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Infaunal community changes as a result of commercial clam cultivation and harvesting

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Abstract

Manila clams, *Tapes philippinarum* (Adams and Reeve) are cultivated beneath plastic netting, to protect them from excessive predation, and harvested after approximately two years. Both the on-growing and harvesting process have the potential to alter benthic communities. In order to study these effects, we surveyed a clam lay and uncultivated areas at a site of commercial clam cultivation in south-east England. Surveys were undertaken at the end of the growing stage, immediately after harvesting by suction dredge and seven months later. Infaunal abundance was greatest within a net covered clam lay than in proximate and distant control areas, but the total number of species encountered was similar in all areas (20-22). These differences were not attributable to variation in sediment structure or environmental variables between the areas sampled. Tube-building polychaetes, such as *Lanice conchilega* and *Euclymene lumbricoides*, were particularly abundant within the cultivated area as was the errant polychaete, *Syllis gracilis*. Harvesting by suction dredge altered sediment composition by removing the larger sand fractions down to the underlying clay substratum, consequently there was a large reduction in the density of all individuals and the total number of species. Seven months later, no significant difference was found between the infaunal community in the harvested clam lay or either of the control areas and sedimentation had nearly restored the sediment structure. These observations indicate that the practice of clam cultivation does not have long-term effects on the environment or benthic community at this site.

Keywords: Clam cultivation, benthic community, harvesting, environmental impact.

Modification de l'endofaune en relation avec l'élevage des palourdes.

Résumé

Les palourdes japonaises, *Tapes philippinarum* sont cultivées sous des filets de plastique pour les protéger d'une prédation excessive et récoltées après deux ans d'élevage approximativement.
À la fois, la croissance et la récolte peuvent altérer les communautés d'organismes vivants du benthos. Afin d'étudier ces effets, nous avons prélevé des échantillons sur des zones cultivées ou non de palourdes, sur un site d'élevage dans le sud-est de l'Angleterre. L'étude a été entreprise lors des dernières étapes de la croissance, immédiatement après la récolte effectuée par une drague à succion et enfin, sept mois plus tard. La faune présente dans le sédiment était plus abondante sous la protection du filet que dans les zones témoins, mais le nombre total d'espèces rencontrées était similaire dans toutes les zones (20 à 22). Ces différences ne sont pas attribuables à la variation de la structure du sédiment ou aux paramètres environnementaux des zones échantillonnées. Les annélides polychètes tubicoles tels que *Lanice conchiliga* et *Euclymene lumbricoides* sont particulièrement abondants dans la zone cultivée de même que le polychète errant, *Syllis gracilis*. La récolte par succion altère la composition du sédiment en enlevant la fraction la plus grossière du sable jusqu'à la couche d'argile sous-jacente. En conséquence, il y a une diminution en densité de tous les individus et du nombre total d'espèces. Sept mois plus tard, aucune différence significative n'était trouvée entre l'endofaune de la zone cultivée et celle de la zone témoin; la sédimentation a pratiquement restauré la structure du sédiment. Ces observations indiquent que la pratique de l'élevage de palourdes n'a pas d'effet à long terme sur l'environnement ou sur la communauté benthique de ce site.

Mots-clés : Élevage de palourdes, communauté benthique.

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INTRODUCTION

The potential impact of various aquaculture practices on the marine environment have been well documented for marine fish farms (e.g. Brown *et al.*, 1987; Gowen and Bradbury, 1987) and mussel culture (e.g. Tenore *et al.*, 1985). Typically, these studies have demonstrated a dramatic change in the proximate benthic communities as a result of extreme eutrophication and resulting anoxic conditions (e.g. Brown *et al.*, 1987; Gowen and Bradbury, 1987). However, the effects of clam cultivation in the intertidal zone are less obvious and consequently relatively unknown (but *see* Mojica and Nelson, 1993). In England and Wales, Manila clams, *Tapes philippinarum*, are cultivated in the sediment and covered with protective netting which prevents excessive predation of the young seed by crabs and shorebirds (Spencer *et al.*, 1992), and to conform to the statutory requirements for the release of non-native species into the wild (Parliament-Great Britain, The Wildlife and Countryside Act, 1981). Both the on-growing and harvesting process, which is normally carried out by suction pump or hand raking in the United Kingdom, have the potential to alter the benthic community. This is currently the subject of a small-scale field trial in the R. Exe, Devon, England, that is being monitored for ecological change at each stage of the cultivation process (Spencer *et al.*, 1993; 1996). However, the effects of cultivation may differ between localities according to their environmental conditions, as a result of the scale of the cultivated area and possibly due to differences in commercial practices. Hence, while we are already studying these effects at an experimentally manipulated site, we wanted to assess the effects at a different locality that is a site of large-scale commercial cultivation. In addition, sampling approximately coincided with harvesting, hence we also assessed the immediate effects of suction dredging on the experimental site. Subsequently, we returned seven months later, in July 1995, to investigate the persistence of harvesting effects on the benthic community. It was not possible to study the harvested clam lay for a longer period, as the plot was re-sown with clam seed immediately after our last survey.

