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WEST ANGLE BAY, A CASE STUDY.
LITTORAL MONITORING OF PERMANENT QUADRATS BEFORE AND AFTER THE *SEA EMPRESS* OIL SPILL

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ABSTRACT

The 140,000 tonne tanker *Sea Empress* ran aground at the entrance to Milford Haven on 15th February 1996 and, over the next five days, spilled over 70,000 tonnes of Forties Blend crude oil into the sea. Permanent quadrats, established prior to the spill, in West Angle Bay and Manorbier Bay were severely impacted by fresh crude oil and chocolate mousse respectively. Neither set of quadrats was subjected to cleaning and, therefore, provided an ideal opportunity for pre- and post- spill monitoring. Permanent quadrats were surveyed and photographed at monthly (West Angle Bay) and three monthly (Manorbier Bay) intervals.

The results of this monitoring programme are presented and illustrate dramatic changes in community structure at West Angle Bay. Limpet mortalities were very high and resulted in a dramatic green phase of *Enteromorpha* spp., followed by a flush of *Porphyra* spp. and ultimately a brown phase of *Fucus vesiculosus* var. *linearis*. By contrast, limpets at Manorbier seemed relatively unaffected by chocolate mousse and dramatic green and brown phases were not evident. The dramatic bleaching of coralline red algae at both sites has subsequently disappeared. Reasons for the differences between the two sites are discussed.

INTRODUCTION

As part of an ongoing programme of littoral monitoring by staff at Orielton Field Centre on the shores of South Pembrokeshire, permanent transects were established at West Angle Bay (SM 85090334) in February 1995 and at Manorbier Bay (SS 05619759) in February 1996. Quarter square metre (50 x 50 cm) quadrats were marked permanently on the rocks using a portable drill, "Rawlplugs" and brass screws at 0.6m intervals from Chart Datum to the top of the supralittoral zone. All quadrats were photographed and detailed assessments of the abundance of algae and animals were made and recorded on standard data sheets.

At 8.07 p.m. on Thursday 15th February 1996, the 140,000 tonne oil tanker *Sea Empress* ran aground on rocks at the entrance to Milford Haven and began to spill crude oil into the sea. Over the next six days, an estimated 72,000 tonnes of Forties crude oil and 360 tonnes of heavy fuel oil were spilled into the sea and contaminated over 100 kilometres of the Pembrokeshire coast.

Fortuitously, both permanent quadrats were oiled during the *Sea Empress* spill, providing the opportunity for pre- and post- spill monitoring. West Angle was one of the most heavily impacted shores and the transect was oiled on at least five occasions by neat North Sea crude oil with an admixture of fuel oil (Plate 1). Extensive cleaning operations were carried out on the beach (Plate 2) but the transect itself was not subjected to any form of cleaning; physical or chemical. Manorbier Bay, on the outer coast, was subjected to a single heavy oiling by 'chocolate mousse' (an emulsion of water in oil) seven days after the initial spill, when the slick that had drifted out into the Bristol Channel returned on south easterly winds to Tenby and Manorbier. Cleaning was confined to the beach and did not impinge on the permanent transect located 300m to the west (*pers. comm.* Jane Hodges, Pembrokeshire Coast National Park Authority).

METHODOLOGY

West Angle Bay is situated in the entrance to Milford Haven (Figs 1 and 2) directly opposite the point at which the *Sea Empress grounded.* It is a fairly sheltered sandy bay facing west but the transect was located on the south facing rocky shore on the northern side (Plate 3) exposed to the full force of waves coming through the entrance. The transect site consisted of steeply sloping (45°) limestone bedrock and, prior to the spill, had a fauna and flora characteristic of a Ballantine Grade 4 'semi exposed shore' (Ballantine, 1961), dominated by limpets and barnacles in the middle shore.

The Manorbier permanent transect was located approximately 200m to the west of Manorbier beach (Fig. 1) on a steeply sloping, south facing Old Red Sandstone bedrock shore, fully exposed to the Atlantic gales. The community there is also barnacle / limpet dominated but more typical of a Ballantine Grade 3 'exposed shore' (Plate 4).

Surveys of the fixed quadrats, established in February 1995 and 1996, were carried out monthly at West Angle Bay from March 1996 and at three monthly intervals from February 1996 at Manorbier. While survey work was carried out on spring tide cycles, whenever possible, poor tides and rough weather prevented examination of the lowest quadrats on some occasions. Each of the permanent quadrats, marked previously with Rawlplugs and brass screws, was relocated and an aluminium 50 x 50 cm quadrat, divided by strings into 25 x $0.01m^2$ squares, was placed accurately on the markers. The lowest quadrat had been established at 0.6m above Chart Datum and a 0.6m cross staff (c.f. Baker & Wolff, 1987) was used to relocate the quadrats at regular height intervals up the shore to the top of the supralittoral zone. At West Angle, this resulted in a total of 14 stations. At Manorbier, a transect of 25 stations was surveyed, to include the wide supralittoral.

Each quadrat was photographed using Kodachrome 64 or 200 ASA colour slide film in a Canon A1 or Nikon F50 camera. In each quadrat, the abundance of the animal and algal species present was assessed using a 7-point abundance scale (modified from Crapp, 1970 after Moyse & Nelson-Smith, 1963; see Appendix 1). Great care was taken not to remove any material from quadrats for identification so all identifications were made in the field (Barrett & Yonge 1958; nomenclature as in Howson 1987). In all cases, however, identification is only given to the nearest certain taxon. Thus *Patella* was only identified to the genus since accurate identification to species requires limpets to be removed from the rock. All data were recorded in pencil on pre-printed data sheets. In addition to the abundance values, the numbers, positions and sizes of limpets were recorded monthly at West Angle Bay. For a more detailed study of growth and recruitment see Williams & Crump (in prep.). At Manorbier, limpet and barnacle counts were made from photographs of the quadrats.

RESULTS

Detailed results and field survey data collected at monthly intervals at West Angle Bay and three monthly intervals at Manorbier, together with the original survey data from 1995 and 1996, are provided in Crump, Morley & Williams (1997). What follows is a summary of the critical changes in the major species.

West Angle Bay

The permanent transect at West Angle Bay (Plate 3) was established [in February 1995] on a south-facing, sunny, shore which closely resembled a Ballantine Grade 4 shore (Ballantine, 1961). Of the brown seaweeds, *Pelvetia canaliculata* (channelled wrack) was occasional to common, but rarely forming a distinct zone; *Fucus vesiculosus* (bladder wrack) was rare, without air bladders, but larger than the typical forma *evesiculosus*; *Fucus serratus* (saw wrack) was occasional to common, usually forming a distinct zone above the *Laminaria* (kelp). *Fucus spiralis* (flat wrack) and *Ascophyllum nodosum* (egg or knotted wrack) were absent. There was no fucoid invasion of the main midlittoral zone, which was barnacle and limpet dominated.

