Fal Moorings Trial

An investigation into the impact of Seaflex moorings on the benthic macrofauna of the Fal Estuary adjacent to Mylor Harbour

Final Report

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An investigation into the impact of SEAFLEX® moorings on the benthic macrofauna of the Fal Estuary adjacent to Mylor Harbour

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1. ABSTRACT

The aim of this independent and impartial research project was to compare and assess the relative ecological impacts (changes in fauna, flora and the seabed habitat) and practicalities of using chain moorings and SEAFLEX® moorings in an estuarine environment.

The survey design agreed at the start of the contract was to compare the benthic fauna at four sites with chain moorings to the benthic fauna at paired sites with a SEAFLEX® mooring. It was intended that three study sites were to be on the soft mud within Mylor Harbour moorings area while a fourth was to be in course mixed sediment at the channel marker buoys. Two of the sites were subsequently withdrawn from the trial by Mylor Yacht Harbour for operational reasons and replaced by two pairs of sites with a more complex sediment and far higher biodiversity than that typical of the mooring area. In these complex sediments it was not unusual to encounter 80 or more species.

A baseline biodiversity soft-sediment survey was carried out within the Mylor Yacht Harbour moorings area.

SEAFLEX® moorings were laid in the late summer of 2005 and immediately afterwards a full set of samples were collected from all the paired moorings. The benthic results have been statistically compared with a series of "baseline" samples collected in the spring of 2006. This analysis has failed to show any significant differences in the abundance of individuals, a range of biodiversity measures or community composition between SEAFLEX® and chain moorings within this trial.

One significant result of note is the one at the single muddy site that remained in the trial. After a period of six months the community adjacent to a SEAFLEX® mooring was far less variable than that around the adjacent chain mooring. In the absence of replication it is difficult to interpret this result with any great confidence but in other studies high variability in the community structure of replicate samples is symptomatic of pollution or disturbance. An increase in sample homogeneity could be regarded as being due to a decrease in disturbance. It would be of benefit to repeat a trial with sufficient replicate samples in soft sediment habitats and for a greater length of time in order to assess the significance of this result with confidence.

2. Introduction

2.1 Project Brief

The aim of this wholly impartial research project is to compare and assess the relative ecological impacts (changes in fauna, flora and the seabed habitat) and practicalities of using chain moorings and SEAFLEX® moorings in an estuarine environment.

2.2 Background

The Fal and Ruan estuary complex (figure 2.1) has long been recognised as a site of marine biological importance at least in part due to the mosaic of contrasting habits that it contains. As a consequence of its relative proximity to marine laboratories in Plymouth, the estuary has a long history of study and its fauna and flora are well characterised. In recent years PML scientists have been active in assessing the effects of pollution from Wheal Jane on the benthic fauna. The whole area is part of a Special Area of Conservation and contains Biodiversity Action Plan habitats, notably maerl beds. The importance of the area is emphasised by recent plans by a consortium of national regulatory bodies and research scientists (including Plymouth Marine Laboratory) to use the Fal/Helford embayment as a demonstration area for trials of the ecosystem approach to marine management.

In recent years there has been increasing concern about the effects of chain moorings on benthic biodiversity. The scale of research has varied between investigations on the moorings used for large naval vessels in Plymouth Sound (Plymouth Marine Laboratory) to the effects of yacht moorings in the Medina Estuary (Medina Field Centre) on the Isle of Wight. In Plymouth Sound studies showed that the area disturbed by mooring chains had a biota significantly different to adjacent undisturbed mud. A similar pattern was observed in the Medina where, despite lower biodiversity, benthic biomass was greater in the disturbed area than outside it. These observations are in keeping with ecological theory which suggests that providing that the energy flow to the sea floor remains constant the frequency of disturbance has a strong effect on local biodiversity. Experiments examining the relationship between productivity and disturbance have been central to PML's core research on functional diversity, an area in which we are among the world leaders.

Traditional chain moorings can cause considerable physical disturbance to the seabed around the mooring block to which they are attached. In aerial photographs of the Fal Estuary (taken at low tide during winter when there are no boats present) disturbance is clearly evidenced by the presence of numerous dark circles on the seabed in mooring areas. Each has a diameter of approximately 10 metres corresponding to the normal sweep of a ground-chain.

It is likely that chronic disturbance from ground chains is associated with significant ecological impacts, particularly on long-lived and slow growing biota. The adverse effect of chain moorings on eelgrass beds is well known. In the Fal, native-oyster fishermen have commented that when moorings are removed and they can fish in the areas affected, they find fewer oysters than in similar areas that have never had moorings.

The areas of habitat affected by chain moorings in the Fal and Helford are designated conservation features of the Fal and Helford Special Area of Conservation (SAC) and are priority habitats in the UK Biodiversity Action Plan (UK BAP). The native oyster is a priority species in the UK BAP. The biota of the study region does not fit well with the accepted JNCC classification. The area among the moorings initially intended for the bulk of the study sites in the Fal is best classified as a low diversity, temporally unstable mud. At present there is little direct knowledge of the ecological impacts of chain-moorings on habitats in the Fal and Helford SAC to inform decisions on future capacity for new moorings.

A potential solution to the damaging effect of chain moorings is to replace them with SEAFLEX® moorings which do not touch the seabed during tidal swinging. However, there has been some question over the suitability of such moorings on the SW Coast of England because it experiences much larger tidal ranges than the Baltic and Fjords of Scandinavia where they were invented and first used.

Mylor Yacht Harbour (Figure 2.1) is set within an area of outstanding natural beauty and a Site of Special Scientific Interest and offers pontoon berths and swinging moorings that provide immediate access to Cornwall's Carrick Roads. It is part of a natural network of creeks and rivers. The area is home to the last oyster fishing fleet still working under sail in the world.

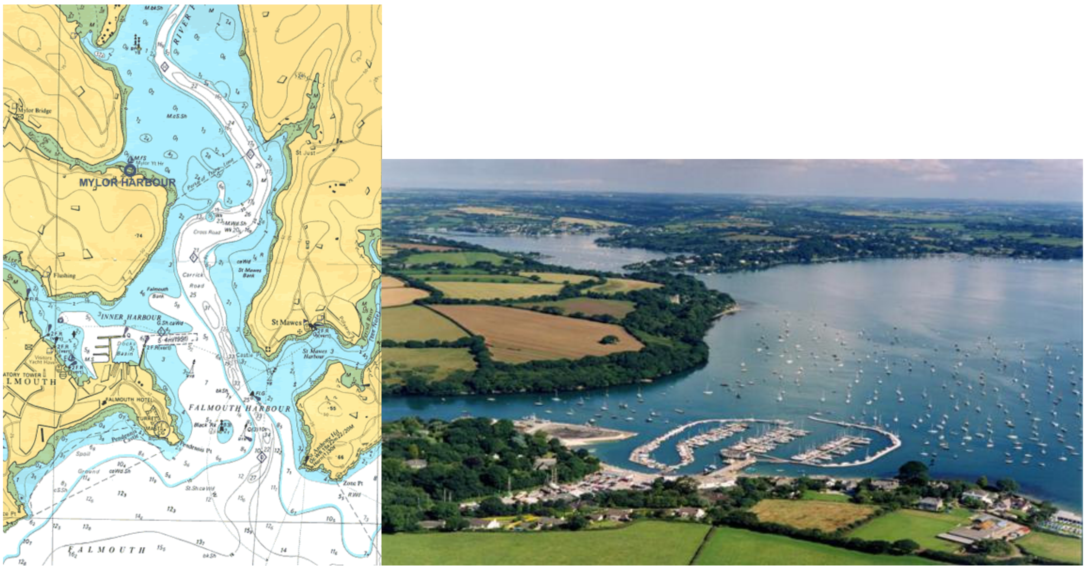

Figure 2.1: Mylor Harbour location and picture

2.3 The SEAFLEX® mooring

The main element of SEAFLEX® is the reinforced homogeneous rubber hawser (Figure 2.2). Each end of the rubber hawser is attached to a stainless steel fitting. The rubber hawser with its end fittings are used in single or multiple strands depending on the force that will be induced. There is an integrated shackle at the base which is attached to an anchor or a concrete block. The SEAFLEX® Buoy is designed to be pollution free. Unlike a chain mooring system the SEAFLEX® system is always under tension and does not touch the seabed during tidal swivelling of the mooring. Thus any aquatic vegetation that might be on the seabed is left undisturbed by the motion of the mooring.

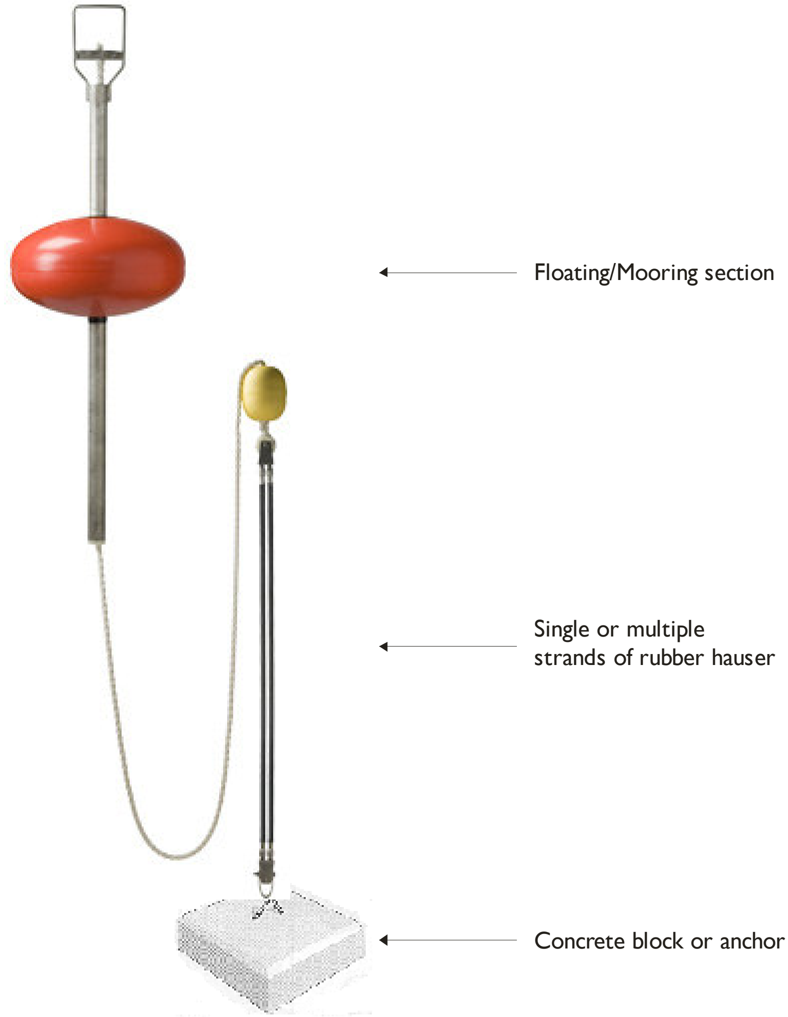

Figure 2.2: The SEAFLEX® Buoy system as used in this trial (from www.seaflex.nu where more information about SEAFLEX® can be obtained). The whole system between the floating/mooring section and the seabed is kept under tension when deployed.

2.4 Disturbance and Biodiversity

Soft sediment ecologists would argue that some degree of disturbance is needed to maintain the biodiversity of the seafloor. The difficulty that they have is to be specific about the frequency of disturbance and the spatial scale of disturbance that is needed to maintain the optimal number of species within a particular area. All benthic assemblages are subject to disturbances that range from the impact on small animals of larger individuals moving through the sediment to storms and anoxia events. In general, small scale events happen frequently and have a virtually undetectable impact from which the assemblage recovers very quickly. Large-scale events are infrequent and may well reset the biota to an unorganised state from which they recover slowly. In between the two extremes there are a plethora of disturbance events that interact to give a benthic assemblage a characteristic diversity; examples relevant to the Fal might include seasonal patterns of river run-off, the patchy deposition and decomposition of algal debris, pit digging by crabs and the feeding activities of flat-fish.

Following a broad-scale disturbance, the numbers of both species and individuals (biodiversity) in an assemblage will build up causing the intensity of both inter and intra specific competition to increase. If an assemblage is left undisturbed for long enough, the species best adapted to local conditions will exploit their advantage over other members of the assemblage. These superior competitors will then exclude less able species and as a consequence biodiversity will decline. If the assemblage continuously undergoes low level disturbance there will always be pockets where the poorer competitors can survive without being out-competed.

Except in instances where a massive disturbance such as a storm has occurred, all macrobenthic assemblages can be envisaged as being composed of a mosaic of patches of various sizes at a range of recovery states. In such assemblages we estimate biodiversity by sampling at scales such that we describe the characteristic variability within it. While a mean estimate of species number is important to us, an estimate of its variance is also fundamental.

2.5 Disturbance and Yacht Moorings

The concerns expressed by local oyster fisherman that the presence of the yacht moorings was having an impact on their fishery are difficult to understand. It is quite feasible that in the mixed sediments around the channel edges there might well be settlement of oyster spat but the channel edge moorings are both temporary and lightly used. There may well be a minor impact in this area. In the main area of the moorings the sea floor is covered by soft mud. This is a habitat that oyster spat actively avoid settling on and hence it is difficult to envisage a mechanism whereby moorings in this area could be detrimental to their settlement.

All seafloor assemblages are subject to disturbance and as the previous section indicated it is the scale and frequency of disturbance that tends to set patterns of biodiversity. At a scale of metres there is considerable potential for the tidal movement of a mooring chain to displace and kill small organisms living at the sediment surface. Deeper living animals would not necessarily be impacted although their feeding might be badly disturbed. Nevertheless, any impact at the scale of metres will only translate to an impact on biodiversity at the scale of hundreds of metres (the community or biotope) if a considerable proportion of that area is swept by chains and provided that there are no other broad scale processes operating. For example, it would be pointless to consider looking for (or attempting to manage) the impact of mooring chains on community biodiversity in areas where the moorings were used infrequently or in shallow water areas where there was frequent disturbance by wind waves or tidal movement.

