.416	21.728
Sand - fine	125-250μm	1.725	1.576	0.311	0.195	10.506	7.616
Sand - very fine	63-125μm	0.091	0.092	0.014	0.02	0.114	0.098
Silt & clay	<63μm	0.016	0.023	0.004	0.006	0.012	0.015
Total		**46.718**	**44.843**	**44.291**	**44.196**	**42.941**	**36.161**

3.2 Cumulative plots of the percentages by weight of the sediment size fractions (Figure 2) show that the granulometry was quite variable between replicates at the *"Ensis"* site, but the duplicate samples were very similar at the other two sites. The median particle diameter (the point at which the curve crosses the 50% line) consistently ranks the sediments (coarsest to finest) E>L>A. There has been no appreciable change in the sediment grades.

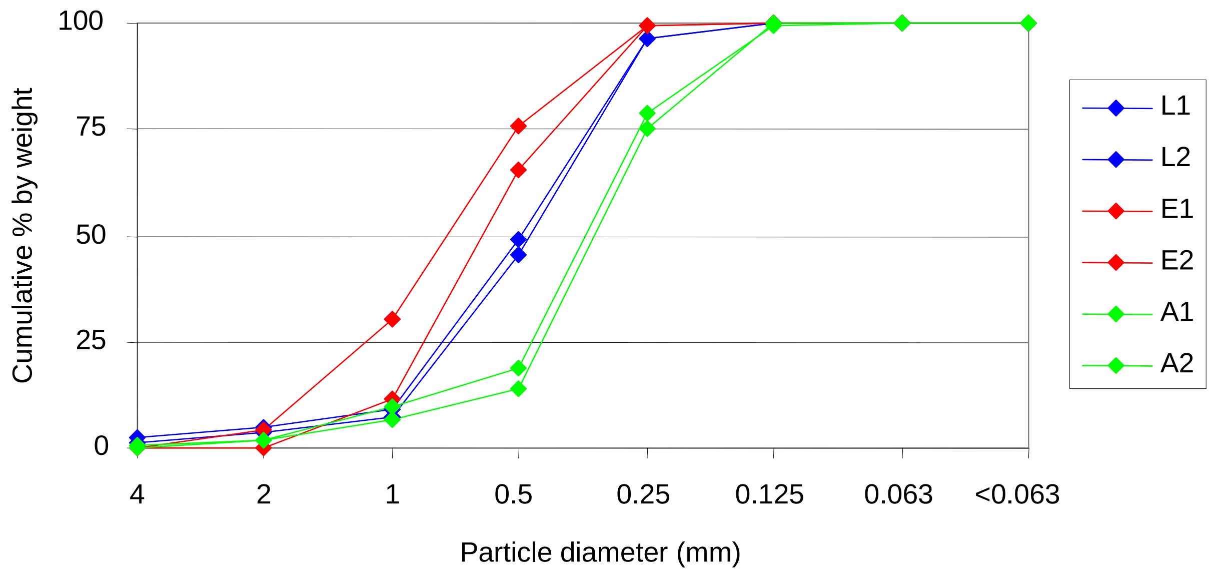

Figure 2 Cumulative plots of sediment fractions for duplicate samples in the three biotopes (L = "*Lanice/Echinocardium*", E = "*Ensis*", A = "*Arenicola*")

Faunal diversity

3.3 The values of a range of biodiversity indices are given in Table 2

Table 2 Univariate community indices for all sample sets designated by biotope and year (L = "*Lanice/Echinocardium*", A = "*Arenicola*", E = "*Ensis*"). Values are calculated for the mean abundances of species in all replicates in that sample set.

Site	S	N	d	J'	ES(50)	H'	Simpson	Δ	Δ*	Δ^+	Λ^+
L2000	30	19.40	9.78	0.79	10.00	2.68	0.93	83.86	90.05	88.70	358.20
L2004	37	61.70	8.73	0.50	8.61	1.80	0.69	62.87	91.76	90.37	292.14
L2009	35	20.30	11.29	0.72	8.00	2.55	0.86	78.79	91.21	89.58	335.86
E2000	60	65.40	14.11	0.78	18.66	3.19	0.95	86.82	91.40	88.14	358.92
E2001	27	56.25	6.45	0.69	8.78	2.27	0.86	71.21	82.88	91.03	296.95
E2004	44	145.80	8.63	0.61	13.74	2.32	0.82	71.84	87.89	89.04	314.49
E2009	28	20.70	8.91	0.74	8.00	2.48	0.90	82.47	91.15	91.09	336.61
A2000	33	54.40	8.01	0.53	8.56	1.84	0.77	67.64	88.24	87.85	335.79
A2004	35	73.10	7.92	0.58	10.89	2.05	0.75	66.49	88.13	87.45	327.12
A2009	24	55.60	5.72	0.45	8.54	1.44	0.56	53.01	94.52	85.45	376.97

3.4 For the "*Lanice/Echinocardium*" biotope all the diversity measures, including the taxonomic distinctness indices, have remained relatively constant over the sampling period. For the "*Arenicola*" biotope the total number of species (S) has decreased, as have some of the species diversity measures, notably species richness (d), evenness (J'), Shannon diversity (H' $\log_e$) and Simpson's index (1-Lambda'). However, average taxonomic distinctness (Δ*) has increased. Diversity values for the "*Ensis*" biotope are more difficult to compare and interpret because of the different numbers of replicates taken (10 in 2000 and 2009, 4 in 2001, 5 in 2004) and the different sampling location in 2004. However, the 2000 and 2009 samples are the same in terms of location and number of replicates, and there has clearly been a dramatic drop in total numbers of species (60 to 28), the number of individuals per sample (65 to 21) and in all species diversity measures. However, this is not the case for average taxonomic distinctness (Δ*).

3.5 AMBI (AZTI's Marine Biotic Index) scores for each biotope on each sampling occasion are given in Table 3.

Table 3 Percentage contribution of each AMBI ecological group, the mean AMBI scores and the Disturbance Classsification for all sample sets designated by biotope and year (L = "*Lanice/Echinocardium*", A = "*Arenicola*", E = "*Ensis*")

Site	I(%)	II(%)	III(%)	IV(%)	V(%)	Mean AMBI	Disturbance Clasification
L2000	75.4	12.6	4.7	0	7.3	0.747	Undisturbed
L2004	84	9.3	5.4	0.2	1.1	0.379	Undisturbed
L2009	81.9	9.5	7	1	0.5	0.393	Undisturbed
E2000	61.3	11.1	24.8	0.3	2.5	1.167	Undisturbed
E2001	36	45.3	17.3	0	1.3	1.297	Slightly disturbed
E2004	9.9	12.6	71.3	5.8	0.4	2.567	Slightly disturbed
E2009	54.1	35.6	10.2	0	0	0.824	Undisturbed
A2000	35.3	2.8	39.7	0.6	21.7	2.628	Slightly disturbed
A2004	56.4	5.9	36.6	0.7	0.4	1.344	Slightly disturbed
A2009	70.9	5.6	23	0.4	0.2	0.867	Undisturbed

3.6 For the "*Lanice/Echinocardium*" biotope the mean AMBI score always indicates an undisturbed assemblage. This is also true for the *"Ensis"* biotope in 2000 and 2009, when the sampling location and number of replicates was comparable, although the intervening period (2001 and 2004) showed indications of slight disturbance. For the "*Arenicola*" biotope the AMBI scores suggested a slightly disturbed assemblage in 2000 and 2004, but undisturbed in 2009.