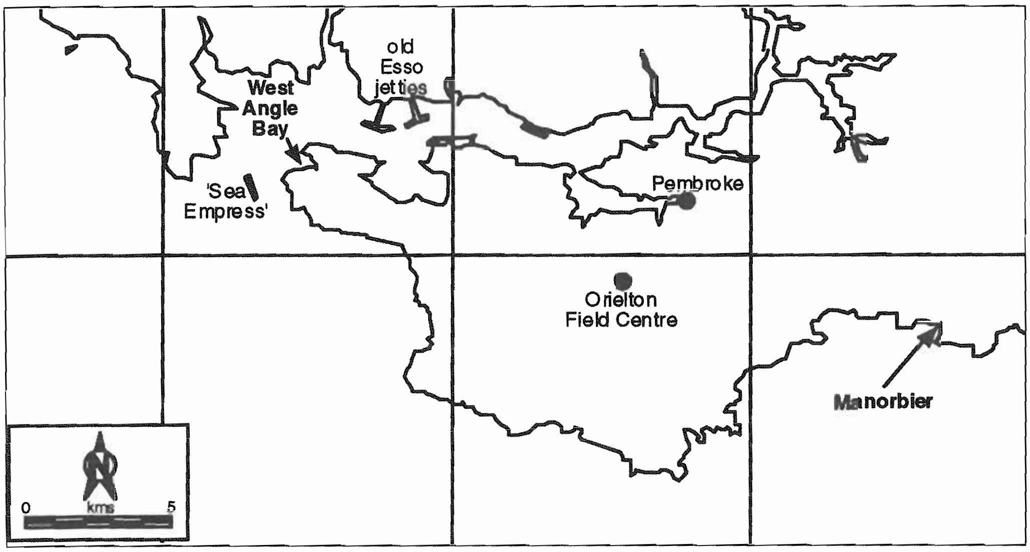

FIG. 1. A map showing the location of he Sea Empress in relation to West Angle Bay and Manorbier

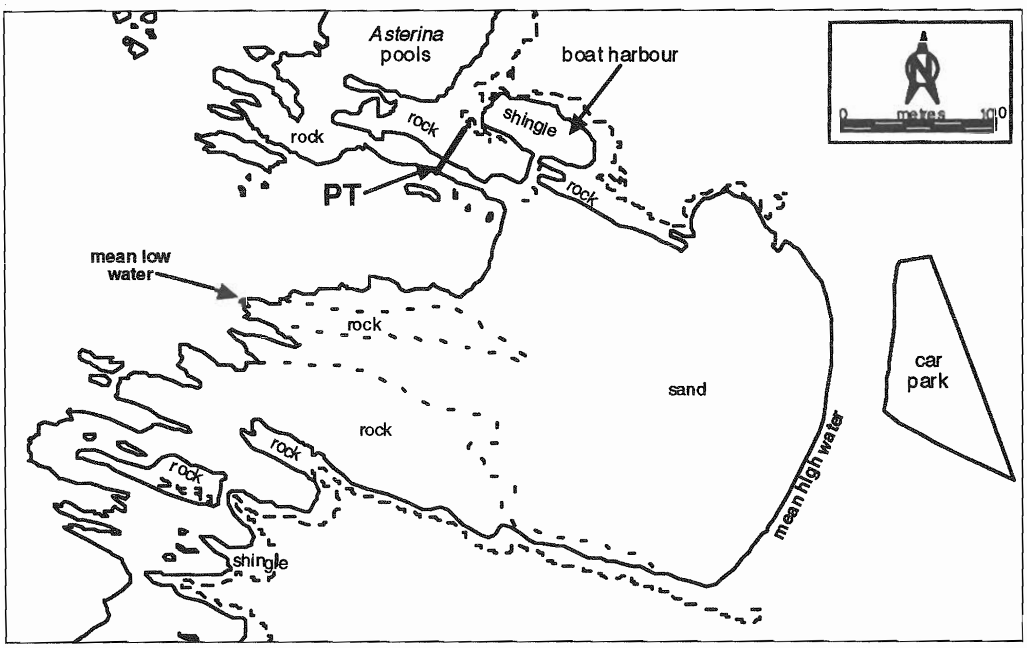

FIG. 2. A map showing the location (PT) of the permanent transect in West Angle Bay. Adapted from OS Map sheet SM8402-8502 with the permission of The Controller of Her Majesty's Stationery Office, © Crown copyright..

Initial observations, immediately after the spill, indicated a high mortality of *Patella* spp. (limpets) on both sides of the bay with large numbers detached from the rocks, narcotised and moribund (Plate 5). There were large numbers of empty home scars and many limpets fell prey to birds (e.g. oystercatchers). In more sheltered parts of the bay, numbers of large limpets, which had clearly emigrated from the adjacent bedrock, were found aggregated on boulders in rock pools. These observations were confirmed when the permanent quadrats were resurveyed in March 1996 and showed a 71% decrease in limpet numbers (from a pre-spill density of 125 m^{-2} down to approx. 40 m^{-2}, see Williams & Crump in preparation) as well as a reduction in their vertical range on the shore (Fig. 3). Comparison with 1995 data shows that much of the reduction in limpet abundance was in the middle and upper shore quadrats which were, perhaps, the most severely impacted by oil. Limpet numbers remained low after the spill and there was no evidence of recruitment of young limpets to the permanent quadrats until June 1997.

Many of the other gastropod species appear to have survived the spill with little or no reduction in numbers. *Gibbula umbilicalis* (purple topshell) may have migrated down the shore, in the immediate aftermath of the spill (see March 1996 Fig. 3), but was observed grazing over oiled rocks in March and had recovered to pre-spill densities by June 1996.

Melarhaphe neritoides (small winkle), similarly, appeared to have been hard-hit by the oil, immediately post spill (Fig. 4), but quickly reappeared in quadrats and was more abundant in March 1997 than in March 1995. *Littorina saxatilis* agg. (rough winkle) showed a small reduction in abundance towards the upper end of its range immediately post spill but, later in the year, recolonised the upper shore.