A series of searches of the scientific literature have failed to reveal any publications on the impacts of mooring chains or mooring buoys on benthic biodiversity. There is an abundant literature on the problems of mooring on seagrass beds but in such circumstances the findings cannot be directly related to the situation in the Mylor Creek area. Much of the literature related to the damage caused by anchoring small vessels and the subsequent damage that is caused to the fabric of the seagrass. Seagrass species can be envisaged to be bioengineers; their presence has a substantial impact on local sediment structure and stability and strongly influences infaunal diversity. When an anchor is dropped and recovered, not only are species displaced but the all the structural properties of the benthos are changed. Such disturbances open the sediment fabric to further damage by tidal currents or storm events that otherwise might have been innocuous. A single anchoring event, impacting maybe less than a square metre of sediment, can lead to a much broader scale and longer lasting impact than might a permanently moored vessel in a muddy estuary.

The mooring of small vessels on coral reefs has also been the subject of many investigations and here again the concern lies in the damage that anchoring does to structural species. In fact, in many countries there have been programmes to install permanent moorings on the coral reefs most frequently visited by divers.

The soft sediment assemblages such as those found close to Mylor Harbour are not greatly influenced by structural species such as seagrass and are seldom seen as areas of high biodiversity value. These factors might account for the general paucity of scientific research. We know of two studies, both undertaken as undergraduate projects where the impact of moorings on soft sediment biodiversity has been assessed; both were referred to above but neither is a direct analogue of the situation in the Fal. The Plymouth Sound studies (conducted by Jane Smith under the supervision of Steve Widdicombe and Mike Kendall) that showed that the area disturbed by mooring chains had a biota significantly different to adjacent undisturbed mud were of the area adjacent to the mooring buoys used by very large naval vessels. The fauna in the most disturbed areas was significantly less diverse than in places with less impact from the chains. The chains fixed to the buoy were massive and the proximity to the entrance to Plymouth Sound probably caused considerably more movement and disturbance than has been encountered in the shelter of the Fal. Nevertheless, this study does indicate that frequent disturbance influences biodiversity.

The study of the effects of yacht moorings in the Medina Estuary, Isle of Wight, (conducted under the supervision of Dr Roger Herbert of the Medina Field Centre) also has important differences from our studies in the Fal, the major one being that the moorings studied dried at low water. In addition to any impact from the mooring, these sites also were disturbed by the tidal grounding of the moored yacht and it is impossible to separate the two impacts. In addition to any impact from the mooring the biota at these sites studied was also damaged by tidal grounding of the moored yacht. It was not possible to partition the cause of damage between the two agents of disturbance.

There is little information in the literature on the impacts of yacht moorings on biodiversity and we have not been able to obtain any further unpublished information or data to contribute to this study although a further SEAFLEX® mooring is currently being trialled as a visitor mooring by Natural England at Lundy Island.

3. Project Calendar

October 2004: Original survey design agreed. It was intended that the benthic macrofauna at four sites with chain moorings should be compared with that at an adjacent SEAFLEX® mooring. It was intended that the project studied three sites within Mylor Yacht Harbour in mooring rows S, P and V in soft sediment plus a single site at the entrance channel marker buoys on coarser sediments

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October 22nd 2004: Baseline survey/preliminary survey conducted using four parallel transects to cover the whole of the Yacht Harbour and include both permanent and temporary mooring areas. This sampling exercise was also intended to provide sufficient information to make an informed choice of sampling gear.

November 3rd 2004: Baseline sampling at the four sites allocated to the SEAFLEX® mooring experiment.

March 30th 2005: Planned first sampling following deployment of SEAFLEX® moorings abandoned when it became clear that Mylor Harbour staff had not yet deployed the SEAFLEX® moorings. 45 new benthic samples were collected to extend baseline information. These samples were subsequently shelved without analysis.

Mid July 2005:

- Only channel marker and one harbour mooring (P) installed
- Other harbour sites at S and V withdrawn from the trial because of operational concerns
- Decision taken to continue the trial by replacement of withdrawn sites with two pairs (chain and SEAFLEX®) at the edge of harbour for speed limit buoys rather than boats

August/September 2005: Mylor Harbour laid SEAFLEX® moorings at the channel edge sites.

September 20 2005. First post-deployment sampling; a baseline for the assessment of change.

March 2nd: 2006. Spring sampling.

September 12. 2006: Autumn sampling (No. 2).

4. Methods

4.1 Survey design

The survey design agreed at the start of the contract was to compare the benthic fauna at four sites with chain moorings to the fauna at paired sites with a SEAFLEX® mooring. It was intended that three of these sites (in mooring rows S, P and V: See below) were to be on the soft mud within Mylor Harbour with a fourth being the channel entrance marker buoys. Furthermore, it was intended that both the SEAFLEX® and chain moorings were to be used to moor vessels.

The final design of the trail was a compromise between the scientific needs of the Cycleau Project and the operational requirements of Mylor Yacht Harbour. Figure 4.1 & Table 4.1 below show the moorings at Mylor and the allocation of buoys finally used.

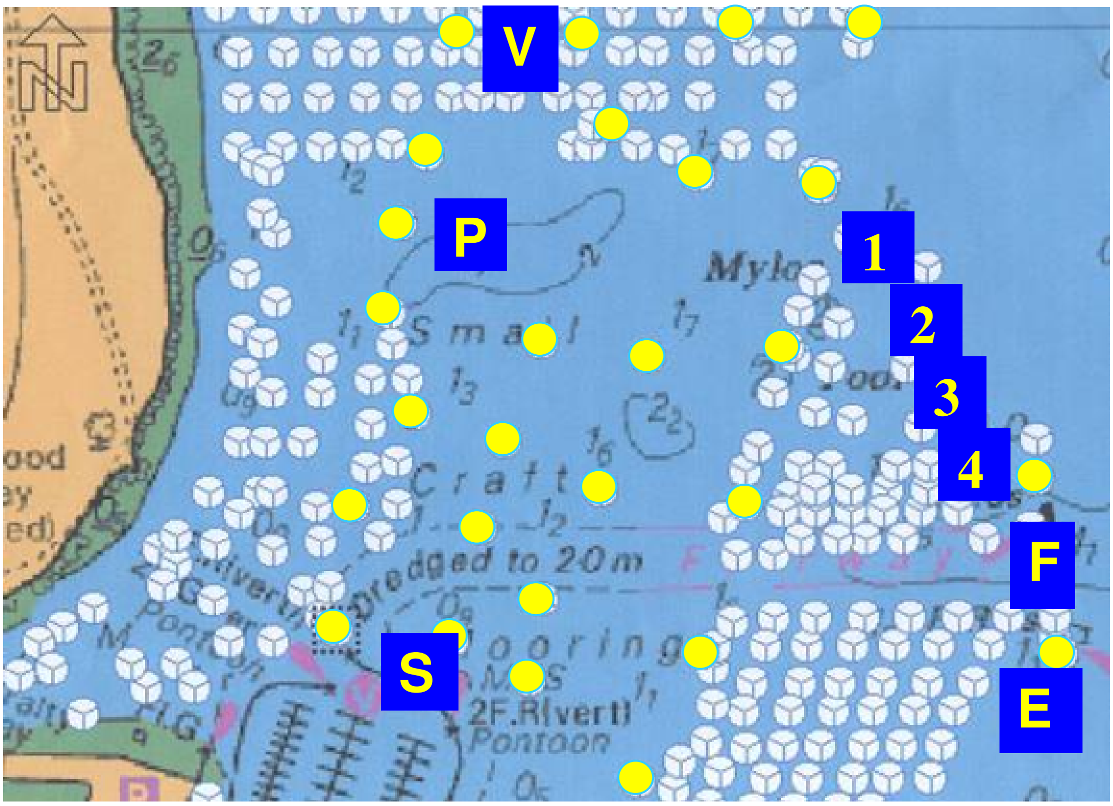


Figure 4.1: Map of Mylor Harbour showing sites sampled. The baseline survey sites are the yellow circles. Sites E, F, P, S and V were those originally included in the moorings trail. Sites 1, 2, 3 and 4 were added in the late summer of 2005.

SEAFLEX® Mooring	Chain Mooring
P4 Channel 1 Channel 3 Starboard (F)	P5 Channel 2 Channel 4 Port (E)

Table 4.1: Allocation of moorings to the final sampling design

4.2 Sampling Methods

Preliminary sampling in November 2004 indicated that the most appropriate sampling tool was the Mini van Veen grab sampler. This 0.025m^2 sampler can be deployed by hand (Figure 4.2) and took an adequate sample on all substrata sampled. In general five samples were collected on each visit of which four were to subject to analysis. The final sample was a safeguard against accident.

Sampling took place from one of the mooring barges operated by Mr Ken Dunstan. Before sampling began the target mooring was picked up by the survey vessel and all slack cable collected so that the vessel's bows lay directly above the mooring. During sampling the vessel swung on the mooring buoy as samples were taken sequentially from bow to stern. This methodology ensured that the vessel was not pushed from the sampling area by wind and tide. In calm conditions the vessel was given "a small kick" of engine power after each sample to move her around the mooring and maximise sampling coverage.

A B

Figure 4.2A: Mini van Veen sampler being deployed; 4.2B: Close up of a sample collected from Mylor Harbour.

On recovery from the grab samples were gently sieved over a 0.5mm mesh and the filtered material returned to Plymouth Marine Laboratory where it was fixed in formalin (c8%) for a minimum of one week. After that period, formalin was washed from the samples using tap water and they were preserved in 70% alcohol prior to extraction and identification. All animal material was extracted from the samples under a binocular microscope and each was identified to the lowest practical level by a trained and experienced operator using standard taxonomic works.

4.3 Data analysis

To examine differences in the community structure between sites with a chain mooring and adjacent sites with a SEAFLEX® mooring, the principal tools used were from the statistical package PRIMER 6 (www.primer-e.com). Where appropriate, differences between sites were tested using 1 way ANOSIM and the differences visualised using nMDS. The latter programme produces plots in which the distance apart of any pair of points is an approximate depiction of the similarity of the faunal assemblage at each (i.e. the closer together points are the more similar they are). Data have been examined with no transformation, a 4th root transformation and a presence/absence transformation. The increasing severity of transformation enables the analyst to determine the relative importance of common and rare species in any differences observed; patterns revealed by untransformed analysis are dominated by the commonest species while in cases of presence/absence transformation all species have equal weighting and any differences revealed will largely be due to differences in the species composition of the samples being compared. Wherever there was good agreement between the various data transformations only the 4th root plots have been presented. Most diversity measures have been calculated from PRIMER6's DIVERSE routine. Three estimators of diversity were considered

- Number of species
- Shannon Diversity. H'. Calculated using base e. The most commonly used diversity measure
- ES(100). This measure estimates the number of species that would be found in a sample of 100 individuals. It standardises diversity for samples with different numbers of individuals.

Chao 1, an estimator of the total size of species pool was determined using EstimateS software (http://viceroy.eeb.uconn.edu/EstimateS). Univariate analyses (1 way analysis of variance and T-tests were performed using MINITAB.

5. Results

5.1 Preliminary Survey

On Friday 22 October 2004 PML Applications Ltd. undertook a habitat survey of the area owned/operated by Mylor Yacht Harbour and its immediate surrounds. On this occasion only a small number of samples were returned to the laboratory for analysis in order to collect data to optimise sampling methods.

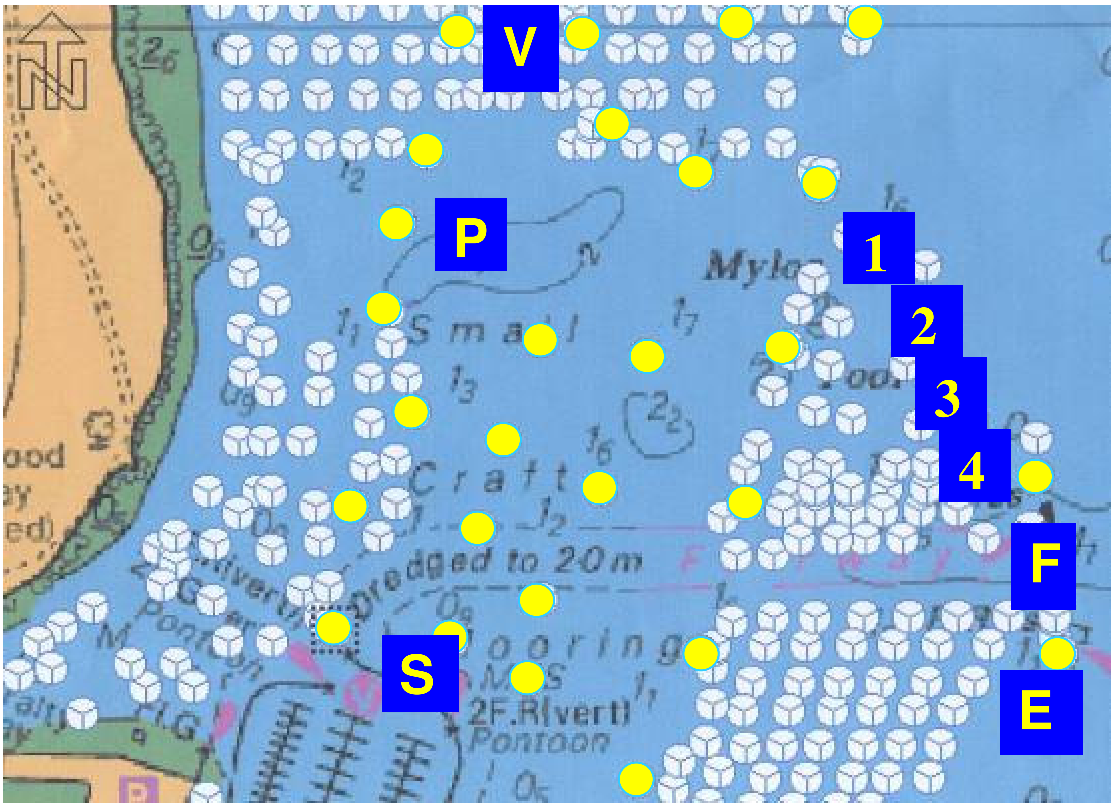


Figure 5.1: Map of the area around Mylor Harbour to show (yellow circles) sites sampled during the baseline survey. Sites E, F, P, S and V were those originally included in the moorings trail. Sites 1, 2, 3 and 4 were added in the late summer of 2005.

5.1.1 Overview of the sampling area

Most of the area sampled (Figure 5.1) was covered by soft mud with a shallow (generally 5mm or less) redox discontinuity or RPD (the depth at which sediment changes colour indicating anoxia). At most inshore sites the brown, often flocculent surface, layer lay above black, anoxic mud. The degree to which this muddy layer was consolidated varied considerably, even within sites; in some places no oxic sediment was encountered. As distance offshore increased a small (probably <5%) proportion of sand was encountered although in a single sample the muddy surface layer overlaid anoxic, well consolidated muddy sand. In the area around the navigation buoys mud was replaced by coarse mixed sediment with some mud infill and occasional pieces of maerl. The biota encountered was similar over most of the area covered by moorings. The dominant feature were 3-4 cm length polychaetes tubes accompanied sporadically by the tubes of spionid polychaetes and ampeliscid amphipods and occasional tellinid bivalves. A high proportion of samples contained the errant polychaetes *Nephtys hombergi*.