METHODS

A survey of the benthic community and physical characteristics of a site of commercial clam cultivation (Whitstable, Kent, south-east England) was undertaken in December 1994 to examine the effects of the growing phase of cultivation on the intertidal benthic community. Further samples were collected immediately after the clams had been harvested and seven month later in July 1995.

Prior to harvesting, three different areas were sampled at the commercial site, these were; beneath the net covered area that contained clams (clam lay); a control area 1 m adjacent to the clam lay; control areas that were 200 m adjacent to the nearest clam lay (*fig.* 1). Although it would have been preferable to sample beneath more than one clam lay, we were restricted by the need to minimise disturbance to the commercial operator. The areas adjacent to the clam lays are subject to trampling disturbance as the seed clams are sown, however, after this operation the area remains relatively undisturbed until harvesting 2 yrs later. Within each area, 3 replicate 15 cm diameter cores (volume = 0.0026 m^3), at five separate positions, were collected for faunal analysis (for detailed layout *see fig.* 1). Samples were sieved over 1 mm mesh and preserved in 4% buffered formalin for later identification. Although it would have been preferable to sieve over 0.5 mm mesh, the increase in time required to process the samples would not have allowed us to collect as many replicates.

At each of the five positions within each area, samples of the sediment, organic and photosynthetic pigment content were collected. Sediment samples were collected by inserting an 8 cm deep, 10 cm diameter corer into the ground until it was flush to the surface. Samples were oven dried at 60°C for 48 h and 100 g of material removed. This was soaked overnight in a one litre solution of sodium hexametaphosphate to disaggregate the sediment particles (Buchanan and Kain, 1971). Each sample was then wet sieved on a 63 μm mesh to determine the fine fraction. The remaining sample was redried as before prior to being put through a stack of geological test-sieves (range 125-63 μm). A dry weight for each size fraction was measured using a top-pan balance to an accuracy of $\pm$ 0.01 g.

Samples for analysis of organic content were collected by inserting a cylinder 10 cm deep, 1.5 cm diameter corer into the ground until it was flush with

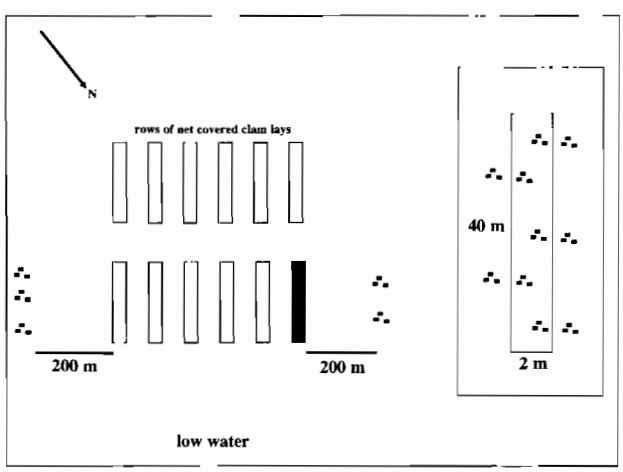

Figure 1. – Layout of the clam lays (20 m long × 2 m wide) showing the position of the near adjacent controls (inset) collected from the walkways (3 m wide). The approximate position of each core is also indicated (•).

the surface. The samples were oven-dried at 60°C for 48 h and ground to powder with a pestle and mortar. Sub-samples weighed before and after combustion in a muffle furnace at 450°C for 5 h, provided an estimate of the ash-free dry weight (AFDW) of the samples.