Barnacle mortality undoubtedly occurred in both species of *Chthamalus* and in *Semibalanus balanoides* (Fig. 5) but was difficult to assess since all three species were quickly covered in green seaweed. This algal growth also prevented the majority of *S. balanoides* cypris larvae settling in late April (as happened elsewhere along the coast, e.g. at Manorbier), but a good settlement of *Elminius modestus* was noted in September and October (Fig. 6). This Australasian immigrant species is usually associated with shores more sheltered than West Angle.

The most dramatic immediate effect of the crude oil on the seaweeds was the marked bleaching of the encrusting coralline algae *Lithothamnion incrustans* and *Phymatolithon purpureum* on the lower shore. *Corallina officinalis*, *Chondrus crispus* and *Mastocarpus stellatus* also showed signs of bleaching (Plate 6). The encrusting corallines, however, recovered quickly suggesting that the damage had been restricted to the surface layers (Yvonne Chamberlain, *pers. comm.*).

The survey of the permanent transect in May confirmed a dramatic increase in *Enteromorpha* spp. which resulted in a green flush of seaweed right across the middle shore (Plates 7, 8, 11 and 12) This green phase is thought to have been the direct result of high limpet mortalities and the consequent decline in grazing pressure. The blanket of slippery green seaweed persisted throughout the late spring and summer (Fig. 7 and Plates 9 and 13)) which made working on the shore extremely hazardous. During the months of June and July, there was also a significant settlement of laver, the red seaweed *Porphyra umbilicalis* (Fig. 7) which added a dull brown hue to the green phase. Cover of *Enteromorpha* spp. began to decrease in September and October and the *Porphyra* had almost disappeared by November. A combination of hot summer sunshine followed by strong autumn gales and low level grazing by the surviving limpets eliminated both genera of seaweed by Christmas, except that growth surviving on the backs of the limpets. Nonetheless, a new flush of *Enteromorpha* and *Porphyra* began to appear in March 1997.

Prior to the oil spill, the bladderless form of bladder wrack, *Fucus vesiculosus* var. *linearis* (at one time called var. *evesiculosus*) was extremely rare on the transect but, in September 1996, there was a quite significant settlement of sporelings of this species in middle shore transects (Fig. 8). These sporelings grew into plants ten centimetres long over the winter and, by May 1997, a conspicuous brown phase was dramatically evident (Plates 10 and 14), covering most of the middle shore. Beneath and around this fucoid canopy was abundant *Enteromorpha* spp. and scattered *Porphyra* spp.

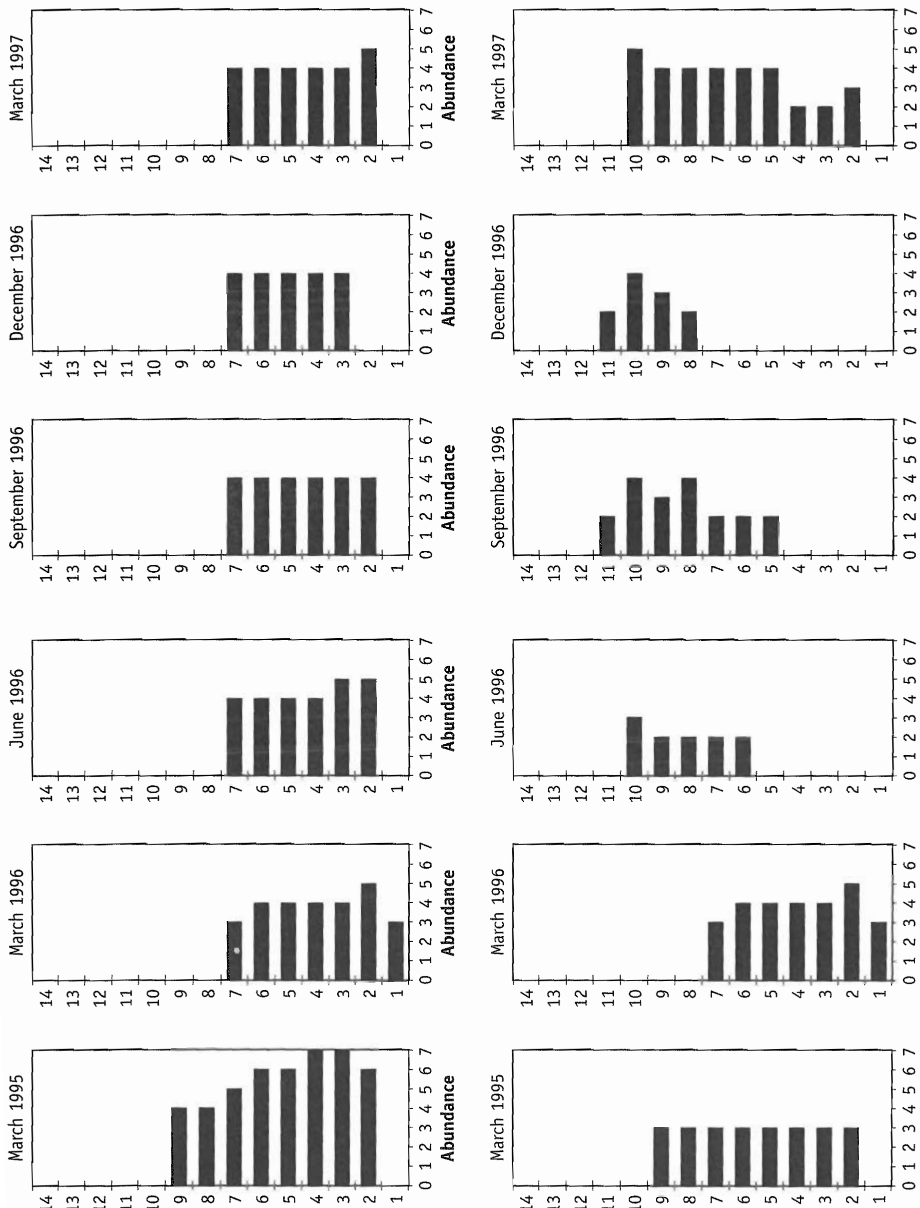

FIG. 3. Variation in the abundance of limpets, *Patella* spp. (top) and rough winkles, *Littorina saxatilis* agg. (bottom) in quadrats on the permanent transect in West Angle Bay between March 1995 (pre-spill) and March 1997. See Fig. 2 for location of the transect; Plates 3 and 11 for its overall appearance. Station No. 5 is illustrated in Plates 7-10.