The impression was of a low diversity, temporally unstable assemblage, which would not fit well into any JNCC biotope category.

5.2 Baseline Survey

The baseline survey took place on November 3rd 2004 and collected 24 samples within the yacht moorings and a further 8 samples at the navigation buoys.

Patterns in similarity of the macrobenthic fauna within the area surrounding Mylor Harbour are summarised by the MDS plot show in figure 5.2. Replicates from each station, with a small number of exceptions, cluster together tightly indicating a high degree of fauna homogeneity at each. The sites are distributed serially along a gradient away from Mylor Creek.

Twenty-four samples (0.6 m^2) taken within the yacht moorings yielded a total of 95 species The Chao 1 statistic suggest that the area contains around 146 species of size and habit such that they can be collected by grab sampling. A total of 165 species was collected from the eight baseline samples collected (a total area of $0.2m^2$). The Chao 1 statistic suggests that the area between the channel entrance buoys might contain in excess of 210 species. Basic biodiversity statistics for each site are presented in Table 5.1 and shown graphically in Figures 5.3 to 5.6.

	Mean no. species	95%CI	Mean no. individuals	95%CI	H'	95%CI	NS (100)	95%CI
SiteS	16.75	4.17	226.5	30.24	1.71	0.20	12.81	2.50
Site P	19	2.20	170.75	75.30	2.13	0.25	16.51	1.87
Site V	30.25	3.56	430.87	61.43	2.37	0.19	18.23	1.14
Buoys	66.87	11.01	999.75	294.41	3.00	0.22	28.11	2.52

Table 5.1: A summary of the diversity of the area close to Mylor Harbour. 95% CI = 95% confidence interval, H' = Shannon diversity (base e), NS(100) is a prediction of the number of species that would be found in a sample of 100 individuals.

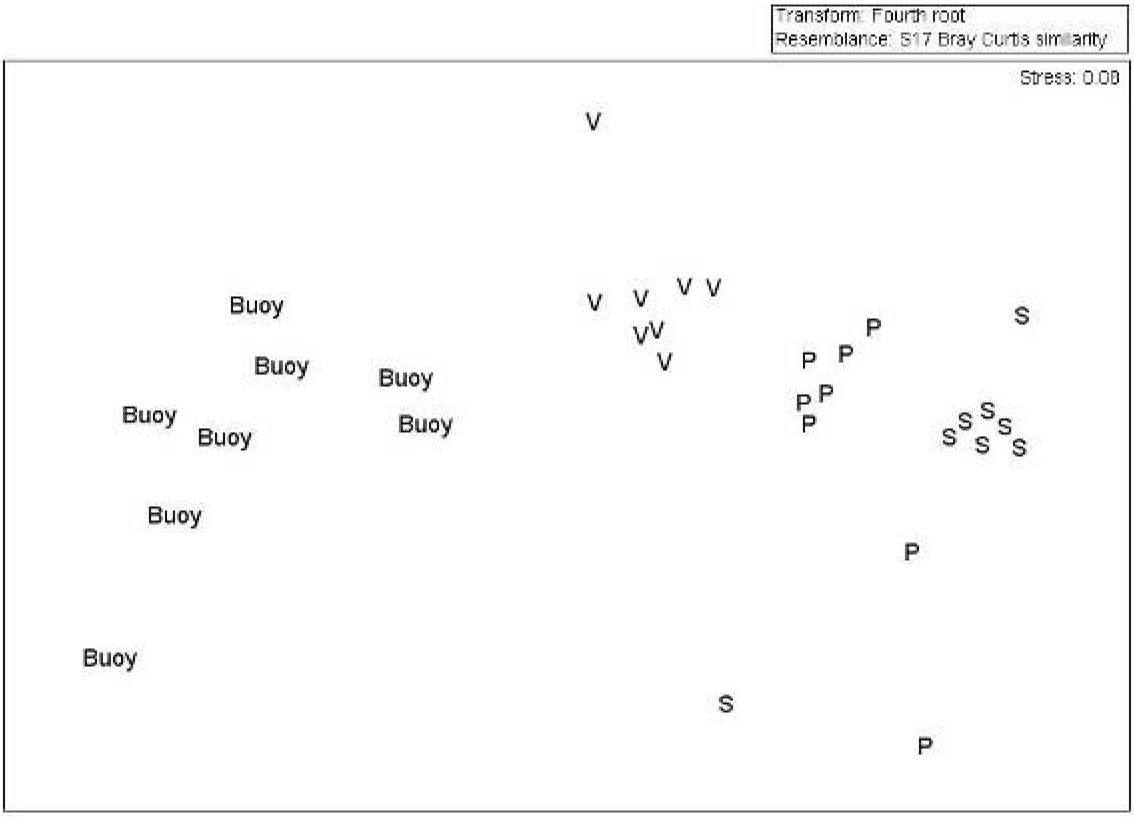


Figure 5.2: MDS plot (fourth root transformed data) indicating patterns of similarity within the benthic biota during the baseline survey. The labels S, P, V and Buoy are site names.

Some species, particularly the polychaetes *Chaetozone gibber* and *Mediomastus fragilis* were common throughout the survey area but other species showed the station to station trends that are summarised below. A full species list is provided in Appendix I and on a CD. Trends in distribution of some representative species are shown in Figs 5.7 and 5.8.

Site S is closest to Mylor Harbour and Mylor Creek and has a fauna that is less diverse than all other sites. Samples from this location were dominated numerically by the small bodied polychaete *Cossura pygodactylata* and the oligochaete *Tubificoides galiciensis.* Small numbers of the bivalve *Abra alba*, the polychaete *Melinna palmata* and the juvenile polychaetes of the genus *Nephtys* were also characteristic.

There was a small increase in most diversity statistics between site S and site P but as Table 5.1 and Figs.5.3 to 5.6 indicates none of these changes are significant. At Site P the most notable changes were the increase in the abundance of *Melinna palmata* and the regular appearance of the amphipod *Ampelisca brevicornis*.

Melinna palmata and *Ampelisca brevicornis* numbers continued to increase to station V. At this station both nemertine worms and burrowing anemonies of the genus *Edwardsia* became common along with the small syllid polychaete *Sphaerosyllis* *taylori*, the cumacean crustacean *Eudorella truncatula* and the opisthobranch mollusc *Retusa obtusa*.

At the navigation buoys the sediment was more complex with both fine material and shell fragments and as a consequence of this heterogeneity there was more than double the number of individuals and species found at site V. Notable diversification was seen among mobile polychaetes such as *Pholoe inornata*, *Glycera tridactyla*, *Ophryotrocha hartmanni* and various phyllodocids. Spionid polychaetes also were in greater evidence here with *Prionospio fallax* and *Polydora caeca* being present in good numbers in most samples as was the fan-worm *Megalomma vesiculosum*. Crustacean diversity and that of small molluscs was also far higher at this station than elsewhere in the study area.

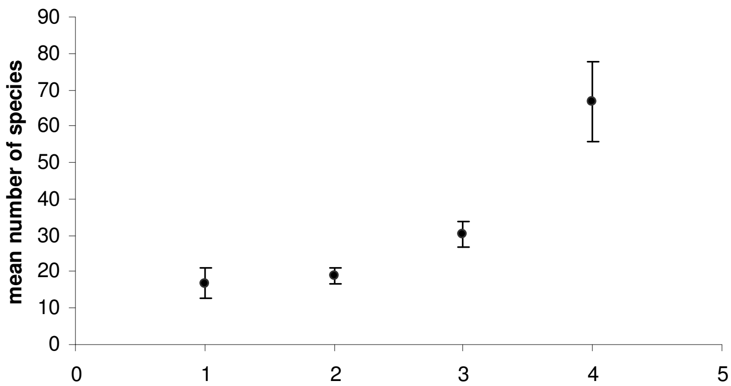


Figure 5.3: The mean number of species ± 95% confidence interval at each site. Key to sites 1=S, 2=P, 3=V and 4= navigation buoys

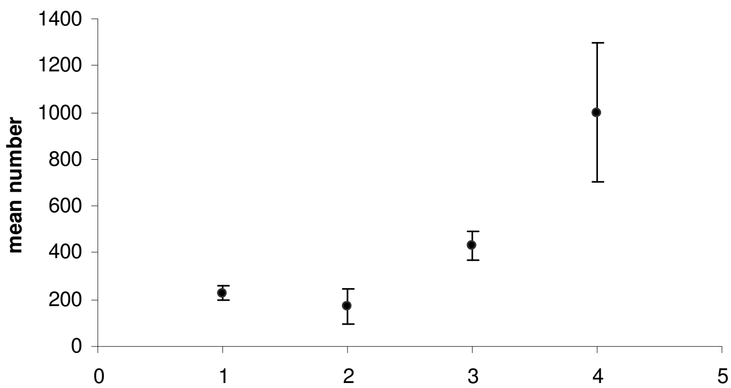


Figure 5.4: The mean number of individuals ± 95% confidence interval at each site. Key to sites 1=S, 2=P, 3=V and 4= navigation buoys

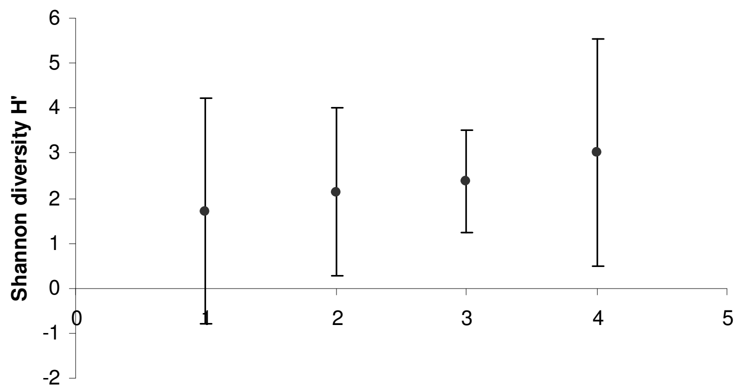


Figure 5.5: The mean Shannon diversity ± 95% confidence interval at each site. Key to sites 1=S, 2=P, 3=V and 4= navigation buoys

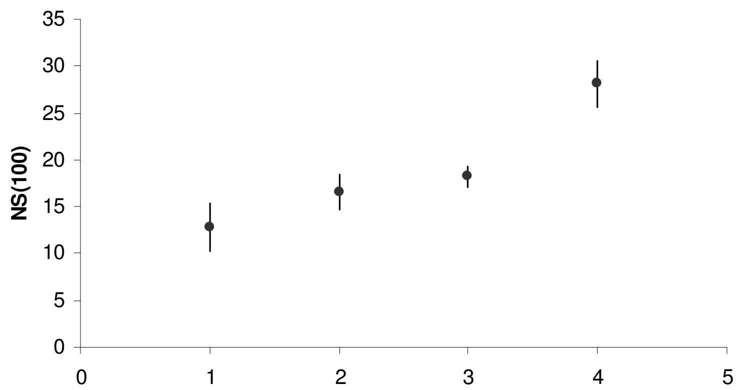


Figure 5.6: The mean Shannon diversity ± 95% confidence interval at each site. Key to sites 1=S, 2=P, 3=V and 4= navigation buoys

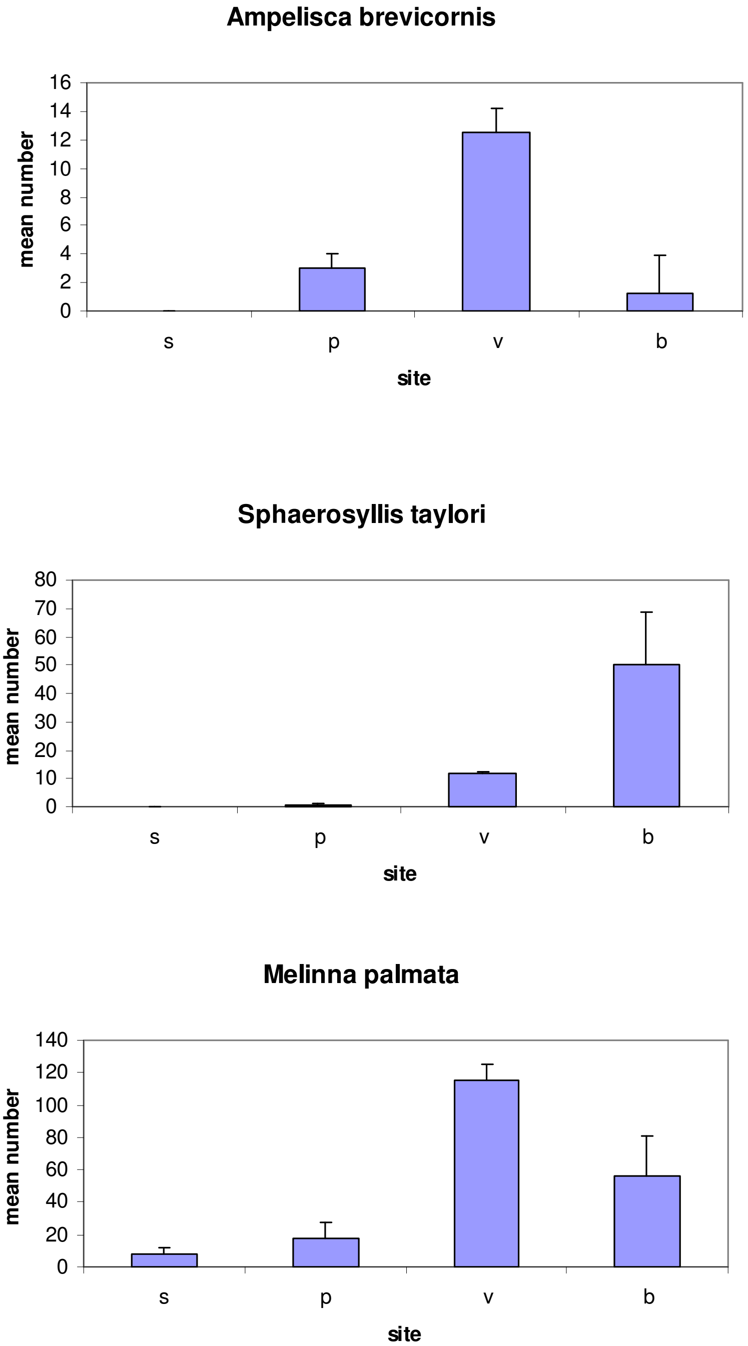


Figure 5.7: The mean abundance of characteristic species of macrobenthos ± 95% confidence interval at each site. The x axis is site; b= navigation buoy