Samples for the analysis of photosynthetic pigment content were collected in the same manner as the organic samples. They were deep-frozen to await analysis. When partially thawed, 10 mm of the core at the end nearest to the water/sediment interface, was cut off and placed into a 15 mm diameter test tube. Chlorophyll pigments were extracted with 3 ml of 90% acetone by leaving the samples overnight in a refrigerator at ca. 5°C. Chlorophyll *a* and phaeopigment concentrations were determined spectrophotometrically by the method of Wolff (1987).

Two weeks later, the clam plot was harvested on an ebbing tide using a commercially developed suction dredge (details available from Mr G. Wordsworth, 16, Holywell Close, West Canford Heath, Poole, Dorset, U.K.). Three hours later infaunal and sediment samples were collected from the harvested area as before. Unfortunately it was not possible to collect organic samples due to a rising tide. Seven months later, we returned to the site and repeated the initial sampling protocol.

During harvesting, four replicate samples of water were collected 50 cm from the sediment surface when water depth was ca. 100 cm. These were collected by immersing four stoppered 1 l bottles simultaneously, and releasing the stoppers remotely when at the required depth. Samples were collected 1 m up-tide, 1, 5, 10, 20 and 40 m down-tide of the suction dredge. Each sample, comprising 250 ml aliquots of water, was filtered onto tared Whatman GFC grade filter papers. These were oven-dried at 80°C for 48 h, weighed and then ashed in a muffle furnace at 450°C overnight and reweighed.

Statistical treatment

Differences in the sediment characteristics and percentage organic content between areas were tested using oneway ANOVA on arcsin transformed data. When significant differences were detected a Tukey-Kramer multiple comparison procedure (T-K) was used to determine which areas differed. The total number of species, individuals, richness, evenness and two measures of diversity; Hill N1 (Simpson's reciprocal D) and Hill N2 (Shannon exp H') were tested for significant differences using the same procedure as above after $\log_e$ transformation.

Prior to analysis of the benthic community data, the data from each set of three replicate cores (total no. of cores collected = 105) was pooled, thus all analyses are performed on the 35 different positions sampled. Multivariate analysis on the whole community was carried out using the PRIMER software package developed at Plymouth Marine Laboratory. Cluster analysis was carried out on $\log_e(x+1)$ transformed data using the Bray-Curtis measure of similarity. The resulting similarity matrix was used to carry out non-metric multidimensional scaling (MDS). An *a priori* analysis of similarities test (ANOSIM) was performed to identify significant differences between samples from the two control areas, the cultivated area and the same areas seven months after harvesting. A similarities terms analysis (SIMPER) was then performed to identify the contribution of each species to the Bray-Curtis similarity measure within groups of similar samples (Clarke, 1993). A principal components analysis (PCA) was performed on four environmental variables measured in December 1994 and July 1995; % > 63 μm (arcsin transformed); % organic content (arcsin transformed); chlorophyll *a* and phaeopigment content.

RESULTS

General observations

The cultivation area is a shallow shelving mudflat that is exposed to the prevailing north easterly winds. The underlying sediment is composed of London clay interspersed with patches of shell debris and lignin deposits from the effluent of a local paper mill. The surface sediment consisted of fine sand and silt, however, patches of clay were occasionally visible on the surface. The plastic netting (0.5 mm square

Table 1. – Mean ± SE (per 0.017 m^2) total species, individuals, richness, evenness, Hill N1 and N2 values for the five samples collected from each area. Significant differences were determined using the Tukey-Kramer multiple comparison test. Means that differ significantly ($p < 0.05$) share the same letter.