3.7 The *k*-dominance plots for each biotope are given in Figure 3. For the "*Lanice/Echinocardium*" biotope the diversity profiles for 2000 and 2009 are rather coincident and cross one another, but the curve for 2004 shows higher dominance, due to the high abundance of two species, *Urothoe* spp. and *Ophelia rathkei*, the first and second ranked species. For the "Ensis" biotope the curve for 2000 is below the others throughout its length, indicating higher diversity, and subsequent to this all the remaining curves are very similar. For the "*Arenicola*" biotope the curves are quite similar and cross one another, but that for 2009 is generally more elevated, due to the higher dominance of the amphipod *Urothoe* spp. than in previous years.

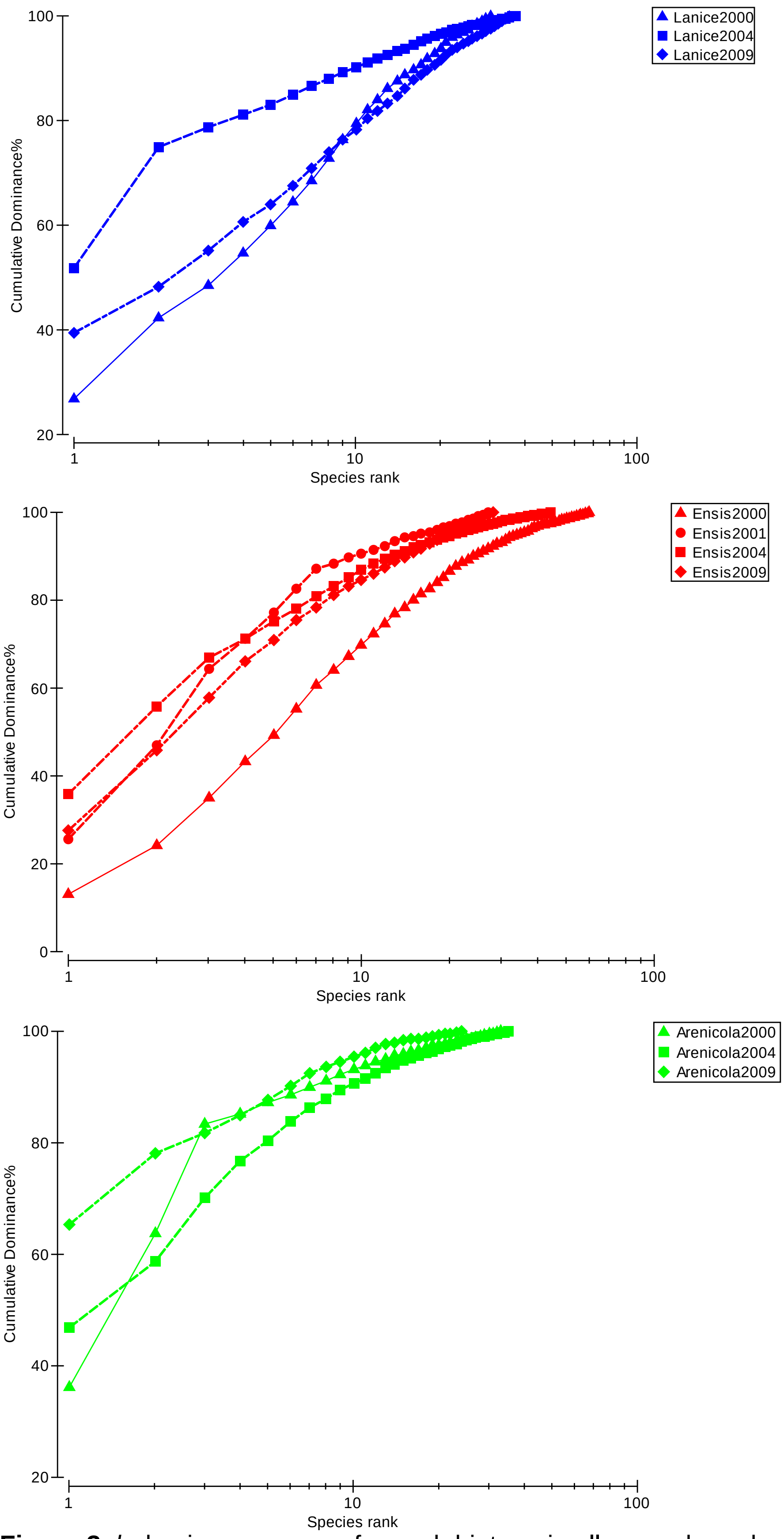

Figure 3 *k*-dominance curves for each biotope in all years, based on total abundances of species in all replicates. Symbols and colours are the same as those used in subsequent Figures: triangles = 2000, circles = 2001, squares = 2004, diamonds = 2009; blue = "*Lanice/Echinocardium"* biotope, red = "*Ensis"* biotope, green = "*Arenicola"* biotope

3.8 In view of the lack of comparability of sample sizes, perhaps the best way of comparing diversity profiles is in terms of the species accumulation curves (Figure 4). These plots allow sample sets with different numbers of replicates to be directly compared. They clearly separate two higher diversity sample sets, "Ensis" 2000 and "Ensis" 2004 from the remainder. Species accumulation profiles are very similar within these two groups of sample sets. Thus, in these terms, the diversity of the "Lanice/Echinocardium" and "Arenicola" biotopes remained unchanged throughout the sampling period, with the diversity of the "Ensis" biotope higher in 2000 and 2004 but similar to the other two biotopes in 2001 and 2009. The 2004 "Ensis" biotope samples should perhaps be discounted from this comparison since they were taken from a different location from the other years. The contrast between high diversity in 2000 (red triangles in Figure 4) and diversity comparable to the other biotopes just a year later in 2001 (red circles in Figure 4) is possibly due to the fact that the "Ensis" 2001 samples were collected in the Spring (April) whereas all the other samples were collected in late summer, and there may be seasonal differences in the number of species present. It is perhaps relevant to note that several of the species that had apparently disappeared in 2001 we small crustaceans (amphipods, cumaceans, tanaids) that might have annual life cycles and thus be seasonal in their occurrence. However, strictly comparable sampling of the "Ensis" site in terms of location and season in 2009 (red diamonds in Figure 4) indicate a clear and dramatic reduction in diversity since 2000.