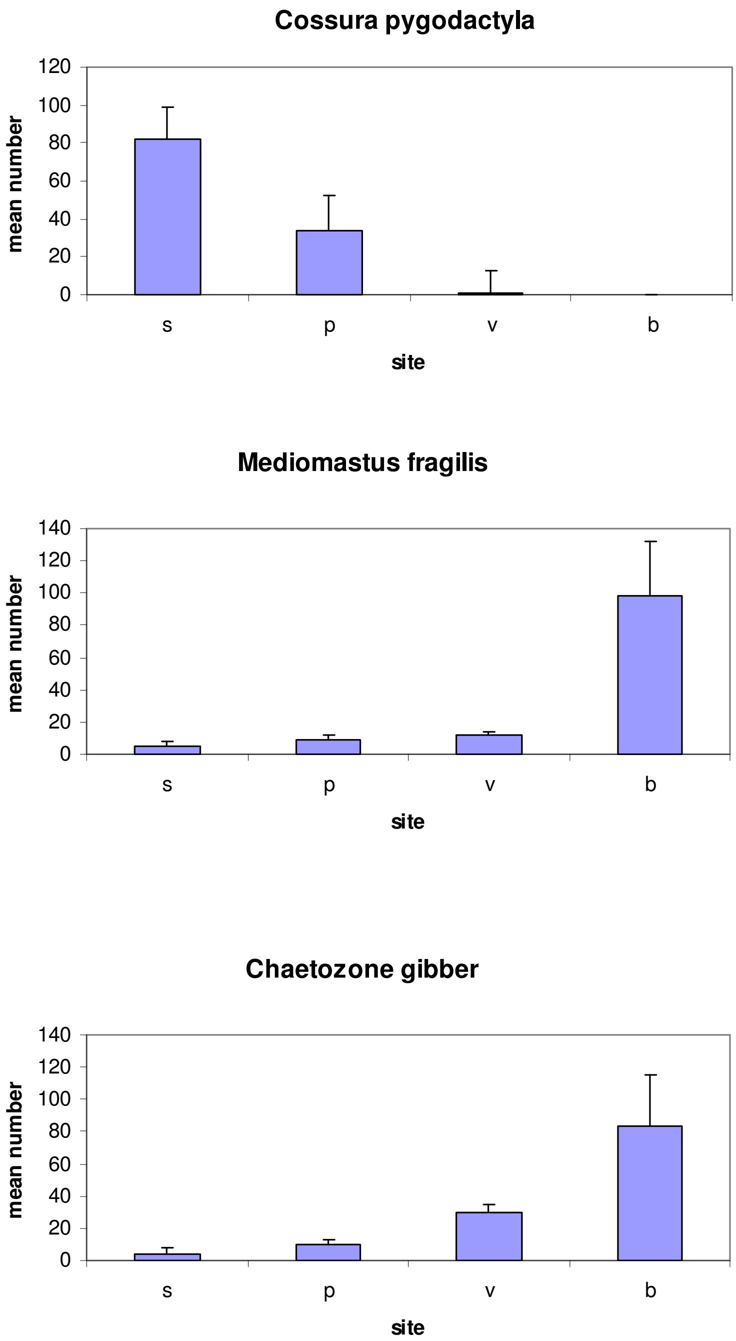


Figure 5.8: The mean abundance of characteristic species of macrobenthos ± 95% confidence interval at each site.

5.2.1 Discussion of baseline

There is a substantial difference between the biota of the soft, often patchily anoxic muds of the yacht harbour and the more complex mixed sediments found around the navigation channel entrance. Diversity and other biological properties of the infaunal assemblage all increase with distance from the mouth of Mylor Creek but it would be difficult to separate any effects of the presence of the yacht harbour from the impact of the freshwater discharge from creek.

The biota at site S is certainly impoverished for a site that is fully marine and at the time of sampling it was observed that in a number of samples the surface sediment was black indicating reduced conditions. Once again, it is difficult to attribute the reduced diversity to any particular cause. Not only had the site closest to the marina (S) been subject to recent dredging but when grabbing, numerous attempts were needed to collect an acceptable sediment sample. These sampling difficulties were largely due to the abundance of large pieces of drifting macro algae lying on top of the sediment. Much of the algal material was old and partially decomposing and had probably come from exposed coastal sites. A layer of algae prevents oxygenated seawater reaching sediment dwelling animals and furthermore as it breaks down it removes oxygen from the surface sediment. In combination there is a strong negative impact on the biota. The reason for the deposition of algae must relate to local hydrography and if it is a regular occurrence then its impact will add to all the other local factors to depress macrobenthic biodiversity.

The biota of sites P and V is broadly similar to that of other sheltered muddy subtidal areas in SW England such as Plymouth Sound, with strong domination by the tube-dwelling polychaete *Melinna palmata* and the infaunal deposit feeding polychaetes *Mediomastus fragilis* and *Chaetozone gibber*. Elsewhere in the region such assemblages also contain deep burrowing mud shrimps but as it requires heavy sampling equipment to collect such animals or video to determine their presence we do not know if they are present or not.

The diversity of the infauna of soft sediments is heavily influenced by the size and variability of the individual mineral particles; in general the more complex the mixture is the greater the diversity of species present. At the navigation buoys the mud of the area around sites P and v was replaced by coarse mixed sediment with some mud infill and occasional pieces of maerl. Thus in addition to a mud fauna there were also species specialising in moving between the grains of coarse sediment, species living attached to coarse sediment and species burrowing into calcareous mat. For such a small sampler the number of species taken was unusually large.

5.3 Comparison of Baseline conditions and these after an over-winter deployment of SEAFLEX® moorings.

After the SEAFLEX® buoys had been in place over winter there was the first chance to compare if differences had developed in the benthic macrofauna in the areas adjacent to the moorings. A summary MDS plot showing similarity among samples is presented as Fig 5.9. The principal feature of this plot is the clear separation of the sites at P, within the muddy area among the yacht moorings from the four new channel edge sites and the two navigation buoy sites. The large amount of information on this plot makes it difficult to draw conclusions simply and for that reason when the data are considered in greater detail the muddy sites and the channel edge sites will be treated separately

It is abundantly clear that the new sites chosen to replace the muddier sites S and V do not reflect conditions within the yacht moorings.

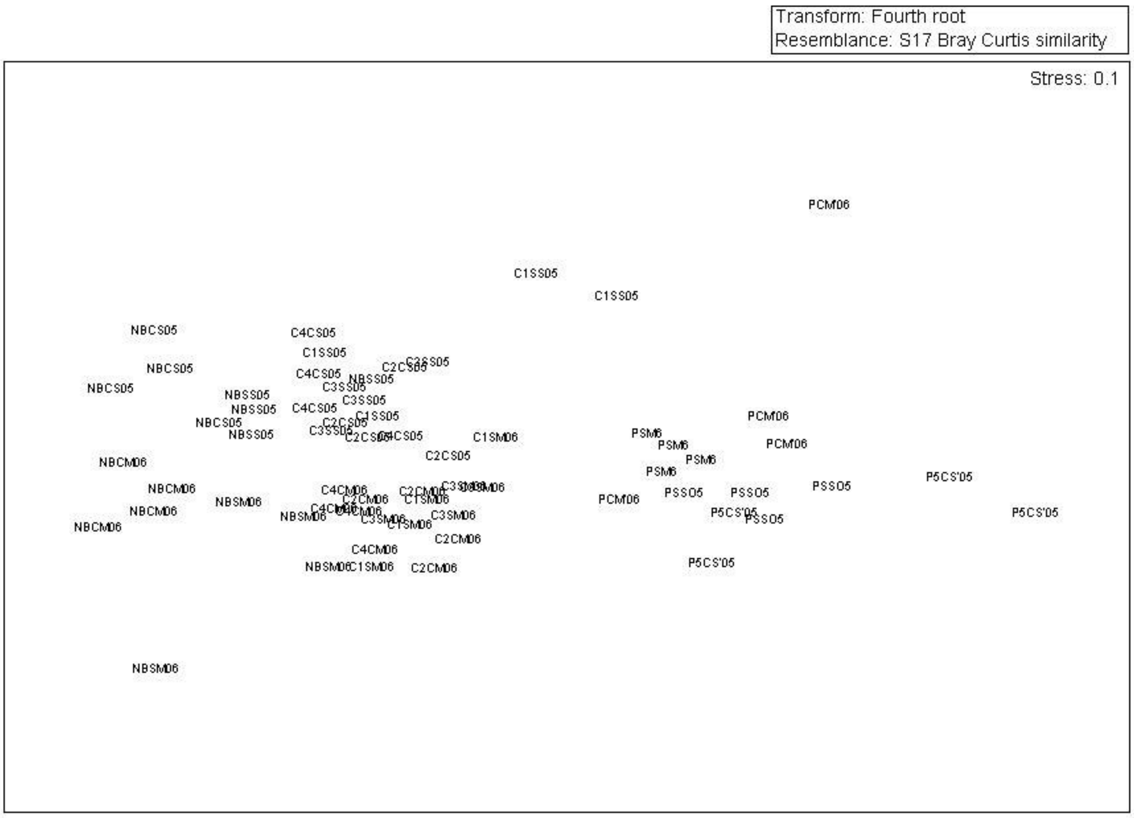


Figure 5.9: MDS plot to compare the similarity of the macrobenthic fauna in pre and post winter samples . Legend is compounded from the following elements Site name (P,C1 C2 C3 C4 (C=channel) and NB(navigation buoy), the treatment C= chain and S = SEAFLEX® and the date of sampling September 2005 (S05) and March 2006 (M06). Thus C4S05 is channel edge buoy 4 with a SEAFLEX® mooring sampled in September 2005.

Note: Figure 5.9 is a complex plot that summarises a mass of information on a large number of species at all sites and dates. Nevertheless it is clearly evident that all of the samples from sites at P lie on the right hand side of the plot and those from the channel edge lie on the left. The very complexity of the plot is the reason that in the text that follows the muddy sites at P will be considered separately to the channel edge sites. The September 06 plots are considered separately.

The simplest way in which we can attempt to visualise changes in the benthic macrofauna resulting from differences in moorings is to compare the two treatments six months after moorings were laid.

5.3.1 Site P

In Figure.5.10 below the similarity of the benthic macrofauna at site P pre and post winter is visualised. This figure shows that the fauna at site P immediately after the laying of the moorings is homogeneous at both SEAFLEX® and chain sites. The first attempt to examine patterns of similarity within the fauna produced a plot that was very difficult to interpret as a single sample from the chain mooring post-winter was substantially different from the remaining samples. To facilitate interpretation this sample was removed from the plots.

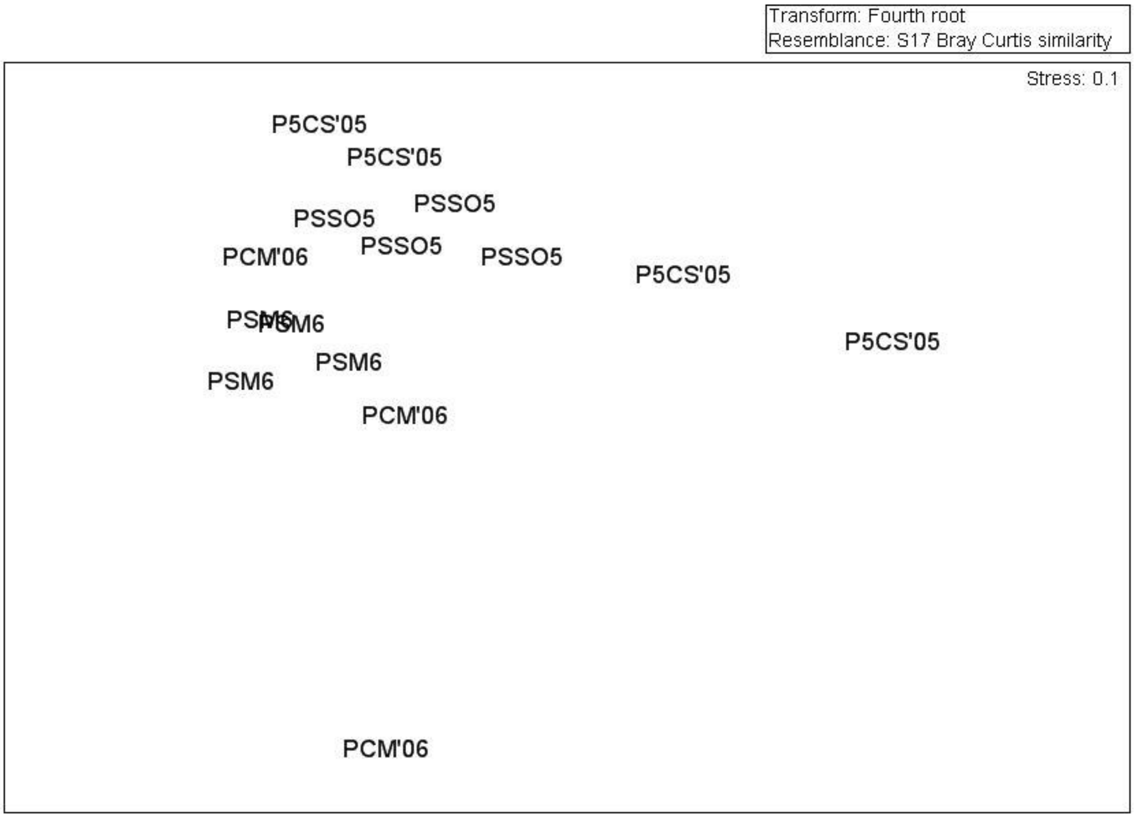


Figure 5.10: MDS plot of patterns in the similarity of macrobenthos samples take from sites with chain and SEAFLEX® moorings immediately after the moorings were deployed and six months after deployment. Sites with chain moorings are plotted with a site designation including C, those with a SEAFLEX® with a designation including S; The suffix S05 or M06 (M6) indicates year of sampling i.e. 2005 or 2006.