	Nov-94				Jul-95		
	Far control	Near control	Clam lay	Post harvest	Far control	Near control	Post harvest
Total species	5.8 ± 1.4	7.0 ± 0.7^{a}	9.0 ± 1.3^{b}	4.0 ± 0.7^{ab}	3.6 ± 0.5	5.4 ± 0.2	3.2 ± 1.0
Total individuals	12.4 ± 2.9^{a}	25.5 ± 7.7^{b}	60.0 ± 14.1^{abc}	19.6 ± 4.9^{c}	15.0 ± 6.7	27.0 ± 11.7	9.0 ± 3.4
Richness	1.8 ± 0.4	1.9 ± 0.1	2.0 ± 0.2	1.0 ± 0.2	1.2 ± 0.2	1.4 ± 0.2	0.8 ± 0.2
Evenness	0.85 ± 0.06	0.77 ± 0.06	0.76 ± 0.04	0.71 ± 0.09	0.8 ± 0.1	0.8 ± 0.1	0.5 ± 0.1
Hill N1	4.7 ± 1.1	4.4 ± 0.4	5.2 ± 0.5	2.5 ± 0.3	3.1 ± 0.5	3.7 ± 0.5	2.7 ± 0.8
Hill N2	5.7 ± 1.3	3.9 ± 0.6	4.1 ± 0.5	2.4 ± 0.4	4.4 ± 1.0	3.7 ± 0.3	2.5 ± 0.6

mesh) on the plots had accumulated patches of loose organic debris and hydriod colonies were attached to its structure.

Effects due to the growing stage

Although the mean number of species per core was greatest in the clam lay, this did not vary significantly from either the near or far control (*table* 1). The total number of species encountered for all samples was very similar: 20 clam lay; 21 near control; 22 far control. The mean abundance of individuals (all fauna pooled for each sample) was significantly higher in the clam lay than in either of the control areas (*table* 1). None of the other measures, *i.e.* richness, evenness or diversity differed significantly between the clam lays or control areas (*table* 1). Average similarity between samples, derived from the Bray-Curtis similarity analysis, was ranked clam lays (mean ± SD, 71.9 ± 6.2) > near controls (55.0 ± 11.1) > far controls (30.0 ± 15.0). Accordingly the coefficient of variation was highest for the far controls (0.50), intermediate for the near controls (0.21) and least for the clam lays (0.09). However, the spatial separation between samples increased in the order clam lay < near control < far control, which may account for some of the increase in variability between control samples. The ANOSIM procedure indicated that there was no significant difference in the benthic community between the near and far control areas (ANOSIM $p = 0.18$). However, the samples collected from the clam lay were significantly different from both the far ($p = 0.007$) and near ($p = 0.024$) controls (*fig.* 2*A*). The SIMPER procedure revealed that the species which contributed most to the similarity between samples collected from the clam lay were ranked *Lanice conchiliga* > *Mysella bidentata* > *Euclymene lumbricoides* > *Nephtys hombergii* (*table* 2). Conversely, *Nephtys hombergii* contributed most to the similarity between samples collected from both controls (*table* 2).

Mean percentage organic content ranged from 1.91 to 2.15% for all samples and did not vary significantly between clam lay, near or far control areas (*table* 3, T-K $p > 0.07$ in all cases). The percentage composition of different sediment grades did not vary between the clam lay, near or far control areas (*table* 3, T-K $p > 0.05$ in all cases). There was a large component of silt/clay from all areas (mean > 22%). Photosynthetic pigment content was similar in all areas (*table* 4, chlorophyll *a*, ANOVA, $F_{2,12} = 0.33$, $p = 0.72$; phaeopigment, $F_{2,12} = 2.66$, $p = 0.11$). Not surprisingly, principal components analysis did not indicate that the differences observed in the benthic community, between control areas and the clam lay, were attributable to the variation in environmental variables (*fig.* 2*C*).

Table 2. – Similarity terms analysis of the five seperate groups of samples which indicates which species contribute most to the similarity within that group. Also shown is the mean similarity (± SD) between samples within each group. Significant differences between groups of samples was ascertained using the ANOSIM proceedure prior to analysis.