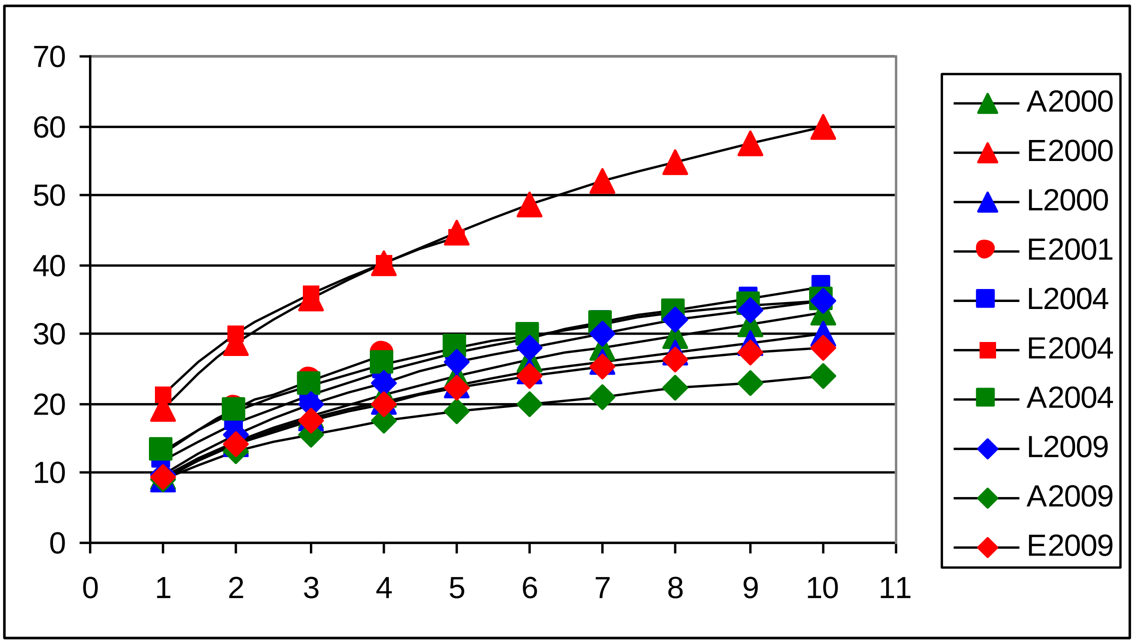

Figure 4 Number of species (y-axis) plotted against replicate number (x-axis), based on means of up to 999 permutations of the sample order, for each biotope and year

Community composition

3.6 A subjective impression of the surface features of the three sites suggested that in the *"Lanice/Echiocardium"* biotope there were fewer feeding fans of the sand-mason worm *Lanice* than in previous years and in the *"Ensis"* biotope there were fewer dead razor shells on the sediment surface and less evidence of the presence of live specimens (i.e. squirting water when disturbed).

3.7 Two dimensional non-metric MDS ordination plots for all sample sets are given in Figure 5. In 2000, as reported previously, the infaunal community consisted of three distinct assemblages corresponding with the three biotopes that had been subjectively identified. The left-hand plots in Figure 5 show that these assemblages remained completely distinct in 2004 and 2009.

3.8 Two-way crossed ANOSIM (Analysis of Similarities) tests for differences in the composition of biotopes, allowing for differences between years, gave a global R-statistic of 0.96 and a significance level of 0.1%. (The R statistic compares similarities in species composition between biotopes and takes a value of 1 when all replicates *within* a biotope are more similar to each other than any replicates *between* biotopes, and a value of zero when there is no difference on average between the within and between biotope similarities. The significance of the difference is determined by a randomisation/permutation test).

3.9 The right-hand plots in Figure 5, for each biotope in all years, indicate clear differences between years for each biotope, but the differences are not so clearly marked as those between the different biotopes in each year.

3.10 Two-way crossed ANOSIM (Analysis of Similarities) tests for differences in the composition between years, allowing for differences between biotopes, gave a global R-statistic of 0.72 and a significance level of 0.1%. (The R statistic compares similarities in species composition between years and takes a value of 1 when all replicates *within* a year are more similar to each other than any replicates *between* years, and a value of zero when there is no difference on average between the within and between year similarities. The significance of the difference is determined by a randomisation/permutation test).

3.11 Two-way SIMPER (Similarity Percentages) analysis has been used to determine the species responsible for the similarity in the species composition among replicates of each biotope across all years, based on the root transformed species abundance data and the Bray Curtis similarity measure (Tables 4-6).

Table 4 Percentage species contributions to the average similarity (46.96) among replicates across all years in the *"Lanice/Echinocardium"* biotope, ranked in order of importance, with a cut-off at 90%

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Urothoe spp.	3.23	15.97	2.00	34.01	34.01
Ophelia rathkei	1.72	6.43	0.89	13.69	47.71
Travisia forbesii	1.07	5.03	0.68	10.71	58.41
Echinocyamus pusillus	0.80	3.04	0.78	6.47	64.88
Perioculodes longimanus	0.77	2.76	0.83	5.88	70.76
Echinocardium cordatum	0.53	2.10	0.58	4.47	75.23
Angulus tenuis	0.51	1.58	0.52	3.37	78.60
Branchiostoma lanceolatum	0.38	1.36	0.44	2.90	81.50
Tellimya ferruginosa	0.30	0.91	0.34	1.95	83.44
Leptosynapta inhaerens	0.23	0.82	0.35	1.75	85.19
Spionidae indet	0.32	0.81	0.42	1.71	86.91
Dosinia exoleta	0.35	0.80	0.34	1.70	88.61
Nephtys caeca	0.33	0.78	0.35	1.67	90.28