In Figure 5.11only the post winter samples are shown and this plot shows clearly that there is far more faunal variability among the sites with chain moorings than there is at sites with SEAFLEX®. The SEAFLEX® sites group together in the upper right hand quadrant of the plot while the chain sites are widely scattered indicating relatively high variability in faunal composition. The single chain site that is highly dissimilar to all others has been omitted from this plot. ANOSIM indicates that the difference between the SEAFLEX® samples and all the chain mooring samples is significant (P=0.03)

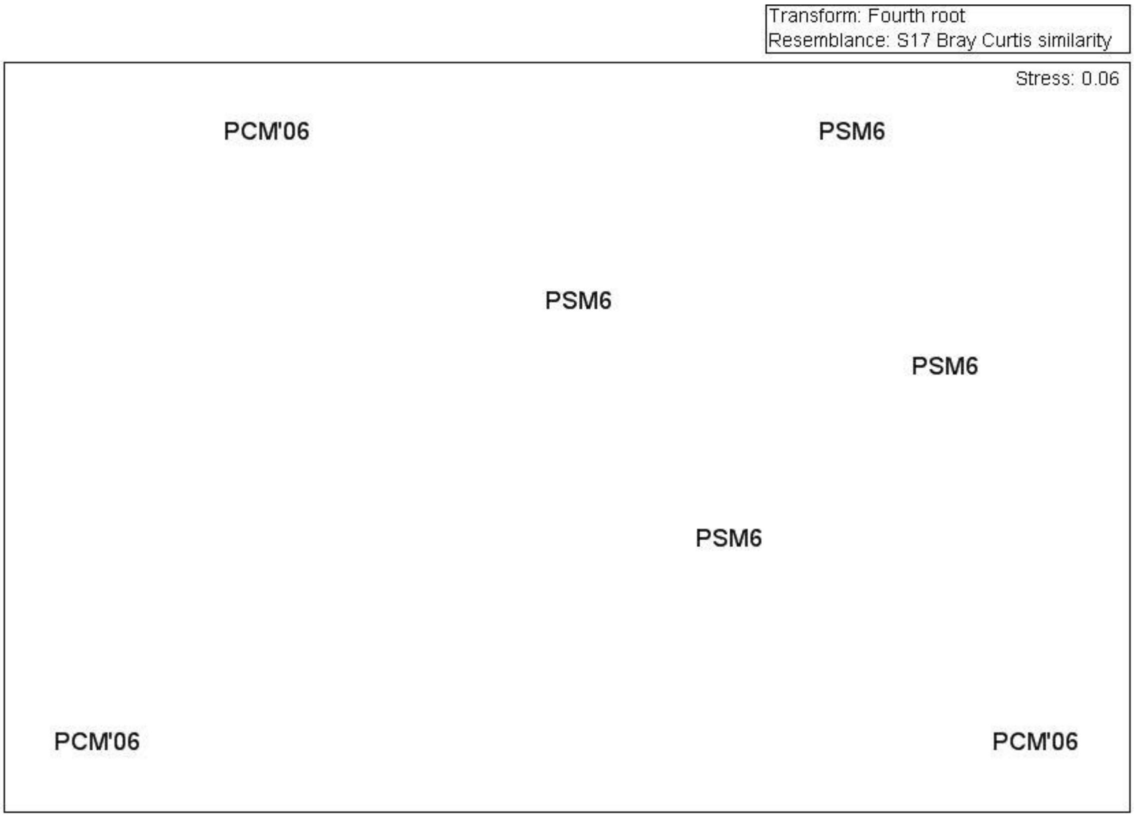


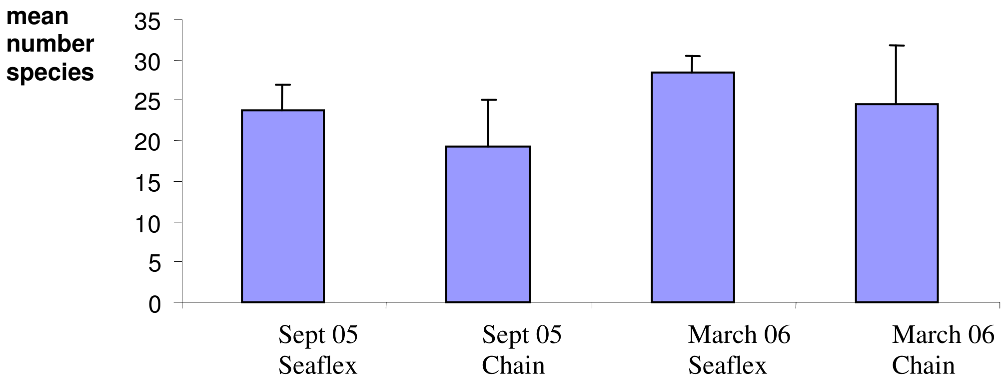
Figure 5.11: MDS plot of patterns in the similarity of macrobenthos samples take from sites with chain and SEAFLEX® moorings immediately after the moorings were deployed and six months after deployment. Sites with a name including S are SEAFLEX®; those with a C are chain moorings.

5.3.1.1 Univariate analyses

The pre-and post -winter samples have been investigated using a suite of univariate tests the results of which are presented in Figures 5.12 to 5.15. The samples were compared by

- The number of species
- The number of individuals
- The Shannon diversity
- The number of species that would be predicted in a sample of 100 individuals.

For all samples and treatments considered there was no statistically significant difference between the four sample sets (using the indicators listed above) indicated by 1 way ANOVA. A specific comparison of SEAFLEX® and chain treatments at station P post winter (two sample T-test) also failed to show any significant difference

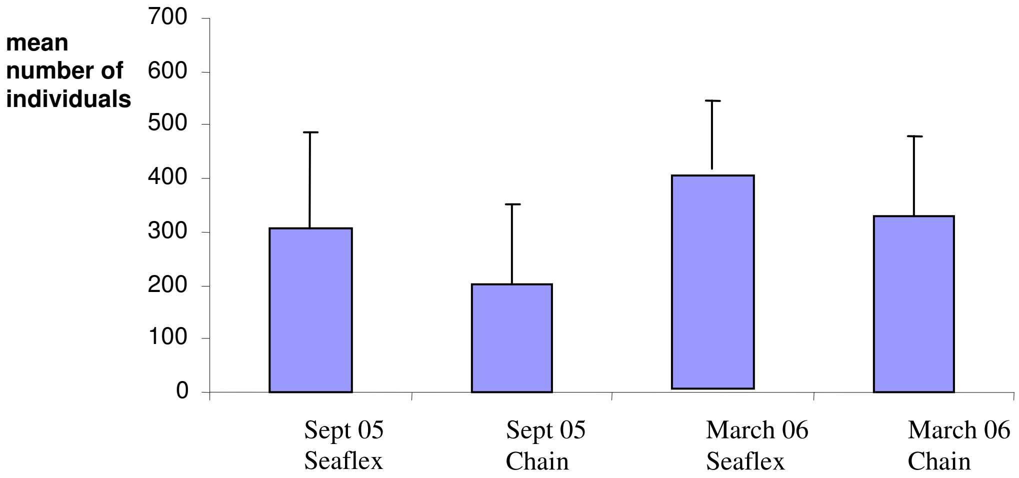


Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	172.5	57.5	2.15	0.148
Error	12	321.5	26.8		
Total	15	494.0			

T-Test of difference T-Value = 1.03, P-Value = 0.344 DF = 6

Figure 5.12: Mean number of species at Site P in SEAFLEX® and chain treatments pre- and post winter. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns and the T test specifically compares the post-winter SEAFLEX® and chain mooring sites

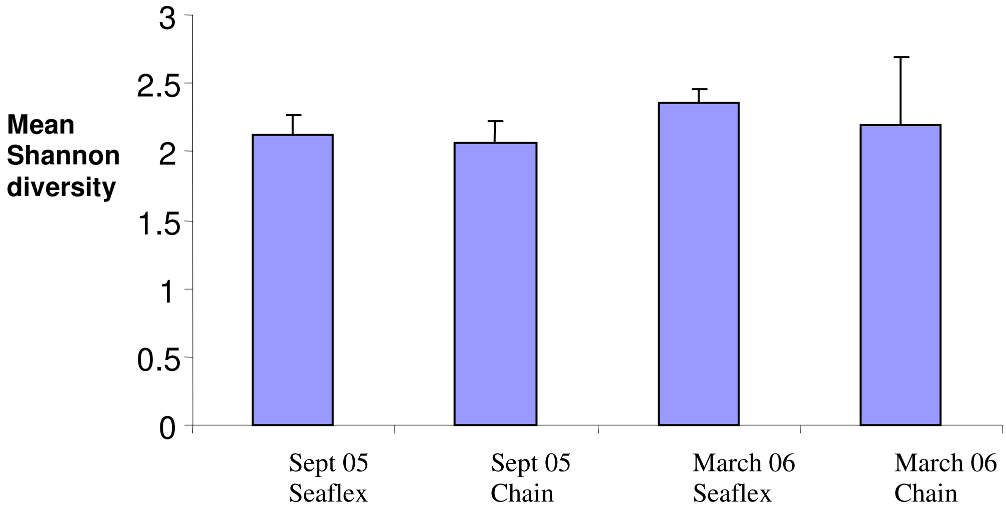


Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	181694	60565	2.34	0.125
Error	12	310202	25850		
Total	15	491895			

T-Test of difference T-Value = 1.57 P-Value = 0.167 DF = 6

Figure 5.13: Mean number of individuals at Site P in SEAFLEX® and chain treatments pre- and post winter. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns and the T test specifically compares the post-winter SEAFLEX® and chain mooring sites

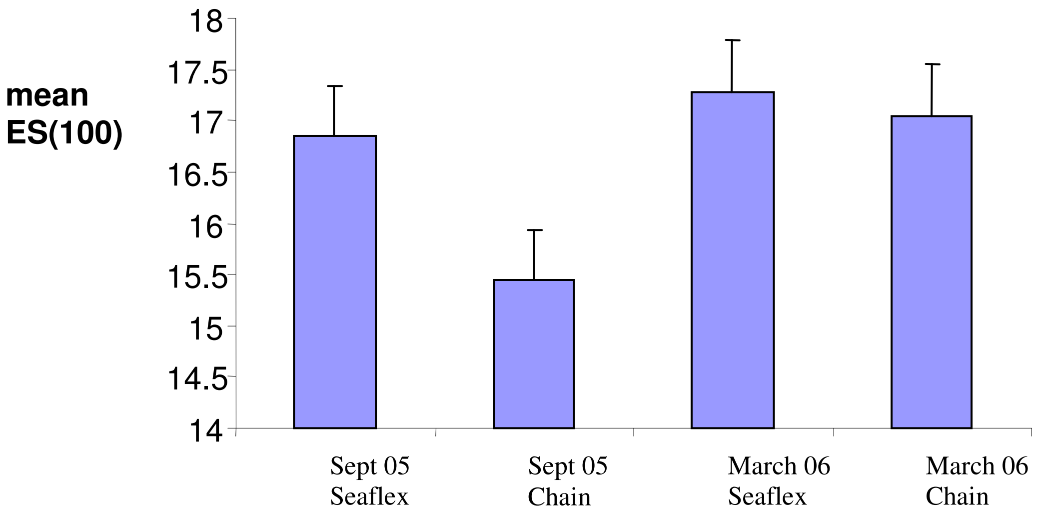


Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	0.2009	0.0670	0.83	0.504
Error	12	0.9723	0.0810		
Total	15	1.1732			

T-Test of difference T-Value = 0.65 P-Value = 0.538 DF = 6

Figure 5.14: Mean Shannon diversity at Site P in SEAFLEX® and chain treatments pre- and post winter. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns and the T test specifically compares the post-winter SEAFLEX® and chain mooring sites



Source	DF	SS	MS	F	P
Factor	3	8.31	2.77	0.44	0.728
Error	12	75.43	6.29		
Total	15	83.74			

T-Test of difference T-Value = 0.10 P-Value = 0.922 DF = 6

Figure 5.15: Mean expected number of species for 100 individuals at Site P in SEAFLEX® and chain treatments pre- and post winter. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns and the T test specifically compares the post-winter SEAFLEX® and chain mooring sites

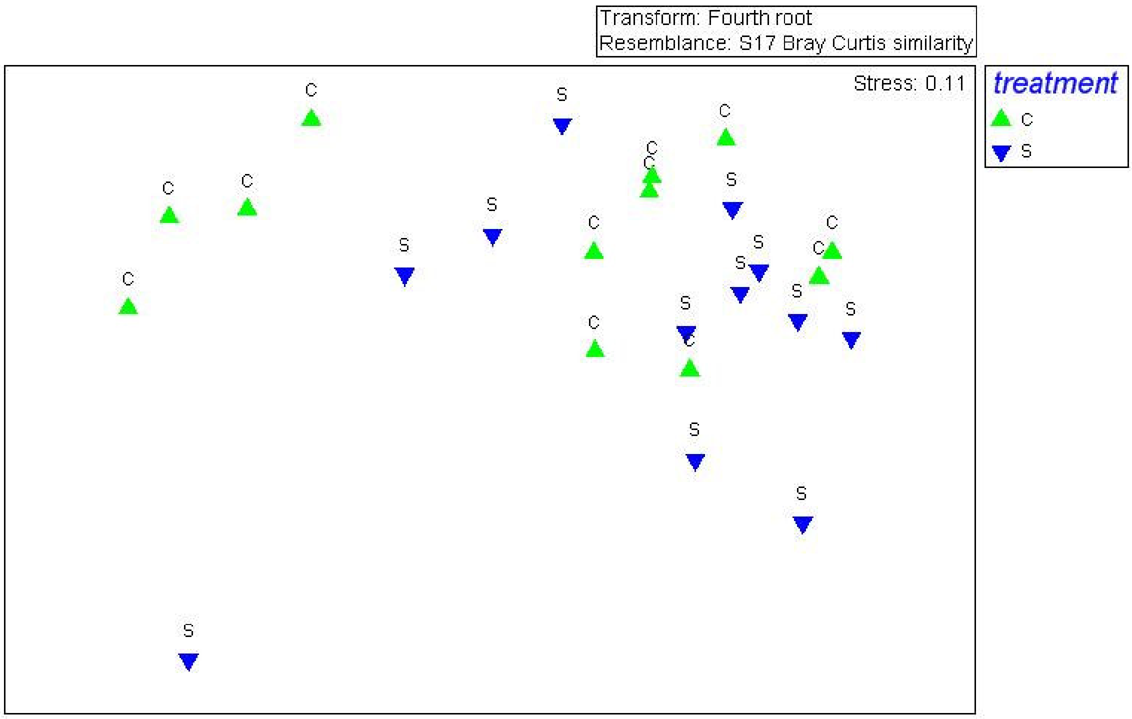
5.3.1.2 Conclusion for Site P

ANOSIM indicates that there is a significant difference between the community structure of four samples collected at the SEAFLEX® mooring and four samples collected at the adjacent chain mooring. It appears that the assemblage is far more homogeneous at the SEAFLEX® mooring than at the normal chain mooring. It is worth emphasising that although the assemblage is more homogeneous at a SEAFLEX® site there is no significant difference in univariate diversity measures.