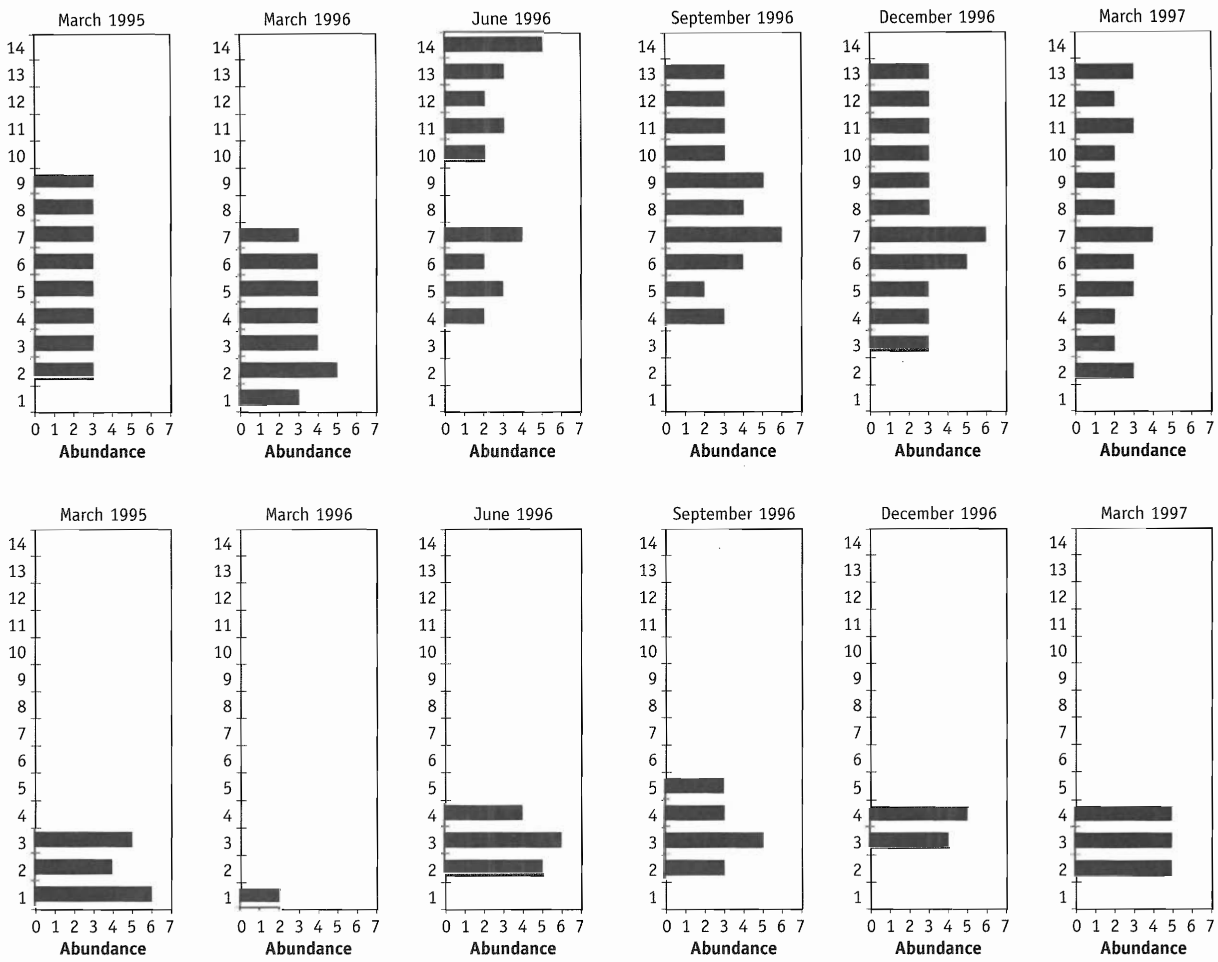

FIG. 4. Variation in the abundance categories of small winkles, *Melarhaphe neritoides* (top) and purple topshells, *Gibbula umbilicalis* (bottom) in quadrats on the permanent transect in West Angle Bay between March 1995 (pre-spill) and March 1997. See Fig. 2 for location of the transect; Plates 3 and 11 for its overall appearance. Station No. 5 is illustrated in Plates 7-10.