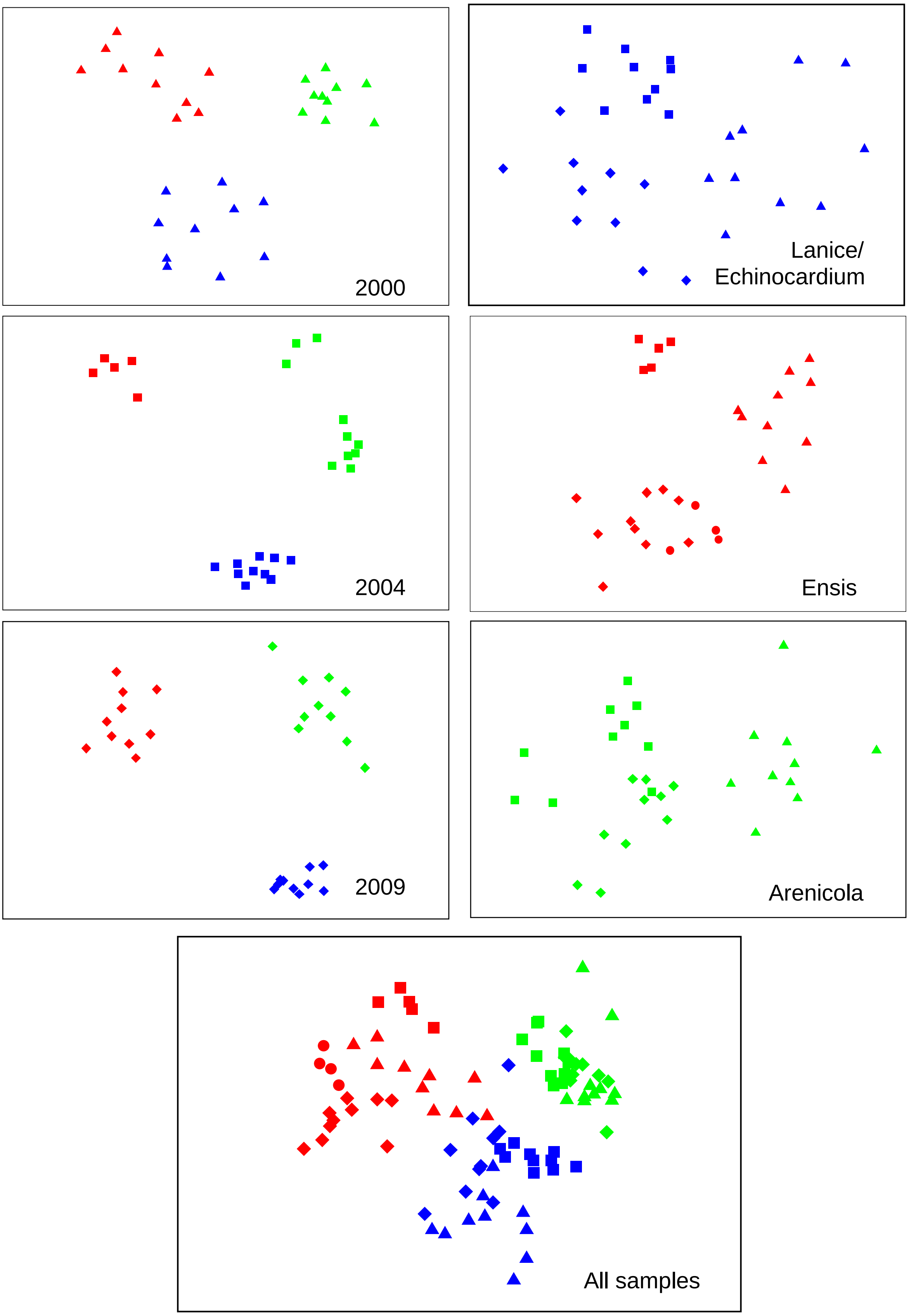

Figure 5 Non-metric MDS ordinations for square-root transformed species abundance data using the Bray-Curtis similarity measure. Left-hand plots are for all biotopes in each year. Right-hand plots are for individual biotopes in all years. Triangles = 2000, circles = 2001, squares = 2004, diamonds = 2009; blue = "*Lanice/Echinocardium*" biotope, red = "*Ensis*" biotope, green = "*Arenicola*" biotope

Table 5 Percentage species contributions to the average similarity (49.92) among replicates across all years in the *"Ensis"* biotope, ranked in order of importance, with a cut-off at 90%

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Dosinia exoleta	1.93	8.40	1.3	16.84	16.84
Ehlersia cornuta	2.03	5.55	1.04	11.12	27.96
Glycera lapidum complex	1.30	5.22	1.04	10.46	38.42
Notomastus latericeus	1.83	3.97	0.86	7.95	46.38
Apseudes latreillii	1.87	3.31	0.75	6.64	53.01
Aonides oxycephala	1.68	2.94	0.82	5.90	58.91
Urothoe spp.	1.28	2.80	0.69	5.61	64.52
Echinocardium cordatum	0.53	2.26	0.62	4.53	69.05
Echinocyamus pusillus	0.99	1.94	0.69	3.89	72.93
Leptosynapta inhaerens	0.62	1.52	0.68	3.05	75.98
Branchiostoma lanceolatum	0.76	1.49	0.51	2.99	78.97
Moerella pygmaea	0.69	1.37	0.51	2.75	81.72
Lutraria lutraria	0.29	0.84	0.36	1.69	83.41
Perioculodes longimanus	0.54	0.83	0.45	1.66	85.06
Iphinoe trispinosa	0.67	0.79	0.53	1.58	86.64
Ensis arcuatus	0.41	0.70	0.47	1.40	88.04
Gari depressa	0.42	0.69	0.49	1.39	89.43
Mediomastus fragilis	0.48	0.47	0.32	0.95	90.38

Table 6 Percentage species contributions to the average similarity (56.19) among replicates across all years in the *"Arenicola"* biotope, ranked in order of importance, with a cut-off at 90%

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Urothoe spp.	4.90	18.71	2.01	33.30	33.30
Scoloplos armiger	3.21	13.76	2.27	24.49	57.79
Malacoceros fuliginosus	1.01	4.13	0.58	7.34	65.13
Nephtys hombergii	0.76	2.92	0.95	5.20	70.33
Notomastus latericeus	1.13	2.82	0.67	5.01	75.35
Euclymene oerstedi	0.71	1.53	0.51	2.73	78.07
Arenicola marina	0.68	1.28	0.52	2.29	80.36
Spio filicornis	0.57	1.16	0.39	2.06	82.42
Pygospio elegans	0.47	1.05	0.41	1.87	84.29
Sphaeroma serratum	0.41	1.00	0.49	1.77	86.06
Crangon crangon	0.47	0.98	0.43	1.74	87.80
Angulus tenuis	0.41	0.83	0.46	1.47	89.27
Perioculodes longimanus	0.40	0.69	0.4	1.23	90.50

3.12 In general, changes in species composition between years resulted from rather subtle changes in the relative abundances of a large number of species, rather than more dramatic changes in abundance of a few dominants. A notable exception to this was the complete disappearance in 2009 of the distinctive cumacean *Apseudes latreilli* from the "Ensis" biotope, which had been very abundant in earlier years.

4 Discussion

Faunal changes over time

4.1 The detailed analysis above shows that, although the species composition of each biotope has changed significantly, the biotopes have retained their integrity between 2000 and 2009. Each biotope in 2009 was closer in composition to that same biotope in 2000 and 2004 than to any other biotope. Diversity profiles (particularly in terms of species accumulation plots) were unchanged for the *"Lanice/Echinocardium"* and *"Arenicola"* biotopes, but for the *"Ensis"* biotope diversity was much lower in 2009 than in 2000, the only other strictly comparable year in terms of sampling location and number of replicates. There were also larger changes in the species composition of the *"Ensis"* biotope between years than in the other two biotopes (right-hand MDS plots, Figure 5). This biotope is a more physically dynamic habitat than the other two, as evidenced by the coarseness of the sediment, and is therefore more likely to be subject to short-term fluctuations in species composition and diversity. Small short-lived species are likely to fluctuate in abundance from year to year, as exemplified by the disappearance of the cumacean *Apseudes latreilli* from this biotope. Some large species that can live for many years may have regular recruitment in each year and establish temporally stable populations, while others may have exceptionally successful recruitment in some years but recruitment failures in others. An example of the former is the clam *Dosinia exoleta*, which was represented in the 2009 samples by about 10 year-classes of various strength (Figure 6). On the other hand another large bivalve, the razor shell *Ensis arcuata*, large specimens of which had initially been used to define this biotope, had virtually disappeared in 2009, while very large and conspicuous specimens of the bivalve *Lutraria lutraria* were present (Figure 7). This species was absent in the 2000 samples and the specimens all appeared to be of the same age (~8 years) with no younger individuals present, suggesting settlement soon after 2000 but with no subsequent recruitment.

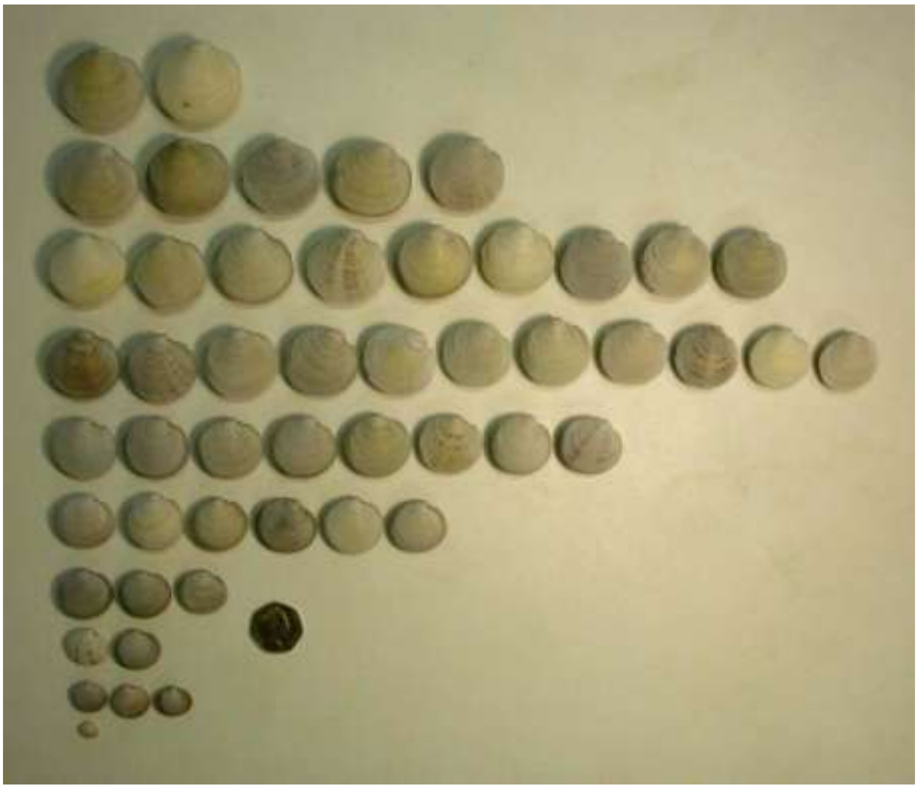

Figure 6 Specimens of the clam *Dosinia exoleta* from the *"Ensis"* biotope in 2009, arranged in year classes and indicating successful regular recruitment each year