It is important to note that the very purpose of statistical tests is to determine if apparent visual differences in the plots are real. In this case four graphs have the same ordering of experiment and treatment. The statistical test tells us that the variance within each column is such that the data in each is more likely to have come from the same normal distribution than from separate normal distributions (i.e. there is no significant difference).

5.3.2 Channel edge and navigation buoy sites

Differences between the biota adjacent to moorings with chain and those with SEAFLEX® were examined using ANOSIM and subsequently visualised using MDS. There was no significant difference in the assemblage (P=0.117 NS) at the two classes of mooring. The MDS plot (Fig 5.16) shows that the there is a gradual change in biota across the sample area: Site 1 and 2 lie at the right hand side of the plot and the navigation buoys on the left. This pattern is far stronger than any pattern resulting from changing the mooring



ANOSIM

Global Test
Sample statistic (Global R): 0.067
Significance level of sample statistic: 11.7% NS

Figure 5.16: MDS plot of patterns in the similarity of macrobenthos samples take from sites with chain and SEAFLEX® moorings six months after deployment of the latter.

5.3.2.1 Univariate Analysis

Figures 5.17-5.20 examine both over-winter change in univariate diversity measures and compare numbers of species. The figures indicate that at the navigation buoys there was a tendency for there to be more species and individuals than at sites further along the channel edge but that there were no such pattern in other measures of diversity. The seasonal signal was not strong and no significant difference between pre- and post-winter samples was evident in any of the measures examined. The post winter samples have been subject to more detailed analysis and the results of this are presented below.

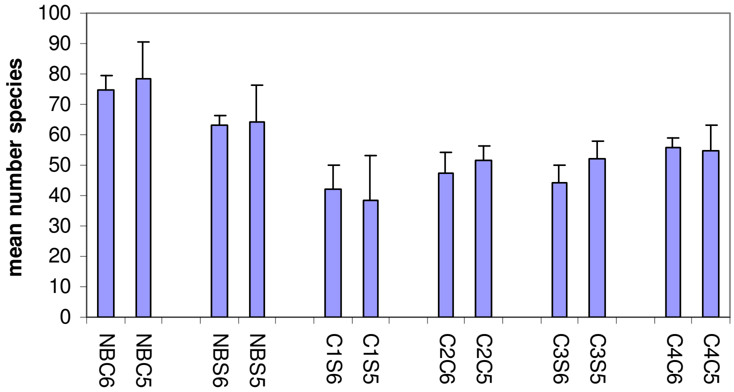


Figure 5.17: Comparison of the mean number of species (± 95% confidence interval) at channel edge sites samples after 6 months SEAFLEX® deployment. Legend is compounded from Site (NB = Navigation buoy), C or S to denote SEAFLEX® or Chain and 5 or 6 to denote sampling in autumn 2005 or spring 2006. Thus NBC6 is the navigation buoy with a chain mooring sampled in 2006.

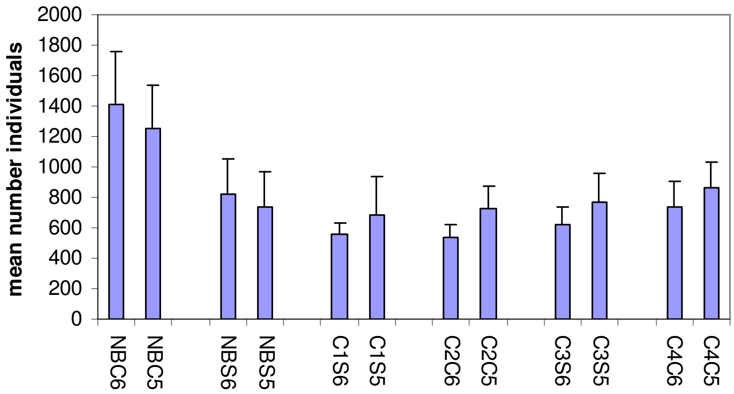


Figure 5.18: Comparison of the mean number of individuals (± 95% confidence interval) at channel edge sites samples after 6 months SEAFLEX® deployment. Legend is compounded from Site (NB = Navigation buoy), C or S to denote SEAFLEX® or Chain and 5 or 6 to denote sampling in autumn 2005 or spring 2006. Thus NBC6 is the navigation buoy with a chain mooring sampled in 2006.

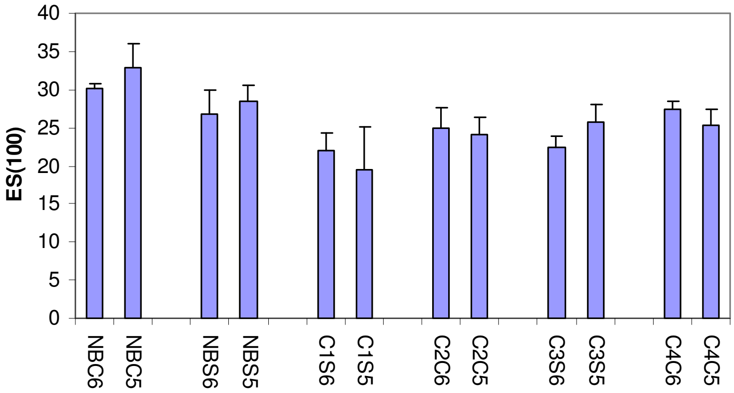


Figure 5.19: Comparison of the mean number species predicted in a sample of 100 individuals (± 95% confidence interval) at channel edge sites samples after 6 months SEAFLEX® deployment. Legend is compounded from Site (NB = Navigation buoy), C or S to denote SEAFLEX® or Chain and 5 or 6 to denote sampling in autumn 2005 or spring 2006. Thus NBC6 is the navigation buoy with a chain mooring sampled in 2006.

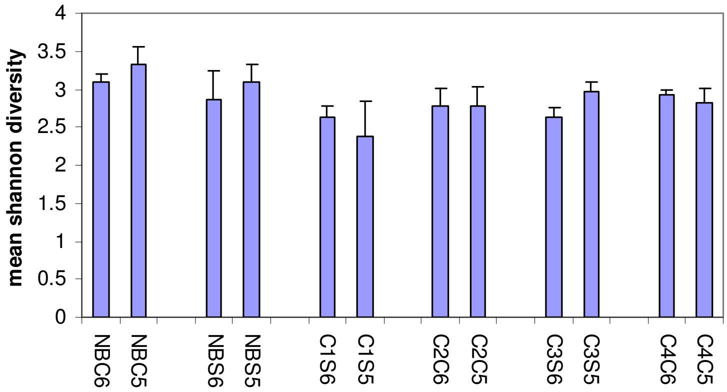
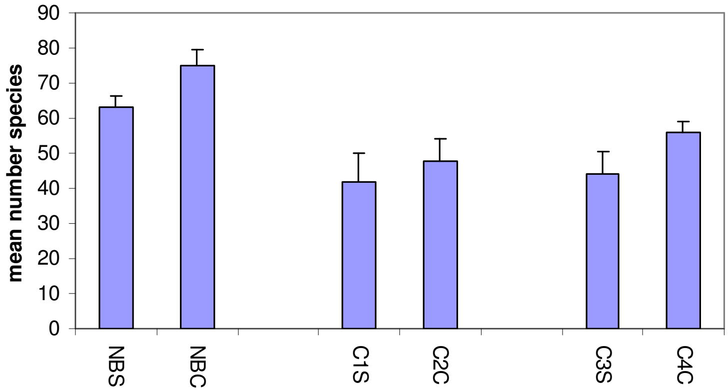


Figure 5.20: Comparison of the mean number species predicted in a sample of 100 individuals (± 95% confidence interval) at channel edge sites samples after 6 months SEAFLEX® deployment. Legend is compounded from Site (NB = Navigation buoy), C or S to denote SEAFLEX® or Chain and 5 or 6 to denote sampling in autumn 2005 or spring 2006. Thus NBC6 is the navigation buoy with a chain mooring sampled in 2006.

Post winter univariate analysis of channel edge samples can be summarised as follows. There were highly significant differences (P=0.0) among the mean abundance of species across the sites that could be largely related to the species richness at the chain mooring at the navigation buoys (Fig.5.21). This was significantly higher than species richness at the adjacent SEAFLEX® mooring.

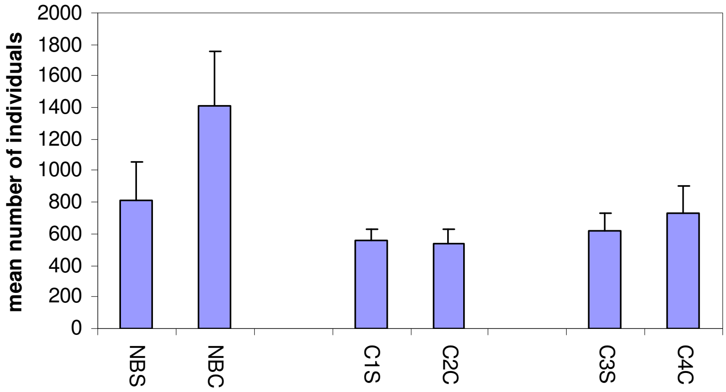


Source	DF	SS	MS	F	P
Factor	5	3238.2	647.6	19.90	0.000
Error	18	585.8	32.5		
Total	23	3824.0			

```
Level     N     Mean    StDev  ------+---------+---------+---------+
NBC       4   75.000    4.546                    (---*---)
NBS       4   63.000    3.559              (---*---)
C1S       4   42.000    8.042  (---*---)
C2C       4   47.500    6.758     (---*---)
C3S       4   44.000    6.377  (---*---)
C4C       4   55.750    3.304           (---*---)
                                ------+---------+---------+---------+
Pooled StDev =    5.705               45        60        75        90
```

Figure 5.21: A comparison of the number of species at SEAFLEX® and chain moorings along the channel edge. As an aid to interpretation the 1 way ANOVA table is provided as well as a further plot of means and confidence intervals.

In Figure 5.22 differences between samples are once again significant as the result of differences at the chain-equipped navigation buoy. All the other sites considered had homogeneous means.

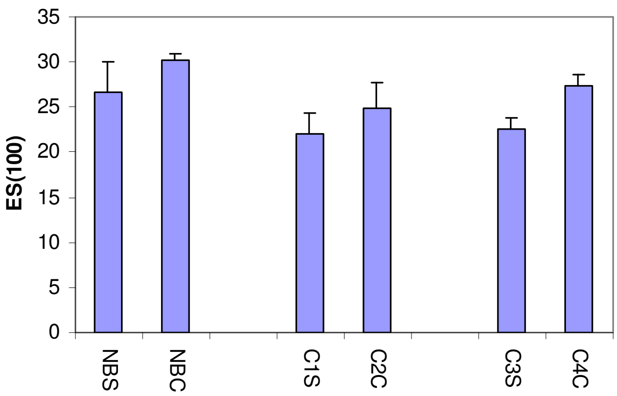



```
Source     DF        SS        MS        F        P
Factor      5   2125760    425152    10.62    0.000
Error      18    720883     40049
Total      23   2846643

Level      N      Mean     StDev  -+---------+---------+---------+-----
NBC        4    1407.8     354.0                       (-----*-----)
NBS        4     817.0     239.9          (-----*-----)
C1S        4     556.0      79.8  (-----*-----)
C2C        4     537.5      90.4  (-----*-----)
C3S        4     622.3     115.5    (-----*-----)
C4C        4     733.8     171.8       (-----*-----)
                                  -+---------+---------+---------+-----
Pooled StDev =   200.1           350       700      1050      1400
```

Figure 5.22: A comparison of the number of individuals at SEAFLEX® and chain moorings along the channel edge. As an aid to interpretation the 1 way ANOVA table is provided as well as a further plot of means and confidence intervals.

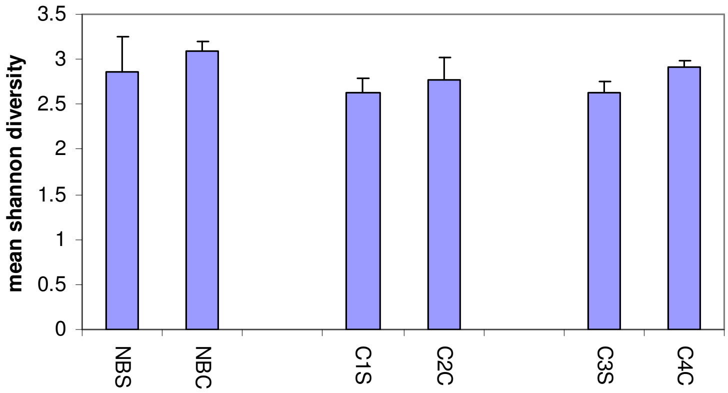
When the two remaining diversity measures (Figures 5.23 and 5.24) were considered the same pattern was evident, although not of significance when the Shannon diversity measure was considered.



Source	DF	SS	MS	F	P
Factor	5	191.90	38.38	8.10	0.000
Error	18	85.29	4.74		
Total	23	277.19			

```
Level   N     Mean    StDev  ----+---------+---------+---------+--
NBC     4   30.117    0.745                    (-----*------)
NBS     4   26.712    3.302           (-----*------)
C1S     4   21.980    2.411  (------*-----)
C2C     4   24.922    2.803       (-----*------)
C3S     4   22.496    1.356    (-----*------)
C4C     4   27.373    1.210            (-----*------)
                             ----+---------+---------+---------+--
Pooled StDev =    2.177          21.0      24.5      28.0      31.5
```

Figure 5.23: A comparison of the number of individuals at SEAFLEX® and chain moorings along the channel edge. As an aid to interpretation the 1 way ANOVA table is provided as well as a further plot of means and confidence intervals.




```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      5    0.6386    0.1277     2.75    0.052 NS
Error      18    0.8371    0.0465
Total      23    1.4757

Level     N      Mean     StDev  -----+---------+---------+---------+-
NBC       4    3.0917    0.1085                  (--------*--------)
NBS       4    2.8598    0.3996           (--------*--------)
C1S       4    2.6235    0.1666  (--------*--------)
C2C       4    2.7692    0.2477        (--------*--------)
C3S       4    2.6376    0.1152  (---------*--------)
C4C       4    2.9193    0.0723              (--------*--------)
                                 -----+---------+---------+---------+-
Pooled StDev =    0.2157              2.50      2.75      3.00      3.25
```

Figure 5.24: A comparison of the Shannon diversity measure H' at SEAFLEX® and chain moorings along the channel edge. As an aid to interpretation the 1 way ANOVA table is provided as well as a further plot of means and confidence intervals.