	No. per 0.017 m²	SD	Cum.%
Far control	Ave. similarity = 30.0 ± 15.0		
Nephtys hombergii	3	1.9	57.4
Euclymene lumbricoides	1.6	1.7	75.4
Lanice conchilega	1.8	2.5	86.2
Corophium volutator	1.8	3.0	90.4
Hydrobia ulvae	0.4	0.6	94.4
Exogone hebes	0.6	0.9	97.3
Near control	Ave. similarity = 55.0 ± 11.1		
Nephtys hombergii	3.8	1.8	28.5
Euclymene lumbricoides	2.6	0.6	54.9
Lanice conchilega	13.2	13.8	80.5
Macoma balthica	1.2	0.8	90.0
Scoloplos armiger	1	1.0	95.4
Melita palmata	0.4	0.6	97.3
Hydrobia ulvae	0.4	0.6	98.7
Cerastoderma edule	0.6	0.9	100.0
Clam lay	Ave. similarity = 71.8 ± 6.2		
Lanice conchilega	24.8	16.6	28.2
Mysella bidentata	12.4	6.4	49.0
Euclymene lumbricoides	7.4	3.7	66.4
Nephtys hombergii	4.8	2.6	80.4
Scoloplos armiger	1.8	1.8	87.3
Syllis gracilis	3.4	4.0	92.8
Macoma balthica	1.6	1.1	97.9
Tubificoides	0.4	0.6	98.5
Ensis americanus	1.2	2.2	99.0
Cerastoderma edule	1	1.7	99.5
Hydrobia ulvae	0.4	0.6	100.0
Clam lay post-harvesting	Ave. similarity = 62.9 ± 11.5		
Lanice conchilega	12.6	9.0	54.7
Euclymene lumbricoides	4.6	3.2	93.4
Nephtys hombergii	1	1.2	98.4
All areas in July 1995	Ave. similarity = 48.5 ± 7.1		
Euclymene lumbricoides	4.1	3.2	35.5
Nephtys hombergii	1.5	1.2	64.2
Lanice conchilega	8	11.2	92.1
Macoma balthica	0.6	0.8	96.3
Scoloplos armiger	0.3	0.6	97.6
Cerastoderma edule	1.1	3.6	98.7
Syllis gracilis	0.5	1.1	99.6
Mysella bidentata	0.3	0.6	100.0

Effects due to harvesting

After harvesting the average similarity between samples collected from the clam lay was lower (mean ± SD, 62.9 ± 11.0), but variation between these samples was lower than the two control

Table 3. – Mean(1 ± SEM) percentage composition of the different sediment size-fractions and the organic content (% AFDW) for each of the areas. Organic content data was not collected after harvesting. Only when the clam lay had been harvested was the sediment structure altered significantly (T-K, $p < 0.025$). For each size fraction, values sharing the same superscript are significantly different from each other.

	Dec-94				Jul-95		
	Far control	Near control	Clam lay	Post harvest	Far control	Near control	Post harvest
Sediment size-fraction							
> 125 μm	38.8 ± 6.8^{a}	36.2 ± 2.0^{b}	47.7 ± 4.4^{c}	16.8 ± 0.3^{abcd}	40.4 ± 7.2	25.4 ± 5.3	23.8 ± 4.6^{d}
> 63 μm	38.5 ± 8.7^{a}	25.7 ± 3.6^{b}	22.3 ± 3.1^{c}	4.6 ± 0.7^{abcd}	26.1 ± 4.3	19.8 ± 5.7	13.2 ± 3.6^{d}
< 63 μm	22.6 ± 8.9^{a}	38.2 ± 5.9^{b}	30.1 ± 8.9^{c}	78.6 ± 1.3^{abc}	33.4 ± 11.9	54.2 ± 13.5	62.9 ± 11.4
% Organic content	2.2 ± 0.3	2.7 ± 0.3	1.9 ± 2.9		2.3 ± 0.2	2.5 ± 0.3	2.1 ± 1.5

Table 4. – The mean (± SEM) concentration of photosynthetic pigments (mg-m^{-2}) in each of the far and near controls and the clam lay in both December 1994 and July 1995. No significant differences occurred between any of the treatments.

	Far control	Near control	Clam lay
Dec-94			
Chlorophyll *a*	2.8 ± 0.7	2.5 ± 0.3	2.2 ± 0.2
Phaeopigment	3.9 ± 0.4	4.5 ± 0.7	2.9 ± 0.2
Jul-95			
Chlorophyll *a*	1.2 ± 0.3	1.8 ± 0.6	1.3 ± 0.3
Phaeopigment	1.8 ± 0.2	3.1 ± 0.9	2.1 ± 0.3

areas (coefficient of variation = 0.18). Harvesting also significantly altered the composition of the infauna in the clam lay (ANOSIM, $p = 0.008$), reducing diversity and the mean number of individuals per sample (*table* 1). Only three species accounted for 98% of the similarity between the samples collected post-harvesting, these were; *Lanice conchilega*, *Euclymene lumbricoides* and *Nephtys hombergii*. None of these samples contained either molluscs or crustaceans.