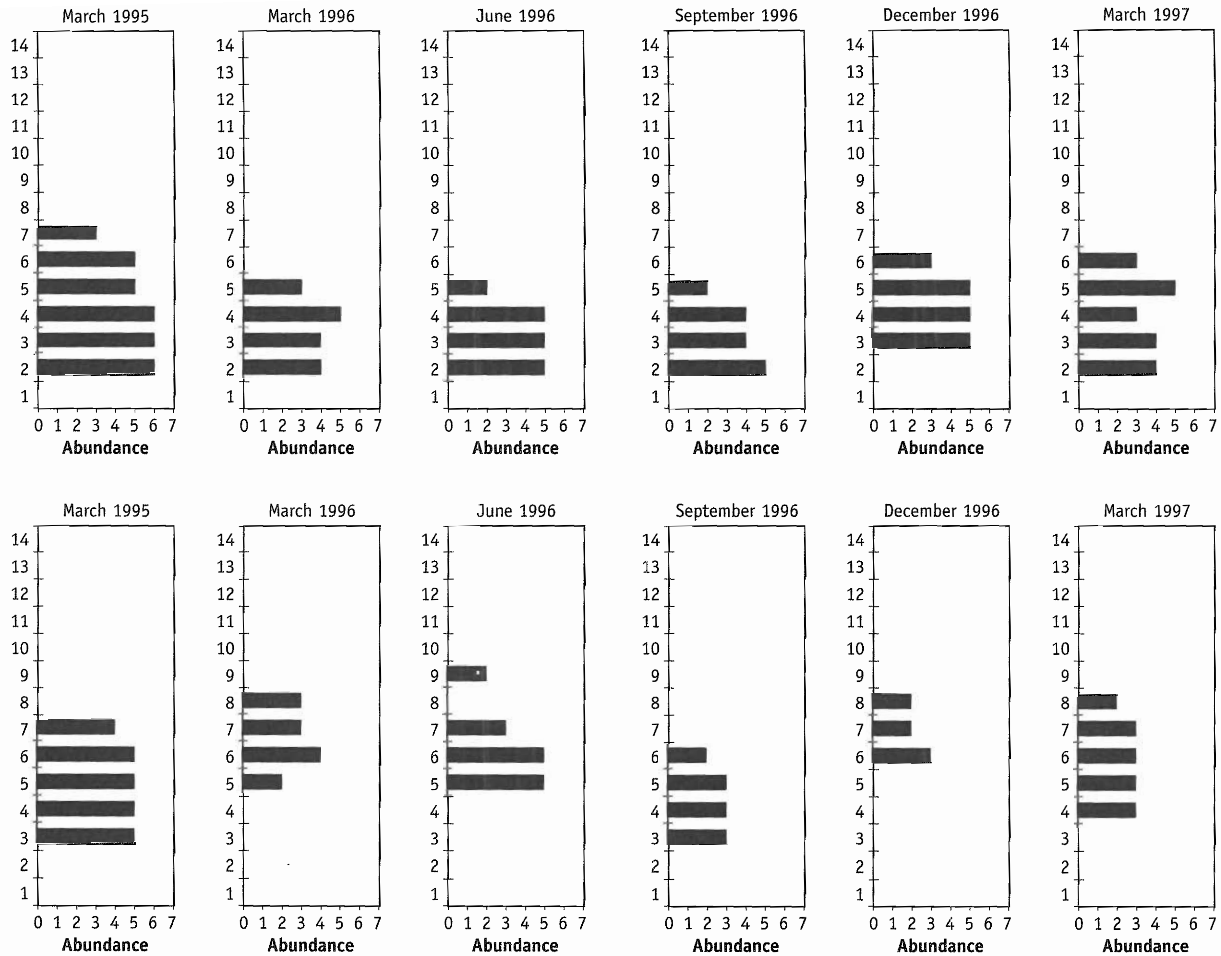

FIG. 5. Variation in the abundance categories of barnacles. *Semibalanus balanoides* (top) and *Chthamalus stellatus* (bottom) in quadrats on the permanent transect in West Angle Bay between March 1995 (pre-spill) and March 1997. See Fig. 2 for location of the transect; Plates 3 and 11 for its overall appearance. Station No. 5 is illustrated in Plates 7-10.

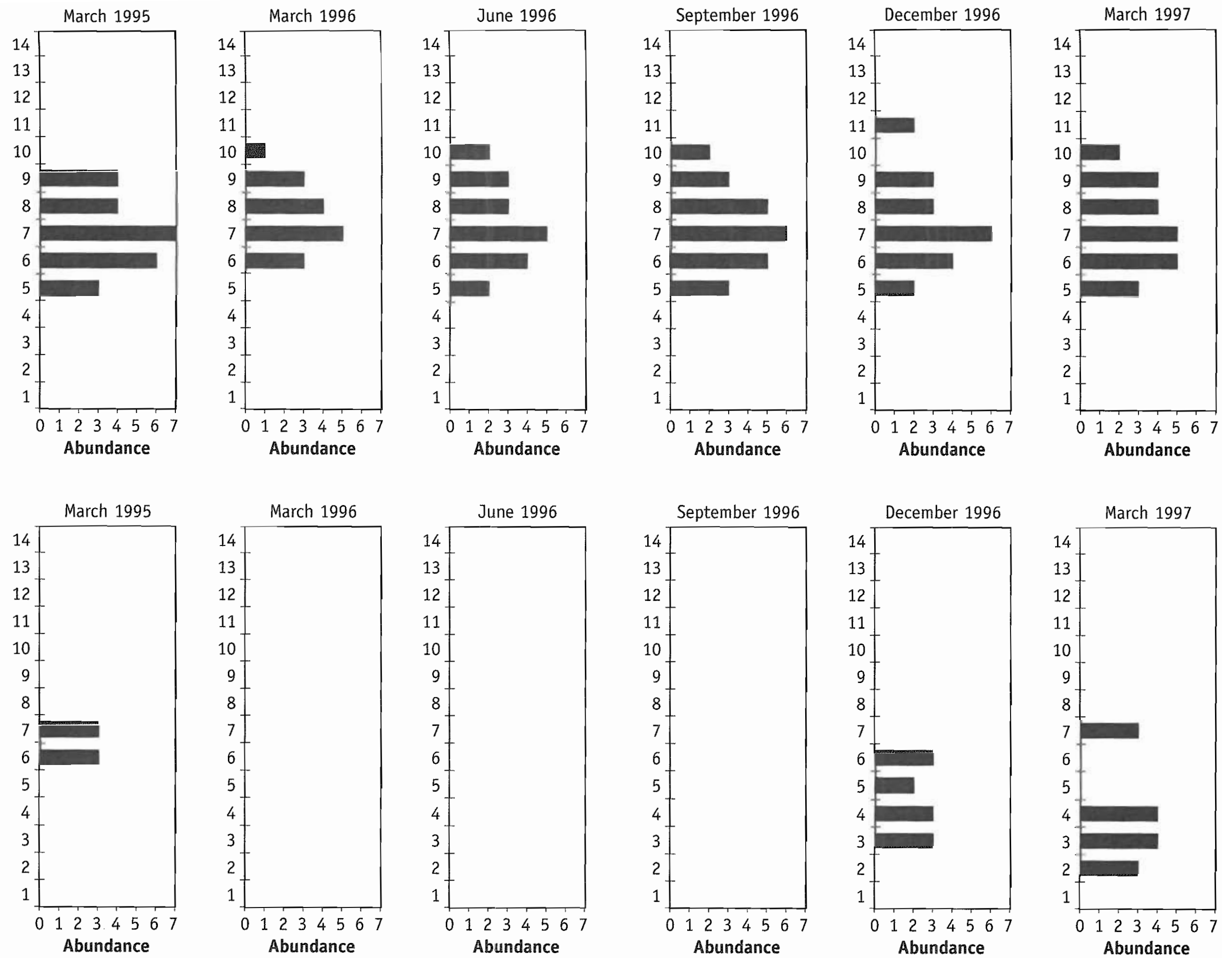

FIG. 6. Variation in the abundance categories of barnacles. *Chthamalus montagui* (top) and *Elminius modestus* (bottom) in quadrats on the permanent transect in West Angle Bay between March 1995 (pre-spill) and March 1997. See Fig. 2 for location of the transect; Plates 3 and 11 for its overall appearance. Station No. 5 is illustrated in Plates 7-10.