5.3.2.2 Conclusions for Channel Edge Sites

There was no clear difference between biota of samples taken at the SEAFLEX® moorings and those taken at chain sites. The differences in dispersion noted at site P were not evident.

5.4 Statistical analysis of data collected on September 12th 2006, i.e. after the SEAFLEX® buoys had been in place for a full year.

Data were collected using methods identical to those reported previously in this report. The approach followed earlier in this report is continued here with the muddy sites around the P buoys being examined separately to those at the channel edge.

5.4.1 Site P

Basic diversity statistics comparing site P4 (SEAFLEX®) for to P5 (Chain) are presented in Figure 5.25. There is no significant difference between treatments in mean number of individuals per sample, number of species per sample, Es_{50} (the predicted number of species for a sample of 50 individuals) or Shannon diversity.

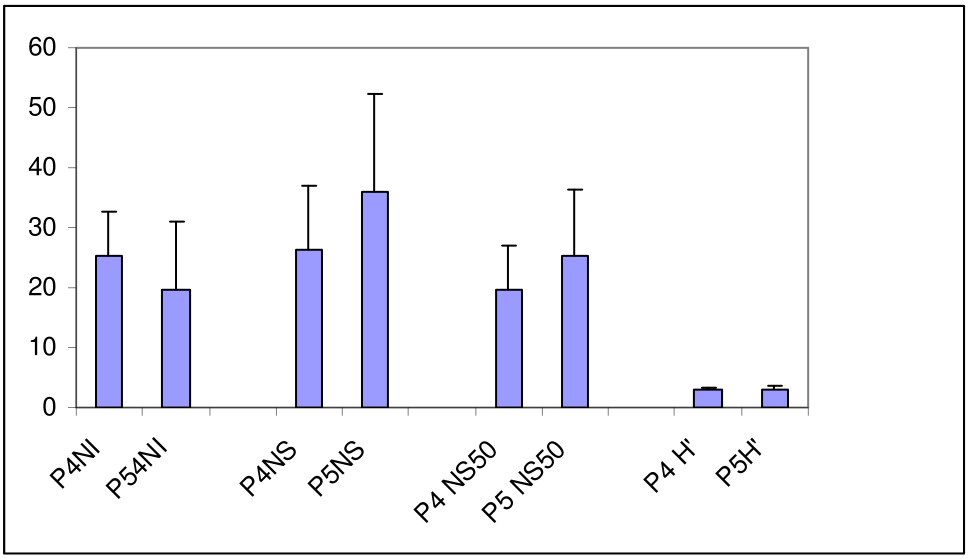


Figure 5.25: Histogram comparing sites P4 (SEAFLEX®) and P5 (chain). NI = number of individuals; NS = number of species; ES50 = the predicted number of species for a sample of 50 individuals and H' is Shannon diversity

A preliminary MDS plot (Figure 5.26) showed that on sample from P5 and one from P4 were substantially different to the remaining six samples. Two outliers (one from each treatment) focussed the pattern strongly and so the analysis was repeated omitting them (Figure 5.27). In the latter analysis no clear pattern emerged and there is no evidence of the SEAFLEX® mooring influencing community structure.

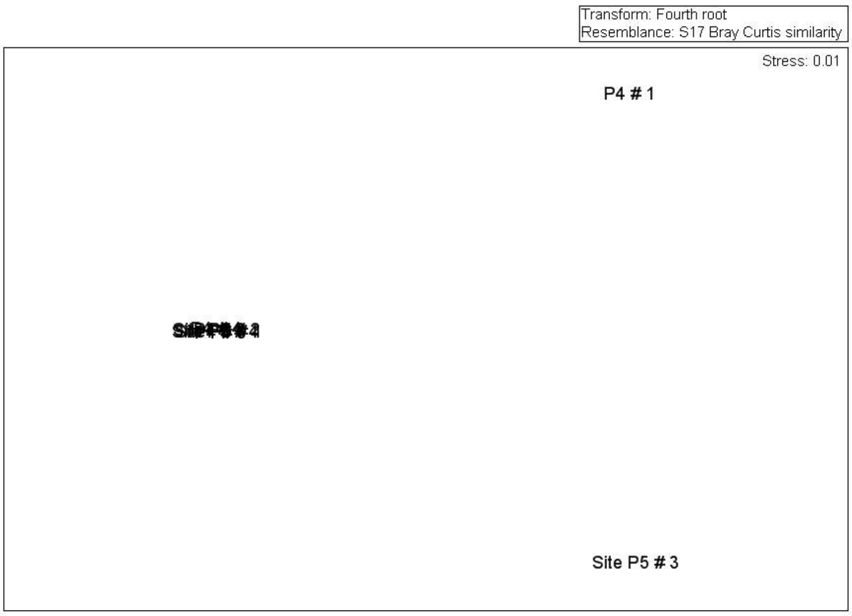


Figure 5.26: Preliminary MDS plot to show patterns of similarity in the fauna of samples taken from sites P4 (SEAFLEX®) and P5 (chain).

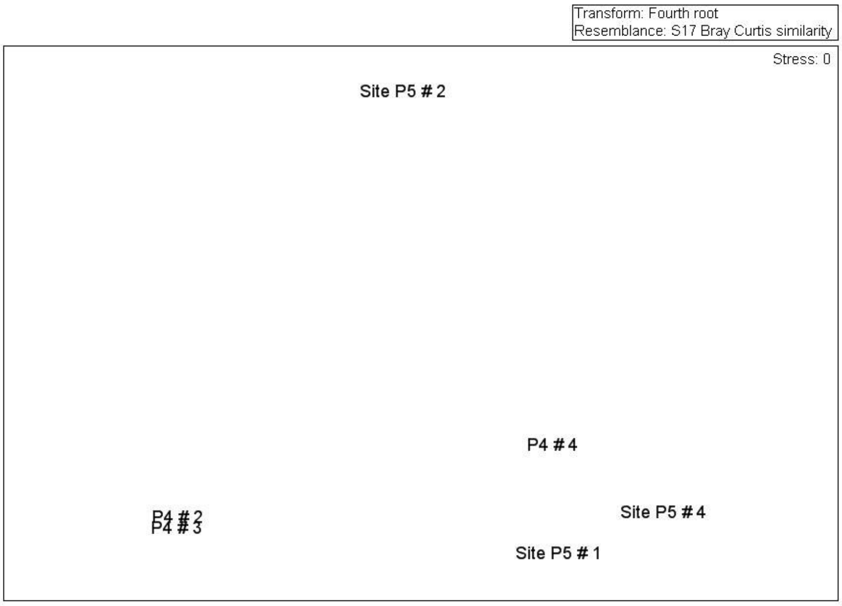
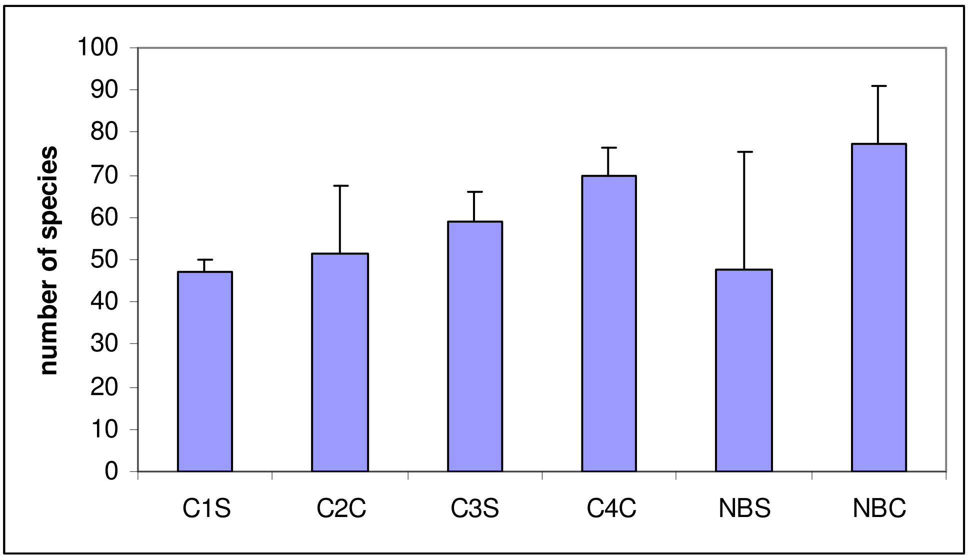


Figure 5.27: MDS plot to show patterns of similarity in the fauna of samples taken from sites P4 (SEAFLEX®) and P5 (chain). In this plot the two outlying samples from Figure 5.26 have been omitted

5.4.2 Channel edge sites

5.4.2.1 Number of species

There was a gradual increase in mean abundance with distance down-channel from the first site the exception was at the SEAFLEX® treated navigation buoy where numbers were highly variable. This variability caused the p value of the analysis of variance (ANOVA) to almost reach significance ($p=0.051$)



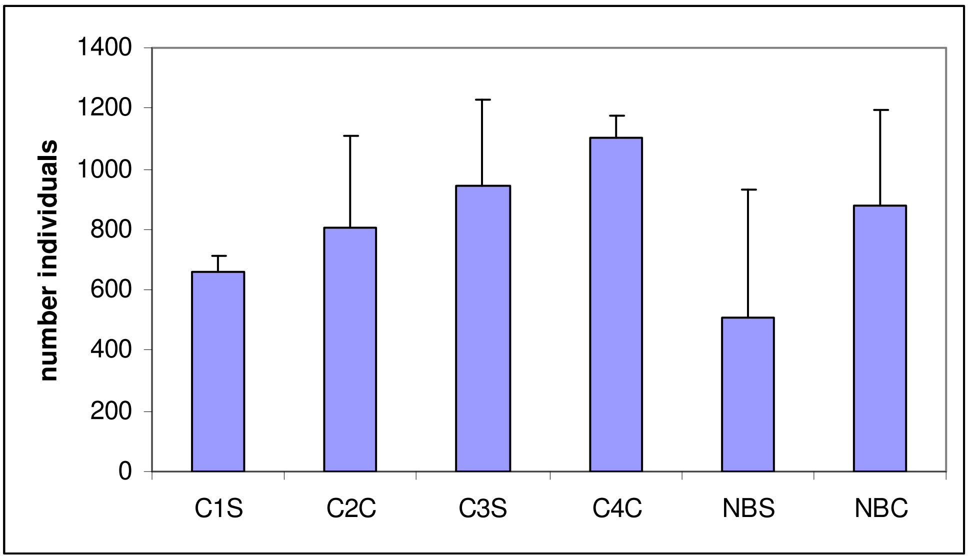
ANOVA (1 way)

Source	DF	SS	MS	F	P
Factor	5	3196	639	2.76	0.051
Error	18	4167	231		
Total	23	7363			

Figure 5.28: Mean number of species at channel edge sites in SEAFLEX® and chain treatments after one year. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns

5.4.2.2 Number of individuals

Although the high variability of the samples at the SEAFLEX® navigation buoy had a strong influence on the analysis there was no reason to suggest there were significant differences in the number of species among samples. No impact of the SEAFLEX® mooring could be detected.



Analysis of Variance

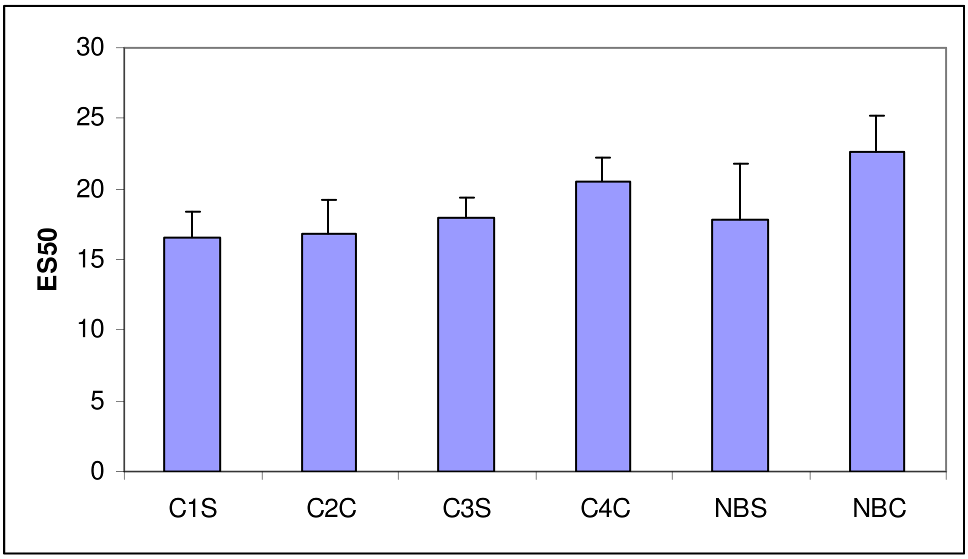
Source	DF	SS	MS	F	P
Factor	5	872899	174580	2.22	0.098
Error	18	1418227	78790		
Total	23	2291126			

Figure 5.29: Mean number of individuals in samples from channel edge sites in SEAFLEX® and chain treatments after one year. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns

5.4.2.3 Diversity measures

ES 50

On this occasion the analysis of variance proved to be significant (P=0.02) but the differences detected relate to the difference between sites 1 and 2 and the highly variable SEAFLEX® navigation buoy rather than relating to any SEAFLEX® chain difference.