Figure 7 Specimens of the clam *Lutraria lutraria* from the *"Ensis"* biotope in 2009, indicating a single year-class with no recruitment in recent years

Biotope definition

4.2 The definition of each biotope remains open to question. As discussed in sections 1.7 to 1.9, none of the biotopes corresponds exactly with any of those currently classified by the JNCC (Connor et al., 2004). Matches can be found with levels 1 and 2 of the biotope classification which relate to the physical characters of the habitat, but at level 3 and higher the faunistic composition begins to comprise part of the definition and no exact matches can be found. Appendix 2 lists potential candidates from the National Biodiversity Network database for level one Littoral sediment (LS) and Sublittoral sediment (SS) habitats previously recorded from Scilly. The latter were considered because, as noted by early naturalists, there are many species that occur intertidally on Scilly that are only found in deeper water elsewhere in Britain. Holme (1961) listed a number of bivalve molluscs that fall into this category, as do the crinoid *Antedon bifida*, the conspicuous orange seven-armed starfish *Luidia ciliaris* and the cephalochordate *Branchiostoma lanceolatum* (the latter being frequent on St Martin's Flats). Harvey (1969) makes a number of suggestions as to the causes of this phenomenon. The relative scarcity of near zero temperatures may permit animals to come up into the littoral, as may the negligible lowering of salinity that might deter some species, especially echinoderms, from littoral life. The phenomenon is not confined to the macrobenthos. Hummon and Warwick (1990) found several meiobenthic interstitial gastrotrich species in sandy beaches of Scilly that elsewhere only occurred sublittorally. They suggested that an additional possible explanation for this was the angularity of the sand grains derived from granite, which were tightly packed and restricted drainage from the beach at low tide, resulting in an interstitial environment no different from the sublittoral. It is clear from Appendix 2 that a large number of records from Scilly provide an uncertain match with a previously recognised biotope, in which cases attempts to ascribe them to such biotopes seems inappropriate.

4.3 Nevertheless, at least three distinct associations of species are present on St Martin's Flats, and more extensive mapping might reveal more. The biotope names initially ascribed to two of these associations, *"Lanice/Echinocardium"* and *"Ensis"*, cannot be retained since *Lanice* and *Ensis* are no longer features of them. A more realistic definition of these assemblages might best be gained from examination of the species that ***consistently*** make a substantial contribution to the Bray Curtis similarity among samples collected from each location (Tables 4-6). Candidate species that ***typify*** that assemblage should be found at a consistent abundance throughout, so the standard deviation of their contribution is low, and the ratio of Similarity/SD is high. For the *"Ensis"* biotope there is a clear candidate for the characterising species: the clam *Dosinia exoleta* makes the greatest contribution to the similarity among replicates and is the most consistent, with the highest Similarity/SD ratio (Table 5). It is also large and easily recognisable (Figure 6). For the *"Arenicola"* biotope (Table 6) the greatest contribution to the similarity among samples is made by *Urothoe* spp., but these amphipods also make the greatest contribution to the *"Lanice/Echinocardium"* biotope. The next most important contribution is made by the polychaete *Scoloplos armiger*, which unique to this assemblage and is also the most consistent, but it is also appropriate to retain the lugworm *Arenicola marina* as an assemblage-defining species in view of its large size and the consistently clear indications of its presence from surface features (casts and burrows). It is therefore suggested that this be designated the *"Arenicola/Scoloplos"* assemblage. The original *"Lanice/Echinocardium"* biotope is the most problematic, since many of the species that contribute to the similarity among samples are also found at the other two sites. However, two ophelliid polychaetes *Ophelia rathkei* and *Travisia forbesii* make the second and third highest contributions to inter-sample similarity (Table 4) and are unique to this assemblage, and it is suggested that this be termed the *"Echinocardium/*Opheliid polychaetes*"* assemblage. The term "assemblage" rather than "biotope" is used here for the purposes of this study, rather than adding to the plethora of named biotopes that already exist and which are constantly being added to with each new area investigated.

Favourable condition

4.4 The Targets relevant to this project are that average sediment particle size parameters and composite species, abundance and diversity "should not deviate significantly from an established baseline, subject to natural change". The obvious problems here are defining the baselines and distinguishing between natural and anthropogenic change.

4.5 Multivariate analyses have shown that, for each of the three study areas, there have been statistically significant changes in species composition between years. There is no reason to suppose that these changes are not natural, and with a naturally fluctuating baseline it is not easy to determine what degree of change is acceptable and how this could be measured. Similarly, a reduction in species diversity in 2009 for the *"Ensis"* biotope, compared with earlier years, is difficult to assess unless the range of natural variation to be expected in such a habitat is known, and sampling on only three occasions cannot establish this.

4.6 The ecological condition determined by the AMBI score is based on a global comparison with other areas. All three biotopes were in the "undisturbed" category in 2009, and future change into a category worse than has been found any of the ealier surveys (Table 3) could, in future, be taken as an unfavourable condition needing further investigation.

4.7 Taxonomic distinctness measures of biodiversity are, unlike species richness measures, relatively insensitive to small natural changes in habitat but are sensitive to anthropogenic disturbance (Leonard et al., 2006). For taxonomic distinctness indices based on simple species lists (presence or absence of species) there is a potential framework within which these measures can be tested for departure from expectation (see Clarke & Warwick, 2001). This envisages a master list or inventory of species encompassing the appropriate region/biogeographic area, from which the species found at one locality can be thought of as drawn. For example, Figure 8 uses the complete faunal list for St Martin's Flats in all biotopes and years. The species complement at any particular biotope and year can be compared with the master list, to ask whether the observed subset of species is representative of the biodiversity expressed in the full species inventory. Clearly, such a comparison is impossible for species richness since the list at one location is automatically shorter than the master list. However, the key point here is that average taxonomic distinctness (Δ^+) of a randomly selected sublist does not differ, in mean value, from AvTD for the master list, and reductions from this level can be interpreted as loss of biodiversity. Furthermore, there is a natural testing framework for how large a decrease (or increase) from expectation needs to be, in order to be deemed statistically significant. For an observed set of *m* species at one location, sublists of size *m* are drawn at random from the master inventory, and their AvTD values computed. From, say, 999 such simulated sublists, a histogram can be constructed of the expected range of Δ^+ values, for sublists of that size, against which the true Δ^+ for that locality can be compared. If the observed Δ^+ falls outside the central 95% of the simulated Δ^+ values, it is considered to have departed significantly from expectation. The construction of these 95%

probability intervals can be repeated for a range of sublist sizes (m = 10, 15, 20, …) and the resulting upper and lower limits plotted on a graph of Δ^+ against m. When these limit points are connected across the range of m values, the effect is to produce a funnel plot (such as seen in Figure 8). The real Δ^+ values for a range of observational studies are now added to this plot, allowing simultaneous comparison to be made of distinctness values with each other and with the expected limits. Similar comparisons can be made for VarTD. In general, impacted assemblages are characterised by decreased AvTD (i.e. this index behaves monotonically) and increased VarTD, but the latter may not always be the case. For the St Martin's flats biotopes, measured values of Δ^+ all fall within the 95% confidence limits of the simulated null distribution based on random samples from the master list (Figure 8), suggesting that biodiversity in these terms does not depart from expectation. If biotopes fall outside these 95% confidence limits in future, an unfavourable condition would be indicated.