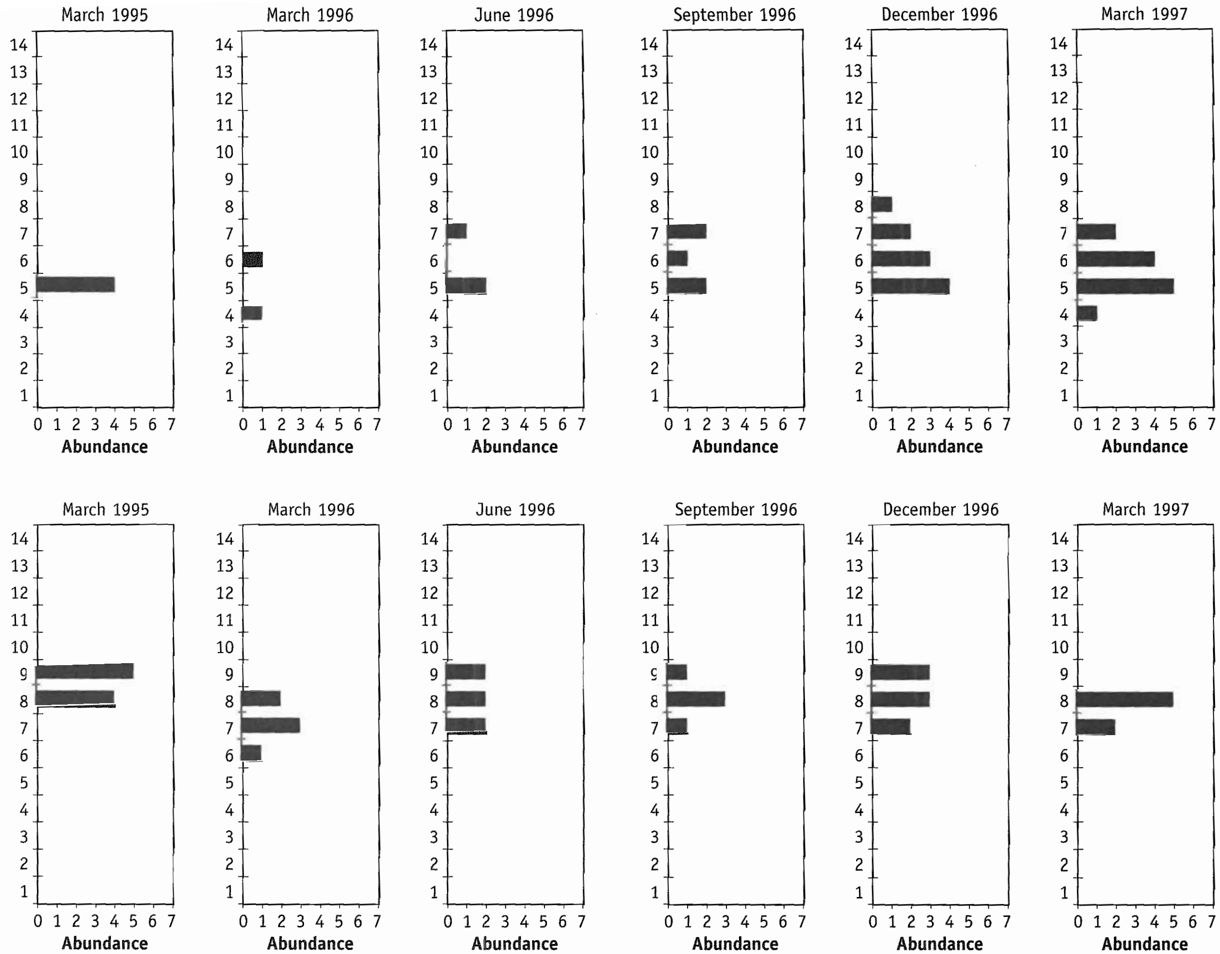

FIG. 7. Variation in the abundance categories of seaweeds. Bladderless bladder wrack, *Fucus vesiculosus* var. *linearis* (top) and channelled wrack, *Pelvetia canaliculata* (bottom) in quadrats on the permanent transect in West Angle Bay between March 1995 (pre-spill) and March 1997. See Fig. 2 for location of the transect; Plates 3 and 11 for its overall appearance. Station No. 5 is illustrated in Plates 7-10.