After harvesting the mean silt/clay content of the sediment samples collected was 78% (*table* 3). This suggests that the larger fractions had been removed down to the underlying clay. Large amounts of sediment were resuspended by the suction dredge which decreased down-tide until, at a distance of 40 m down-tide, they reached similar levels to those samples collected 5 m up-tide of the dredge (*table* 5).

Changes after seven months

Pair-wise comparison of the control areas with the harvested clam lay indicated no significant differences in the benthic community (*table* 1, *fig.* 2*B*, ANOSIM, $p > 0.38$ in all cases). The benthic community in both the far and near controls had not altered significantly between December 1994 and July 1995 (ANOSIM, $p > 0.25$). However, the community in the harvested clam lay was significantly different seven months later (post-harvest December 1994 v post-harvest July 1995, ANOSIM, $p = 0.016$). This difference was mainly due to a decrease in the mean abundance of *Lanice conchilega* and *Euclymene lumbricoides*, which accounted for 60% of the dissimilarity between these groups of samples.

The proportion of the > 125 μm and > 63 μm sediment fractions in the harvested plot had increased significantly since December 1994 (*table* 3). None of the sediment fractions in the harvested plot differed significantly from the sediments in the control areas (*table* 3). As in December, photosynthetic pigment concentration did not vary significantly between areas (*table* 4, chlorophyll *a*, ANOVA, $F_{2,12} = 0.04$, $p = 0.95$; phaeopigment, $F_{2,12} = 0.75$, $p = 0.49$).

Table 5. – Mean ± SE dry weight of suspended material (mg/l) collected at various distances up-tide and down-tide of the suction dredge, and the corresponding change in organic content (% AFDW). Means that share the same superscript letter are not significantly different from each other (Tukey-Kramer, multiple comparison test $p < 0.05$).

	Distance from dredge (m)					
	Uptide	Downtide				
	–5	1	5	10	20	40
Dry wt. (mg/l)	288 ± 35^{a}	4059 ± 1029^{b}	2322 ± 109^{b}	783 ± 15	522 ± 48	290 ± 10^{a}
Organic content (%)	13.01 ± 0.85	3.27 ± 0.47^{a}	2.54 ± 0.51^{a}	5.10 ± 0.31	6.80 ± 0.84	8.93 ± 0.75

DISCUSSION

Effects of the on-growing phase

Neither sediment particle size composition nor organic and photosynthetic pigment content varied between the control areas and the clam lay. Hence differences detected between the clam lay and control areas would appear to be attributable to the clam cultivation rather than to variation in substratum characteristics (*fig.* 2). Although there was a tendancy for the number of species found beneath the netting to increase, this was not significant. Faunal diversity might be expected to increase within the clam lay as the netting may reduce the effects of wave action (*i.e.* disturbance), provides a more complex habitat structure, and also provides a substratum for epizoites such as hydroids. On the other hand, the density of individuals was much greater within the clam lay than in either of the controls, which had a similar density of individuals. Multivariate analysis of the community data indicated that the community sampled beneath the netting was significantly different from the control areas. The control areas were dominated by the errant polychaete, *Nephtys hombergii*, whereas the clam lay was dominated by deposit feeding worms, *Lanice conchilega* and *Euclymene lumbricoides* and the bivalve *Mysella bidentata* (*table* 2). A similar distribution of species was found at the River Exe, although the species differed, deposit feeding worms and bivalves dominated the net covered plots, whereas control areas were dominated by *Nephtys hombergii* (Spencer *et al.*, 1996). The River Exe study examined the effects of net and clams (as in the present study) and the effects of net only. We found that the presence of netting, not the clams, was the main cause of community changes (Spencer *et al.*, in press). The increase in abundance of these species may be due to several factors. The protective netting is specifically designed to exclude predators of clams, such as shore crabs and birds, that will also eat other infauna (Spencer *et al.*, 1992). A more likely explanation is the change in hydrography associated with the netting that reduces water flow and increases sedimentation rate. This increases food supply and the likelyhood of larval settlement (Eckman, 1983; Butman, 1986; Butman *et al.*, 1988). There was a tendency for the control areas immediately adjacent to the clam lay to have higher numbers of some infaunal polychaetes (*table* 2), and some of these samples appear to be more similar to those collected from the clam lay than the far controls (*fig.* 2*A*). It is possible that these adjacent controls, collected in close proximity to the nets, are also influenced by the effects of net covered plots.