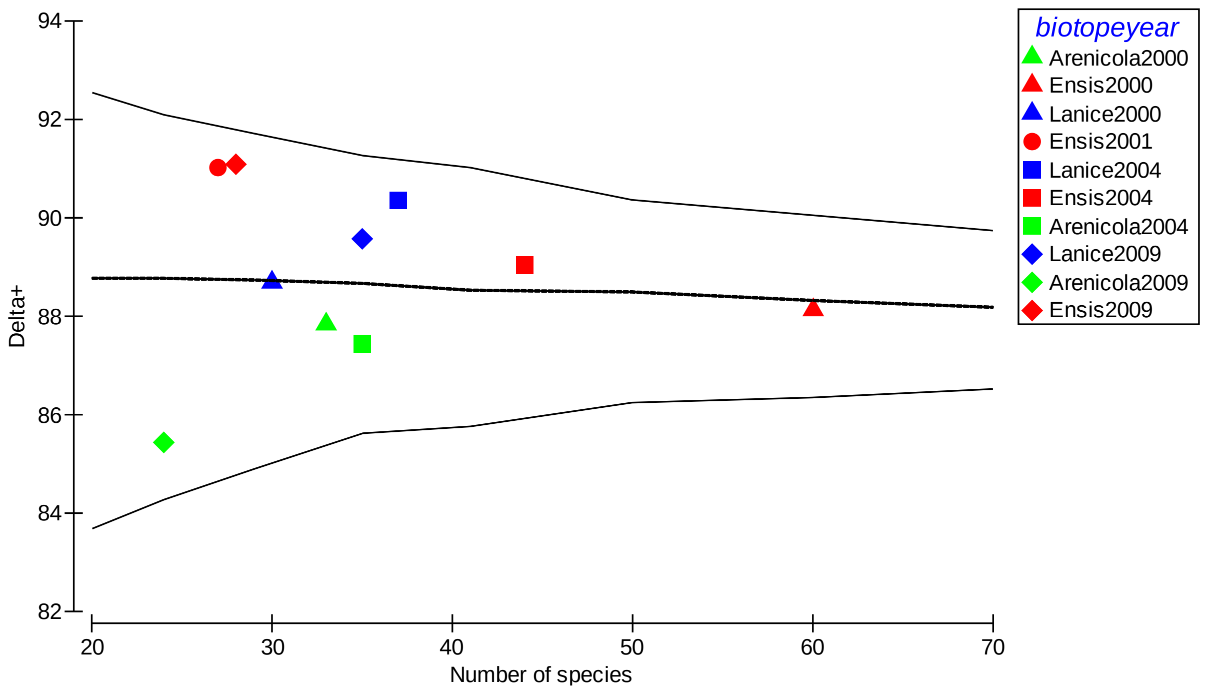

Figure 8 Frequency-based funnel plot for simulated AvTD for a range of sublist sizes (x-axis). Funnel indicates limits within which 95% of simulated Δ^+ values lie. The thick line indicates mean Δ^+ (the AvTD for the master list) and data points are the true AvTD (y-axis) for each biotope/year combination plotted against their sublist size (x-axis)

5 Recommendations

5.1 The current sampling and analytical protocols are considered appropriate for future monitoring.

5.2 The original *"Ensis"* biotope should be redefined as the *Dosinia exoleta* assemblage, the *"Arenicola"* biotope as the *"Arenicola/Scoloplos"* assemblage and the *"Lanice/Echinocardium"* biotope as the *"Echinocardium/*Opheliid polychates*"* assemblage.

5.3 In order to sample the *Dosinia exoleta* assemblage at the same location as in 2000 and 2009, a low tide of 0.5 m or lower must be chosen. In 2004 the site was not exposed on a 0.7 m tide.

5.4 Natural England might wish to undertake a grid sampling survey over the whole area of St Martin's Flats, in order to ascertain the degree to which the three chosen monitoring locations are representative of the two habitats listed in Annex 1 of the EU Habitats Directive and for which the Isles of Scilly were selected as a Special Area of Conservation, namely "Mudflats and sandflats not covered by water at low tide" and "Sandbanks which are slightly covered by seawater all the time".

5.5 Some consideration might also be given to the determination of species biomasses as well as abundances (simple blotted wet-weights would suffice). This would open more opportunities for the assessment of anthropogenic disturbance, for example the abundance / biomass comparison (ABC) method or the phylum level meta-analysis (see Clarke & Warwick, 2001).

6 References

BORJA, A., FRANCO, J. & PÉREZ, V. 2000. A marine biotic index to establish the ecological quality of soft bottom benthos within European estuarine and coastal environments. *Marine Pollution Bulletin,* 40, 1100-1114.

BORJA, A., MUXIKA, I. & FRANCO, J. 2003. The application of a Marine Biotic Index to different impact sources affecting soft-bottom benthic communities along European coasts. *Marine Pollution Bulletin,* 46, 835-845.

CLARKE, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology,* 18, 117–143.

CLARKE, K.R. & WARWICK, R.M. 2001. *Changes in marine communities: an approach to statistical analysis and interpretation. 2nd Edition.* Plymouth Marine Laboratory, Plymouth.

CONNOR, D.W. and others. 2004. *The Marine Habitat Classification for Britain and Ireland Version 04.05.* JNCC, Peterborough. ISBN 1 861 07561 8 (internet version) URL: **www.jncc.gov.uk/** [Accessed May 2010]. Marine Habitat Classification.

HARVEY, L.A. 1969. The marine flora and fauna of the Isles of Scilly. The islands and their ecology. *Journal of Natural History*, 3, 3-18.

HOLME, N.A. 1961. The bottom fauna of the English Channel. *Journal of the Marine Biological Association of the United Kingdom,* 41, 397-461.

HOWSON C.M. & PICTON, B.E. 1997. *The species directory of the marine fauna and flora of the British Isles and surrounding seas.* Ulster Museum Publication No. 276, Ulster and the Marine Conservation Society, Belfast and Ross-on-Wye.

HUMMON, W.D. & WARWICK, R.M. 1990. The marine flora and fauna of the Isles of Scilly - Gastrotricha. *Journal of Natural History*, 24(2), 519-525.

LEONARD, D.R.P., CLARKE, K.R., SOMERFIELD, P. & WARWICK, R.M. 2006. The application of an indicator based on taxonomic distinctness for UK marine biodiversity assessments. *Journal of Environmental Management,* 78, 52-62.