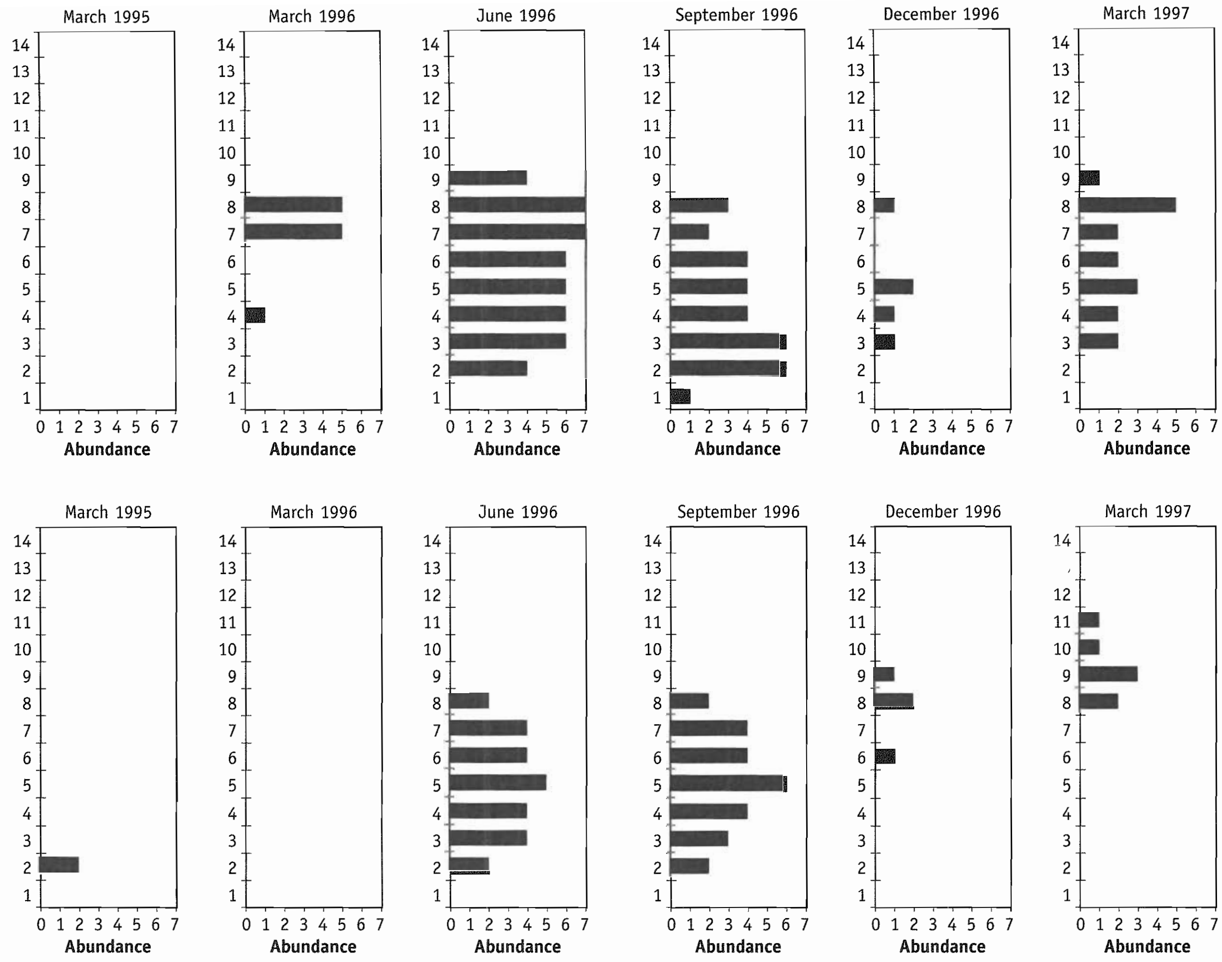

FIG. 8. Variation in the abundance categories of seaweeds. Green algae, *Enteromorpha* spp. (top) and laver, *Porphyra umbilicalis* (bottom) in quadrats on the permanent transect in West Angle Bay between March 1995 (pre-spill) and March 1997. See Fig. 2 for location of the transect; Plates 3 and 11 for its overall appearance. Station No. 5 is illustrated in Plates 7-10.

Manorbier

Manorbier is a classic example of an exposed shore (Grade 3 on the Ballantine Scale) and characteristic of much of the South Pembrokeshire outer coast. The shore is dominated by barnacles and limpets. *Chthamalus* spp. are abundant, from mid to upper shore, while *Semibalanus balanoides* dominates the bottom half of the shore. *Patella* ranges from common to extremely abundant with densities exceeding $200m^{-2}$ in the middle shore. *Melarhaphe neritoides* and *Littorina saxatilis* agg. become extremely abundant in the upper shore and large numbers of small mussels, *Mytilus edulis*, occur in cracks, crevices and dead barnacles in the middle shore. On the permanent transect, kelps, *Laminaria* spp., are common on the lower shore where a reef breaks the wave action. Red algae form a dense carpet on the lower shore and such species as *Mastocarpus stellatus* and *Palmaria palmata* cover a turf of *Corallina officinalis* and a continuous film of encrusting algae (the so called "*Lithothamnion*" band). Browns, *Fucus serratus*, *F. vesiculosus* var. *linearis* and *Pelvetia canaliculata*, are rare as are most other algae in the middle and upper shore, except in numerous rock pools.

Chocolate mousse coated large areas of the rocky shore platform (Plate 15) but, because of the broken nature of the shore, it tended to collect especially in gullies and crevices. Oil also "painted" large sections of the supralittoral zone, where it remained for several months. On the transect, the steep gradient of the shore, combined with the cleaning effect of continuous wave action, meant that all quadrats were apparently clear of oil by 28th February when the first post-spill examination was made. No oil has subsequently appeared in quadrats.

The initial survey of 28th February did reveal, however, dramatic and extensive bleaching of the *Corallina* sp. and the encrusting "*Lithothamnion*" band on the lower shore and in shallow pools (Plate 16). In general, there was no clear evidence of mortality or ill effects on the other organisms surveyed in quadrats. By August, a mini green phase had developed in the bottom three quadrats in the lower shore, but this was not associated with mortality of *Patella* spp. and may be a seasonal phenomenon. The numbers of limpets found in quadrats in February and August 1996 were not significantly different ($T = 1$, $p<0.05$, Wilcoxon matched pairs), although some empty home scars were seen. Similarly, barnacles do not appear to have been seriously affected by the spill and any mortality was compensated by a healthy post-spill settlement of *S. balanoides* in April, which led to a significant increase in barnacle numbers ($T = 0$, $p<0.05$, Wilcoxon matched pairs).

Discussion

Patella vulgata, the common limpet, has long been regarded as a keystone species (Lewis 1976) and its role in structuring rocky shore communities of animals and plants is well known (Jones & Baxter 1985). The dramatic change from limpet/ barnacle dominated shores to shores covered in green and brown seaweeds was particularly well demonstrated on Cornish shores in the aftermath of the *Torrey Canyon* oil spill in 1967 (Smith 1968; Southward & Southward 1978). in that case, the limpet mortality was extremely high, due to the use of very toxic emulsifiers, and it took 5-10 years for the limpet/fucoid balance to re-establish (Hawkins & Southward, 1990).

In the aftermath of the current oil spill, emulsifiers were not used in the vicinity of either permanent transect and limpet mortality varied from 70% in some quadrats at West Angle Bay to almost nil at Manorbier. This difference was probably due to the different toxicity of neat crude oil and weathered "chocolate mousse". Undoubtedly, the high mortality of *Patella* spp. at West Angle Bay compared with Manorbier can be invoked to explain most of the changes in species composition in the majority of quadrats.

Experiments carried out in the 1970s at West Angle Bay, involving the removal of all the limpets from large 2x2 m squares on slopes adjacent to the permanent transect (Crump, unpublished), resulted in both green and brown algal squares, (see also Jones 1948; Southward 1956; Hawkins 1981; Hawkins & Hartnoll 1983). The heavy settlement of *Porphyra* had not been anticipated but it is an ephemeral species prone to limpet grazing.

In the case of the *Torrey Canyon* spill, large numbers of juvenile limpets invaded the fucoid covered shores less than 12 months after the event (Southward & Southward 1978), survived well and prevented further settlement of seaweed. While large numbers of small juvenile limpets (>3mm) have been observed on the lower and mid shore of Manorbier in March and April 1997, very few have been recruited as yet on the permanent quadrats at West Angle Bay. *Patella vulgata* larvae, however, settle from the plankton in autumn in shallow pools and damp places before moving out on to the open rock surfaces (Bowman & Lewis 1977) and would be very susceptible to desiccation on the permanent quadrats. Limpet recruitment was generally poor at all sites within Milford Haven in 1996. (J. Moore, *pers. comm.*)

While the numbers of limpets (*Patella* spp.) showed no significant increase in the first twelve months at West Angle Bay, the surviving individuals increased dramatically in size from a mean of 18.95 ± 4.73 mm to 30.29 ± 7.99 mm. (Plate 13). Increase in limpet size was almost certainly attributable to a superabundance of food in the early months after the spill, coupled with the decreased intraspecific competition. It remains to be seen if these initial growth rates will be maintained as the shore becomes covered in mature seaweeds, which are inedible to limpets, and juvenile limpets invade the quadrats. The limpet populations at West Angle Bay will be the subject of continuing study over the next few years (Williams & Crump, in preparation).