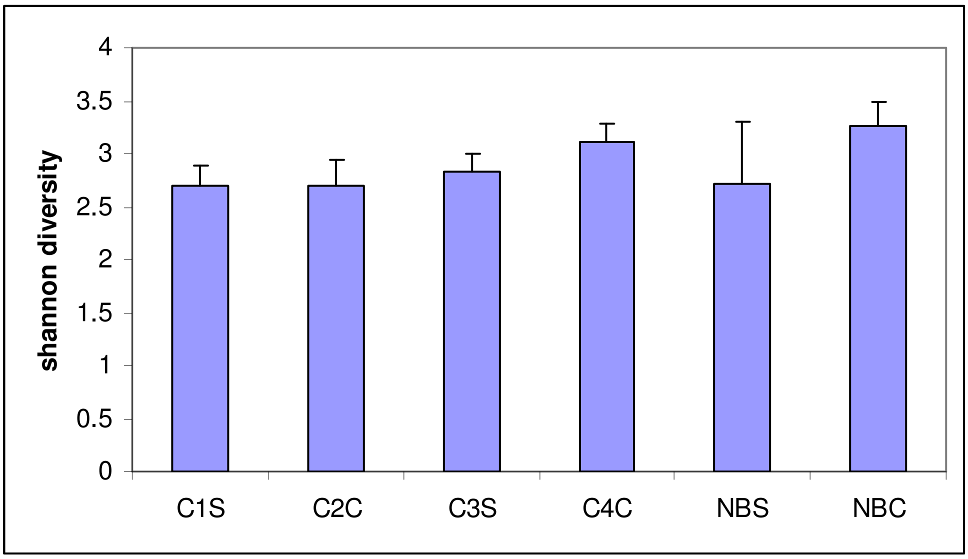
Analysis of Variance

Source	DF	SS	MS	F	P
Factor	5	112.69	22.54	3.54	0.021
Error	18	114.71	6.37		
Total	23	227.40			

Figure 5.30: Expected number of species that would be found in a sample of 50 individuals taken from channel edge sites in SEAFLEX® and chain treatments after one year. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns

Shannon Diversity

The analysis of variance presented with Figure 5.31 is not significant and suggest all samples might be taken from the same homogeneous distribution. No effect of SEAFLEX® moorings is evident.



Analysis of Variance

Source	DF	SS	MS	F	P
Factor	5	1.1806	0.2361	2.46	0.072
Error	18	1.7275	0.0960		
Total	23	2.9081			

Figure 5.31: Mean Shannon diversity (H') in samples taken from channel edge sites in SEAFLEX® and chain treatments after one year. Error bar = 95% Confidence Interval. The analysis of variance table tests for significant differences between columns

Multivariate analysis

An MDS plot of channel edge sites is presented as Figure 5.32. In this figure the separation of any pair of points is a measure of the similarity of their fauna. In this plot sites are arranged in a sequence that matches their distributing along the channel edge. Once again a pair of highly dissimilar samples at the SEAFLEX® navigation buoy (referred to as F in Figure 5.32) is clearly evident. There is no clear separation of SEAFLEX® and chain sites but as the moorings were laid sequentially along a gradient in the habitat pair-wise separation would be very difficult.

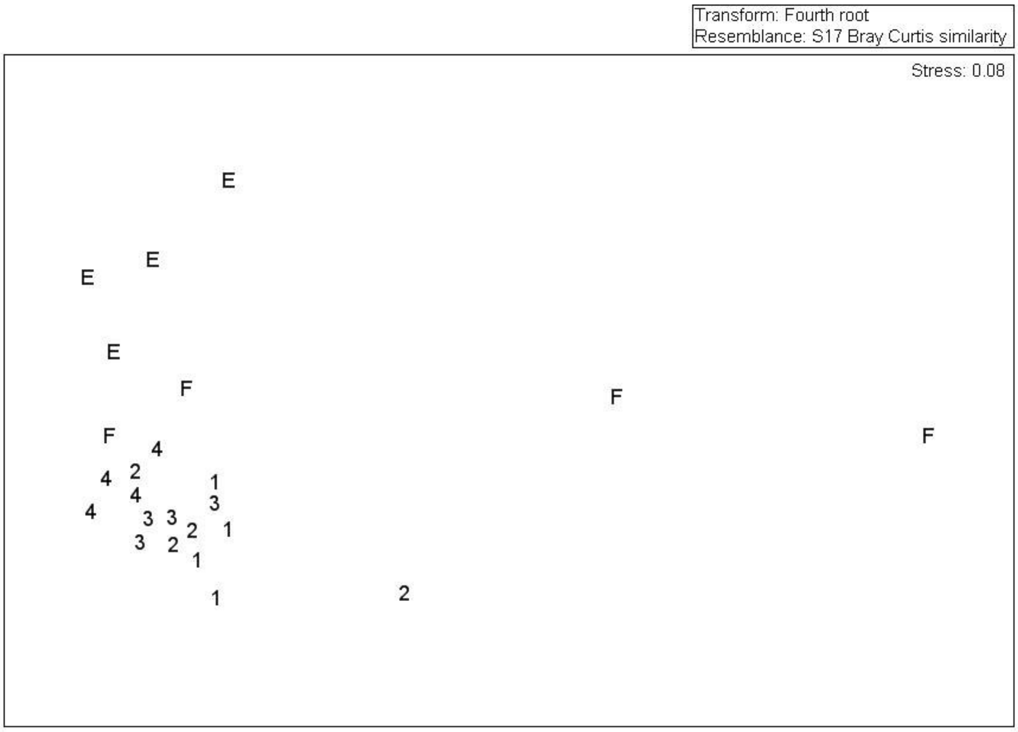


Figure 5.32: An MDS plot of channel edge sites.

5.4.3 Conclusions

At the end of the first six months of the mooring trial there was a suggestion in the data that sites with SEAFLEX® mooring had a fauna that was far more homogeneous than that found in sites that had a chain mooring. This trend was no longer evident when data were collected a full year after deployment.

No other trends were evident at the end of six months. In this trial we have been unable to demonstrate that the use of a SEAFLEX® mooring has any beneficial effect on the macrobenthic biota of the area of the Fal adjacent to Mylor harbour. This does not necessarily mean that deployment of the mooring in the context of marine conservation will never be beneficial. The initial sampling design advocated by PML Applications Ltd would have had a far higher chance of finding such a difference but the harsh compromises that were enforced out of operational necessity by the operators of Mylor Harbour greatly reduced the probability of finding differences between chain and SEAFLEX® moorings. Had the differences in biota been large the later sampling design might have found them but more subtle differences would have been more difficult to uncover.

6. A brief report regarding the experience of using a *SEAFLEX®* mooring.

In conjunction with this independent and impartial PML Applications Ltd research project for Cornwall County Council, Mylor Yacht Harbour has also been participating in the Cycleau project investigating the viability of using a SEAFLEX® mooring system instead of the conventional chain system. There follows a report of their findings written by Matthew Oakes of Mylor Yacht Harbour.

Mylor currently has a swinging mooring area consisting of 236 chain moorings most of which are anchored using a chain trott system. The average depth at low water is about 2m and we have up to 6m of tidal variation above this. We have been very interested in the idea of using the SEAFLEX® moorings ever since we installed a new marina here 5 years ago using SEAFLEX®. As we currently spend a lot of time and money each winter replacing chain and shackles on our moorings the idea of a very low maintenance mooring was certainly commercially attractive. We have heard of successful applications of the SEAFLEX® mooring around the world but a lot of these have been areas with a small tidal range or very deep water. The combination of shallow water and a 6m tidal range was to be a new test for the SEAFLEX® mooring.

From the outset we were naturally cautious with installing these moorings as we were to be using them to moor boats worth in excess of £100,000 and for customers who expected a very high level of service from us. We initially replaced one of our chain moorings with a SEAFLEX® mooring with the intention of installing more should this prove a success.

Following the installation we immediately discovered that the mooring buoy supplied with the system would not sit upright at low water. This not only meant that customers were unable to retrieve the mooring whilst the buoy was upside down but it also looked very threatening amongst our A4 riding buoys and led some customers to believe that it was a piece of scientific monitoring equipment! To overcome this initial problem we simply replaced the buoy supplied with a standard A4 riding buoy attached to which was a short pickup rope and buoy. This in no way affected the performance of the mooring system but allowed it to blend in better with our current moorings.

Once we were able to permanently moor a boat to the mooring we continued with using it just as we would if it were a standard chain mooring. The position it was located in would have normally allowed a boat of 40' to be moored and so this is the length of boat that we first trialled on the mooring.
It immediately became apparent that there was a problem with doing this in that the 40' boat began to hit other boats on the nearby moorings at lower states of tide. As the tide falls on a chain mooring the chain gathers in one position and keeps the boat in one place but we discovered that as the tide falls on a SEAFLEX® mooring the swinging room just increase and increases until at low tide you have a boat that requires a radius of 80ft swinging room as opposed to 40ft. This is certainly a problem that would need to be addressed for the system to be used commercially. For both business reasons and the preservation of clear sailing waters it is important

that swinging room is kept to a minimum to enable as many boats as possible to occupy one space.

Once we moved the 40' boat to another mooring we trialled a 20' boat. Although we were unable to keep the boat on the mooring for a long period of time due to same reasons as before we were able to use the mooring long enough to test it a little further. During this time we encountered a few more areas for development which I have outlined below.

1. A chain mooring system is designed such that heavy chain under the water acts as a shock absorber gently taking up the pull of a boat on its mooring as the boat is battered by wind or rides the waves. A SEAFLEX® mooring consists of a short length of SEAFLEX® (large bungee cord) and strong rope. This SEAFLEX® is not elastic enough for small boats and too elastic for heavy boats. This leads to an uncomfortable jarring effect on smaller vessels which can prove damaging. It is thought that with some further research the SEAFLEX® could be graded depending on the weight to be placed on the mooring thus possibly overcoming this problem.
2. During the time that we observed the behaviour of the 20' boat on the mooring we noticed that problems arose as a result of having one mooring type (i.e. a SEAFLEX® mooring) amongst another mooring type (chain). If the wind is blowing from the East whilst the tide falls and then shifts to another direction (i.e. Westerly) then the differing behaviour of the SEAFLEX® and chain moorings can cause boats to collide. The boats on the chain moorings will simply face in the opposite direction but not actually move position as the weight of the chain gathered on the seabed will continue to anchor them in one place. The boat on the SEAFLEX® mooring however will not have the gathered chain to anchor it and so swing around a large arc before settling up to 80' from its previous position. This obviously resulted in problems with the boats colliding under these circumstances. To over come this we would suggest that the SEAFLEX® moorings should not be mixed amongst chain moorings and therefore overcoming this problem of differing behaviours. We do not have any empty space in our mooring area and so the only way we could continue to test the mooring system was to use speed marker buoys and a heavy channel marker mooring which was away from our boats therefore allowing the trial to continue.
3. Following the removal of the 20' boat from the SEAFLEX® mooring we noticed that with no boat moored to the mooring there are problems with the marker buoy sitting a long way from the mooring block. This meant that in our shallow water mooring area at low tide we had trouble with boats fouling their propellers on the rope that leads down to the SEAFLEX®. This does not happen with a chain mooring as the chain is much heavier and sinks. This could be overcome by using a weighted line but that may then have an effect with the line disturbing the seabed.
4. Servicing a SEAFLEX® mooring requires a diver as you cannot lift a 2 ton block with the SEAFLEX®. Currently chain moorings can be lifted out the water for inspection and servicing but this cannot be done with a SEAFLEX® mooring without the aid of a diver attaching a lifting chain to the mooring block adding a lot more time and expense. This could be over come with

further development thus saving the diving costs and making the SEAFLEX® system more attractive.

We (Mylor Yacht Harbour) hope the testing done at Mylor has proven useful for the future development of the SEAFLEX® mooring system. Our experience has suggested that as the mooring currently stands it would be better suited in a deeper water environment where the depth at low water exceeds the tidal range. With a little more development this mooring system may well prove invaluable in a delicate area such a coral reef or in other similarly sensitive areas.

Matthew Oakes
Mylor Yacht Harbour.

7. Discussion

The first question to address is "Do SEAFLEX® moorings disturb the benthos less than chain?" and in this series of tests at Mylor the answer has to be "there is no evidence that they do". However there a number of caveats that must be considered before the moorings are dismissed as ineffective. The first of these relates to experimental design; the original experiment was centred on muddy sites close to the yacht harbour and it is unfortunate that these were abandoned for operational reasons. If attempting to seek for the influence of physical disturbance on the benthos it would be these soft, low energy sites that would be the first choice of the experimenter. At coarser more current exposed sites such as those given to us at the channel edge one might imagine that a greater physical disturbance would be needed to have a biological impact. It must also be questioned how well any result from the channel edge site could be transferred back to the generality of yacht moorings. This was the outer fringe of the mooring areas and it is the final place that berths are allocated and then only in summer. Had there been a significant difference between SEAFLEX® and chain sites across the study then it would have told us that in all probability in quieter water the impact of changing mooring type would have considerable. On the other hand, our failure to find a mooring-induced effect does not necessarily mean that the moorings will not reduce impacts in more typical settings.

Site layout would also be an important factor to reconsider. A linear series of sites lying along an environmental gradient will always produce community data carrying a strong signal and this makes it difficult, for any secondary signal to be picked out. Ideally all of the study would have been in the muddy area with sufficient sites to give good replication and tighter error terms around univariate estimators and in ANOSIM.

The most significant result, the greater homogeneity of the benthic assemblage at the SEAFLEX® site at P is intriguing. It is easy to imagine that constant disturbance to a benthic assemblage and constant patchy recovery will lead to high variability in the biota collected in benthic samples. Indeed it has been proposed that such variance might be used as an indicator of an assemblage subject to pollution or disturbance (Clarke, K. R. (1993). "Nonparametric Multivariate Analyses of Changes in Community Structure." Australian Journal of Ecology **18**(1): 117-143.). However the study changing of patterns of multivariate variance in relation to SEAFLEX® moorings would require far more data than we have available from a single site.

Finally, the extent of the problem of yacht moorings chains having a significant impact on the benthos of the Fal has to be examined. Mylor Yacht Harbour's moorings are largely situated in an area that has a benthic assemblage broadly similar to the shallow subtidal of other estuaries in SW England. This biota exists in an area subject to the runoff from Mylor Creek and appears to be subject to the frequent deposition of macroalgal debris; these are natural stressors that will impact benthic biodiversity. It must be considered if these factors have a greater influence on the benthos than the effects of mooring chains. If such is the case then the chains will be impacting an already impoverished fauna.

In September 2006 we were briefly able to examine the seafloor around station P and found ourselves unable to see the sediment surface for drift weed. However, in addition to the weed there was considerable human debris; bottles, cans, paper goods and fishing equipment. While such goods have little independent impact on the benthos they are indicative of an area under anthropogenic pressure from multiple sources. If the moorings are impacting the biodiversity of the benthos around Mylor Yacht harbour then it is highly probable that they are acting in concert with a variety of other potentially damaging factors.

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