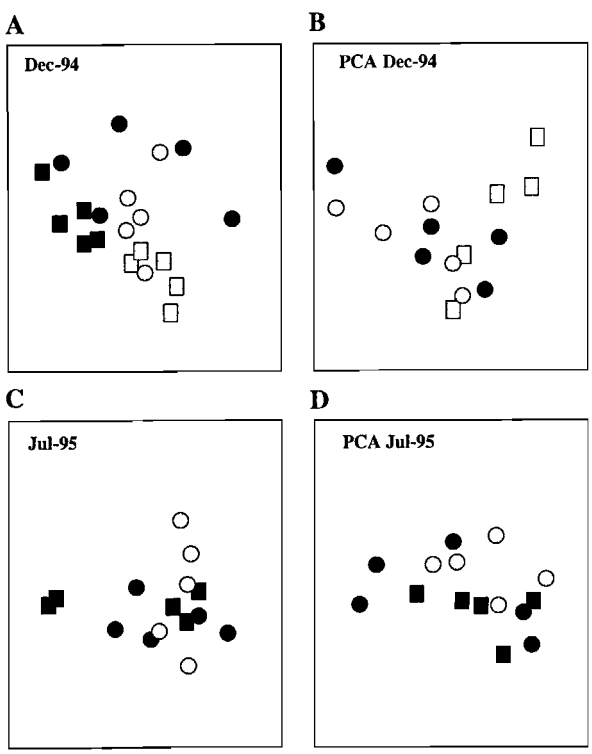

Figure 2. – **A)** The first two axes of the MDS plot of the community data for the far controls (filled circles), near controls (open circles), clam lay (open squares) and the clam lay after harvesting (filled squares) in December 1994 (stress = 0.10). **B)** The first two axes of a PCA of the environmental variables for December 1994, which account for 84% of the variation. **C)** The MDS plot of the community data for the far and near controls and harvested plot in July 1995 (stress = 0.08) and **D)** the first two axes of the corresponding PCA of the environmental variables which accounted for 94% of the variation.

Post-harvesting

Suction dredging had a profound effect on the community. It removed large quantities of sediment and the associated animal community, particularly crustaceans and bivalves. Variation between the post-harvesting samples was quite low indicating that the effect of dredging was uniform across the clam lay (*fig.* 2*A*). Analysis of sediment samples after harvesting indicated that the upper layers of the sediment had been removed exposing the underlying clay which may be unsuitable for larval settlement.

Seven months later, although the silt/clay fraction still constituted the largest proportion of the sediment in the harvested area, the proportion of the > 125 μm and > 63 μm fractions had significantly increased (*table* 3). The density of individuals in the harvested plot decreased significantly from December to July. We attribute this to our inability to differentiate between live, undamaged fauna and those damaged by the dredging process while sorting samples in the laboratory. However, multivariate analysis was unable to differentiate between the harvested and control areas. Furthermore, a SIMPER analysis revealed that *N. hombergii* contributed most to the similarity between samples collected from the clam lay seven months after harvesting. *N. hombergii* dominanted

control areas both in the present and in the R. Exe study (Spencer *et al.*, 1996). These observations indicate that the effects of clam cultivation and harvesting were barely detectable after seven months.

CONCLUSION

The use of protective plastic netting increases sedimentation rate and leads to an increase in the abundance of deposit-feeding infauna. Diversity was not affected by clam cultivation. Variation between samples was lowest within the cultivated area, possibly indicating that the net covered areas afforded some protection from frequent wave disturbance or caused a more even settlement of invertebrate larvae. Harvesting removed a large proportion of the infauna, but seven months later it was not possible to differentiate between the harvested and control areas. It seems that clam cultivation increases productivity within limited areas during the growing process and that the effects of harvesting do not persist more than seven months.

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