Appendix 1 Species abundance data

Table A Species abundance data for the "*Lanice/Echinocardium*" biotope, September 2009

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Total
NEMERTEA	0	0	0	1	0	1	0	0	0	0	**2**
Glycera capitata	0	0	1	0	0	0	0	0	3	0	**4**
Platnereis dumerilii	0	0	0	1	0	0	0	0	0	0	**1**
Nephtys caeca	0	1	1	0	1	2	2	0	0	0	**7**
Nephtys hombergii	0	0	0	0	1	0	1	1	0	0	**3**
Marphysa bellii	0	0	0	0	0	0	0	0	1	0	**1**
Aonides oxycephala	1	1	0	0	0	0	0	0	0	0	**2**
Aonides paucibranchiata	0	0	0	0	1	0	0	0	0	0	**1**
Chaetozone sp.	0	0	1	0	0	0	0	0	1	0	**2**
Capitella sp.	1	0	0	0	0	0	0	0	0	0	**1**
Notomastus latericeus	1	1	0	0	0	0	2	0	0	0	**4**
Ophelia rathkei	7	1	1	0	0	0	3	1	5	0	**18**
Travisia forbesii	0	0	0	0	1	1	0	0	1	0	**3**
Lanice conchilega	1	0	0	0	0	0	0	0	0	0	**1**
Thelepus sp.	0	0	1	0	0	0	0	0	0	0	**1**
AMPHIPODA	0	0	1	0	1	1	0	0	0	0	**3**
Perioculodes longimanus	0	0	0	0	0	1	0	0	0	0	**1**
Potocrates altamarinus	0	0	0	0	0	0	0	0	1	0	**1**
Urothoe spp.	8	4	19	13	4	9	9	7	6	1	**80**
Atylus swammerdamei	0	0	1	1	0	0	0	0	0	0	**2**
Bathyporeia pelagica	1	0	0	0	0	0	0	0	0	0	**1**
Haustorius arenarius	2	0	0	0	0	0	0	0	0	0	**2**
Megaluropus agilis	0	0	0	0	0	1	0	0	0	0	**1**
Leptocheirus hirsutimanus	1	0	0	2	0	0	0	0	0	0	**3**
Iphinoe trispinosa	0	0	1	1	0	0	1	0	0	0	**3**
Crangon crangon	0	0	1	6	4	0	0	0	0	0	**11**
Cerastoderma edule	0	0	0	0	0	0	1	0	0	0	**1**
Ensis arcuatus	0	0	0	0	0	0	1	1	0	0	**2**
Angulus tenuis	0	0	0	0	0	0	0	0	0	1	**1**
Moerella pygmaea	0	0	0	1	1	0	1	0	2	0	**5**

Table continued…

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Total
Echinocyamus pusillus	1	2	1	0	0	2	4	2	1	1	**14**
Echinocardium cordatum	0	0	1	0	1	1	1	1	1	1	**7**
Leptosynapta inhaerens	0	1	1	0	0	1	1	1	1	0	**6**
Ammodytes tobianus	0	0	0	0	0	0	0	1	0	0	**1**
Branchiostoma lanceolatum	1	1	1	1	0	1	1	0	0	1	**7**

Table B Species abundance data for the "*Ensis*" biotope, September 2009

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Total
Glycera lapidum complex	1	1	2	2	4	2	2	7	1	3	**25**
Ehlersia cornuta	2	9	0	10	3	3	0	5	1	5	**38**
Nephtys cirrosa	0	1	0	0	0	0	0	1	0	0	**2**
Spionidae indet	0	1	0	0	0	0	0	0	0	0	**1**
Aonides oxycephala	1	0	0	0	0	0	0	0	0	0	**1**
Aonides paucibranchiata	0	0	0	1	0	0	0	0	0	0	**1**
Mediomastus fragilis	0	0	0	1	0	0	0	0	0	0	**1**
Notomastus latericeus	0	2	0	0	3	1	3	4	1	3	**17**
Perioculodes longimanus	0	0	0	0	1	1	0	1	0	1	**4**
Potocrates altamarinus	0	0	0	0	0	1	0	1	0	1	**3**
Urothoe spp.	0	0	0	0	3	0	1	2	0	0	**6**
Orchomene nanus	0	0	0	1	0	0	0	1	1	0	**3**
Crangon crangon	1	0	1	0	0	0	0	0	0	1	**3**
Liocarcinus marmoreus	0	0	1	0	0	1	0	0	0	0	**2**
Parvicardium ovale	0	0	0	1	0	0	0	0	0	0	**1**
Tellimya ferruginosa	0	0	0	0	1	0	0	0	0	0	**1**
Lutraria lutraria	0	0	1	0	2	1	0	1	1	0	**6**
Ensis arcuatus	1	1	0	0	0	0	0	0	0	0	**2**
Angulus tenuis	0	0	0	0	0	0	1	0	0	0	**1**
Moerella pygmaea	0	1	0	1	0	0	0	0	1	0	**3**
Gari depressa	0	0	0	0	1	0	0	1	0	0	**2**
Dosinia exoleta	1	4	7	16	5	7	3	4	5	5	**57**
Echinocyamus pusillus	0	1	0	1	0	0	0	0	0	0	**2**
Echinocardium cordatum	1	1	0	1	0	2	1	1	1	1	**9**
Spatangus purpureus	0	1	0	0	1	0	0	0	0	0	**2**
Leptosynapta inhaerens	0	1	0	0	0	1	0	0	0	0	**2**
Ammodytes tobianus	0	0	1	0	0	0	1	0	0	0	**2**
Branchiostoma lanceolatum	0	1	2	2	3	0	0	0	2	0	**10**

Table C Species abundance data for the “*Arenicola*” biotope, September 2009

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Total
NEMERTEA	0	0	0	0	1	0	3	1	0	1	**6**
Phyllodoce sp.	0	0	0	0	0	0	1	0	0	0	**1**
Spaerosyllis taylori	0	0	0	0	0	1	0	1	1	1	**4**
Nereidae juv.	0	0	0	0	0	0	0	0	0	1	**1**
Nephtys hombergii	1	2	1	2	2	3	1	1	2	1	**16**
Marphysa bellii	0	1	0	1	0	1	0	0	0	1	**4**
Scoloplos armiger	9	9	8	13	1	6	5	5	12	2	**70**
Pygospio elegans	5	0	0	3	1	0	2	1	0	2	**14**
Magelona filiformis	0	0	0	0	0	0	0	0	0	1	**1**
Capitella sp.	1	0	0	0	0	0	0	0	0	0	**1**
Notomastus latericeus	2	7	7	1	0	0	0	1	2	1	**21**
Arenicola marina	1	3	4	0	0	1	0	1	2	0	**12**
Clymenura clypeata	0	0	0	0	0	0	1	1	0	0	**2**
Euclymene oerstedi	0	0	0	6	3	1	1	4	0	2	**17**
Polycirrus sp.	0	0	0	0	0	0	1	1	0	0	**2**
Urothoe spp.	32	49	65	37	7	62	32	15	59	6	**364**
Bathyporeia pelagica	0	0	1	0	0	0	0	0	0	0	**1**
Crangon crangon	0	2	0	0	0	1	0	0	1	1	**5**
Carcinus maenus	1	0	0	0	0	0	0	0	0	0	**1**
Hinia reticulata	0	1	1	0	1	1	0	0	1	1	**6**
Cerastoderma edule	0	0	0	0	0	0	0	0	1	0	**1**
Angulus tenuis	1	0	0	0	1	0	0	2	0	0	**4**
Angulus squalidus	1	0	0	0	0	0	0	0	0	0	**1**
Moerella donacina	0	0	0	0	0	0	0	1	0	0	**1**

Appendix 2 Sand biotopes

Table A List of potential candidate biotopes from the National Biodiversity Network database for level one Littoral sediment (LS) and Sublittoral sediment (SS) habitats previously recorded from Scilly

Location Name	Biotope Code	Match
Bryher Flats, Bryher	LS.LCS	Certain
St Martin's Flats	LS.LCS	Uncertain
Great Porth Entrance (Bryher)	LS.LCS	Uncertain
Bryher Flats, Bryher	LS.LSa	Certain
Samson Flats	LS.LSa	Certain
Rushy Point, Tresco	LS.LSa	Uncertain
St Martin's Flats	LS.LSa	Uncertain
Pilchard Pool, Porth Cressa, St Mary's	LS.LSa.FiSa.Po	Uncertain
Porth Coose, St Agnes	LS.LSa.FiSa.Po	Uncertain
Pentle Bay, Tresco	LS.LSa.FiSa.Po.Aten	Uncertain
St Martin's Flats, St Martins	LS.LSa.MuSa.Lan	Uncertain
Pilchard Pool, Porth Cressa, St Mary's	LS.LSa.MuSa.Lan	Certain
Samson Flats, Samson	LS.LSa.MuSa.Lan	Certain
Periglis, St Agnes	LS.LSa.MuSa.Lan	Uncertain
Porth Hellick, St Mary's	LS.LSa.MuSa.Lan	Uncertain
St Helen's	LS.LSa.MuSa.Lan	Uncertain
St Helen's	LS.LSa.MuSa.Lan	Uncertain
Foremans Island	LS.LSa.MuSa.Lan	Uncertain
Foremans Island	LS.LSa.MuSa.Lan	Uncertain
Station 7, St Mary's Sound	SS.SCS.CCS.Blan	Certain
Station 1, S of St Mary's and St Agnes	SS.SCS.CCS.Blan	Certain
Station 2, S of St Mary's and St Agnes	SS.SCS.CCS.Blan	Certain
Station 2, Broad Sound	SS.SCS.CCS.Blan	Uncertain
St Helen's Pool	SS.SCS.CCS.MedLumVen	Uncertain
St Mary's Road	SS.SCS.CCS.MedLumVen	Certain
Off Darrity's Hole	SS.SCS.CCS.MedLumVen	Certain
Station 4, Eastern Isles	SS.SCS.CCS.MedLumVen	Certain
Station 5, Eastern Isles	SS.SCS.CCS.MedLumVen	Certain
Station 1, N of St Martin's	SS.SCS.CCS.MedLumVen	Certain

Table continued…

Location Name	Biotope Code	Match
English Island Zostera bed, St Martin's	SS.SCS.ICS	Certain
Crow Bar	SS.SCS.ICS	Certain
Station 6, The Road	SS.SCS.ICS.CumCset	Uncertain
Station 2, Broad Sound	SS.SCS.ICS.Glap	Uncertain
Station 2, St Mary's Sound	SS.SCS.ICS.Glap	Certain
Scattering Rocks	SS.SCS.ICS.MoeVen	Certain
Crow Bar	SS.SCS.ICS.MoeVen	Certain
SW of Samson	SS.SCS.ICS.MoeVen	Certain
Tresco Flats	SS.SCS.ICS.MoeVen	Certain
SW of Crow Rock, St Marys Sound.	SS.SCS.ICS.MoeVen	Certain
SW of Crow Rock, St Marys Sound.	SS.SCS.ICS.MoeVen	Certain
St Mary's Road South.	SS.SCS.ICS.MoeVen	Certain
W of Chimney Rocks	SS.SCS.ICS.MoeVen	Certain
N of St Agnes	SS.SCS.ICS.MoeVen	Certain
N of Kittern, St Agnes.	SS.SCS.ICS.MoeVen	Certain
Cromwells Castle, between Bryher and Tresco.	SS.SCS.ICS.MoeVen	Certain
N St Martins Bay	SS.SCS.ICS.MoeVen	Certain
Station 11, St Mary's Sound	SS.SCS.ICS.MoeVen	Uncertain
Station 2, Eastern Isles	SS.SCS.ICS.MoeVen	Uncertain
Station 5, N of St Martin's	SS.SCS.ICS.MoeVen	Uncertain
Station 10, N of St Martin's	SS.SCS.ICS.MoeVen	Uncertain
Station 4, Crow Bar	SS.SCS.ICS.MoeVen	Uncertain
Station 5, Crow Bar	SS.SCS.ICS.MoeVen	Uncertain
Station 6, Crow Bar	SS.SCS.ICS.MoeVen	Certain
Station 9, Crow Bar	SS.SCS.ICS.MoeVen	Uncertain
Station 10, Crow Bar	SS.SCS.ICS.MoeVen	Uncertain
Station 1, The Road	SS.SCS.ICS.MoeVen	Uncertain
Station 2, The Road	SS.SCS.ICS.MoeVen	Uncertain
Station 3, The Road	SS.SCS.ICS.MoeVen	Uncertain
Station 1, St Mary's Sound	SS.SCS.ICS.MoeVen	Uncertain
Transect 1 North	SS.SCS.ICS.MoeVen	Uncertain
Transect 5 North	SS.SCS.ICS.MoeVen	Uncertain
Transect 7 North	SS.SCS.ICS.MoeVen	Certain

Table continued…

Location Name	Biotope Code	Match
St Helens Pool	SS.SMx.IMx	Uncertain
Crow Bar	SS.SMx.IMx	Uncertain
Station 8, N of St Martin's	SS.SMx.IMx	Uncertain
Station 6, S of St Mary's and St Agnes	SS.SMx.IMx	Uncertain
Transect 3 West	SS.SMx.IMx	Uncertain
Scattering Rocks (E.Tresco)	SS.SSa.IFiSa	Certain
St Mary's Road	SS.SSa.IFiSa	Certain
Old Grimsby Harbour	SS.SSa.IFiSa	Certain
Near Cruthers Island	SS.SSa.IFiSa	Certain
Anchorage, St Mary's Roads.	SS.SSa.IFiSa	Certain
Station 10, St Mary's Sound	SS.SSa.IFiSa	Certain
Station 2, Crow Bar	SS.SSa.IFiSa	Certain
Station 6, N Bryher	SS.SSa.IFiSa	Certain
Station 9, N Bryher	SS.SSa.IFiSa	Certain
Station 1, Broad Sound	SS.SSa.IFiSa	Certain
Station 7, Broad Sound	SS.SSa.IFiSa	Certain
Station 9, Broad Sound	SS.SSa.IFiSa	Certain
Station 8, S of St Mary's and St Agnes	SS.SSa.IFiSa	Certain
Station 11, S of St Mary's and St Agnes	SS.SSa.IFiSa	Certain
NE of the Bow	SS.SSa.IFiSa.IMoSa	Uncertain
Station 10, Eastern Isles	SS.SSa.IFiSa.NcirBat	Uncertain
Station 12, S of St Mary's and St Agnes	SS.SSa.IFiSa.NcirBat	Uncertain
Transect 4 North	SS.SSa.IFiSa.NcirBat	Uncertain
Porth Cressa	SS.SSa.IMuSa.AreISa	Certain
Pentle Bay, Tresco	SS.SSa.IMuSa.EcorEns	Certain
Foremans Island	SS.SSa.IMuSa.EcorEns	Certain
Tresco Flats, Plumb Island to Appletree Point	SS.SSa.IMuSa.EcorEns	Uncertain
St Mary's Roads North.	SS.SSa.IMuSa.EcorEns	Certain
St Mary's Road	SS.SSa.IMuSa.FfabMag	Certain
Station 3, Crow Bar	SS.SSa.IMuSa.FfabMag	Uncertain
Station 4, The Road	SS.SSa.IMuSa.FfabMag	Uncertain