The effects of oil spills on seaweeds are not well documented but brown seaweeds are relatively insensitive to oil due to the slimy mucilage which coats all their surfaces and they are usually washed clean by the next high tide (Moore & Guzman 1995). The dramatic bleaching of the encrusting coralline algae observed during the *Sea Empress* spill has not, to my knowledge, been recorded widely before* although an oil and dispersants have been shown to have adverse effects on the pigmentation of sublittoral red algae under experimental conditions (Mullett 1982; Grandy 1984). The encrusting corallines, though severely bleached in some cases, did recover subsequently and have been the subject of a separate study (Chamberlain 1997).

In permanent quadrats at both Manorbier and West Angle Bay, lichens in the supra-littoral zone seem to have been relatively unaffected, although some bleaching of *Lichina pygmaea* was observed at both sites. Some lichens are particularly sensitive to oil pollution (Ranwell 1968; Brown, 1974; Cullinane *et al.*, 1975) and are the subject of study at other sites where they occur (Crump & Moore, 1997).

CONCLUSION

It is apparent that West Angle Bay was one of the most severely impacted shores and the transect was oiled on at least five occasions by neat crude oil. As a consequence, limpet mortality was high and resulted in a release of grazing pressure which produced a dramatic green phase of *Enteromorpha* spp. in spring followed by a flush of laver, *Porphyra* spp., in the summer of 1996. In 1997, the transect and the whole shore was dominated by a brown phase of *Fucus vesiculosus* var. *linearis*. Limpet recruitment was low and severe community disruption is likely to continue at this site for at least five years.

By contrast, Manorbier was lightly oiled with highly weathered chocolate mousse. The shore is subjected to considerable wave action which removed most of the oil from the transect within days. Limpet mortality at Manorbier was very low and as a consequence the dramatic green and brown phases were not observed. A good barnacle settlement in April 1996 compensated for any barnacle mortality and recruitment of large numbers of limpets in the winter 1996/7 restored the community ecology. As with much of the outer coast, the platform at Manorbier seems to have recovered remarkably quickly from the spill.

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* Although it is very evident in photographs taken in Brittany, a few months after the *Amoco Cadiz* spill in 1978. Ed.

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APPENDIX 1
Table of Abundance Values

1 Lichens, encrusting algae & sea mats

E	7	> 80% cover
S	6	50 – 80% Cover
A	5	20 – 49% cover
C	4	1 – 19% cover
F	3	Large scattered patches
O	2	Widely scattered patches, all small
R	1	Only 1 or 2 patches
N	Ø	Absent

2 Seaweeds

E	7	> 90% cover
S	6	60 – 90% Cover
A	5	30 – 59% cover
C	4	5 – 29% cover
F	3	< 5% cover, zone still apparent
O	2	Scattered plants, zone indistinct
R	1	Only 1 or 2 individuals
N	Ø	Absent

3 Limpets, *Patella* spp, and large winkles, *Littorina* spp.

E	7	> 200 m^{-2}
S	6	100 – 200 m^{-2}
A	5	50 – 99 m^{-2}
C	4	10 – 49 m^{-2}
F	3	1 – 9 m^{-2}
O	2	1 – 9. $10m^{-2}$
R	1	<1. $10m^{-2}$
N	Ø	Absent

6 Topshells, *Nucella* & anemones

E	7	> 100 m^{-2}
S	6	50 – 100 m^{-2}
A	5	10 – 49 m^{-2}
C	4	1 – 9 m^{-2}, sometimes more
F	3	<1 m^{-2}, sometimes more
O	2	Always <1 m^{-2}
R	1	<1. $10m^{-2}$
N	Ø	Absent

7 Mussels, *Mytilus edulis*

E	7	> 80 % cover
S	6	50 – 80 % cover
A	5	20 – 49 % cover
C	4	Large patches but < 20% cover
F	3	Many individuals & small patches
O	2	Scattered individuals, no patches
R	1	<1 m^{-2}
N	Ø	Absent

8 *Pomatoceros* spp.

E	7	
S	6	
A	5	> 50 tubes. $10cm^{-2}$
C	4	1 – 50 tubes. $10cm^{-2}$
F	3	10 – 49 tubes. m^{-2}
O	2	1 – 9 tubes. m^{-2}
R	1	<1 tube m^{-2}
N	Ø	Absent

4 Small winkles, *Melarhaphe neritoides* and *Littorina saxatilis*, & small barnacles

E	7	> 5 cm^{-2}
S	6	3 – 5 cm^{-2}
A	5	1 or 2 cm^{-2}
C	4	10 – 99. $10cm^{-2}$
F	3	1 – 9. $10cm^{-2}$; never more than 10cm apart
O	2	1 – 99. m^{-2}; few within 10cm of each other
R	1	<1. m-2
N	Ø	Absent

5 Large barnacles (*Balanus perforatus*)

E	7	> 3 cm^{-2}
S	6	1 – 3 cm^{-2}
A	5	10 – 99. $10cm^{-2}$
C	4	1 – 9. $10cm^{-2}$
F	3	10 – 99. m^{-2}
O	2	1 – 9. m^{-2}
R	1	<1. m^{-2}
N	Ø	Absent

9 *"Spirorbis"* spp.

A	5	> 5 tubes. cm^{-2}; on 50% of suitable surfaces
C	4	> 5 tubes. cm^{-2}; on 5 – 49% of suitable surfaces
F	3	1 – 4 tubes. cm^{-2}; on 1 – 4% of suitable surfaces
O	2	< 1 tube. cm^{-2} on suitable surfaces
R	1	< 1 tube. m^{-2} on suitable surfaces
N	Ø	Absent

10 *Crabs*

Count numbers seen in the area

Plate 1. West Angle Bay, 17th February 1996. Photograph taken from near the words "high water" in Fig. 2 looking north-west. The boat harbour is beyond the tractor and trailer.

Plate 2. The initial mechanical clean-up operation in West Angle Bay, 17th February 1996, removing oil from the sand.

PLATE 3. General view of the permanent transect site on the north side of West Angle Bay in March 1995 ("PT" in Fig. 2).

PLATE 4. General view of the permanent transect at Manorbier in March 1995. The quadrat is 0.5m x 0.5m

PLATE 5. Narcotised and moribund limpets falling off the rock at West Angle Bay, 18th February 1996.

PLATE 6. Bleached red algae on the lower shore of West Angle Bay, 28th February 1996.

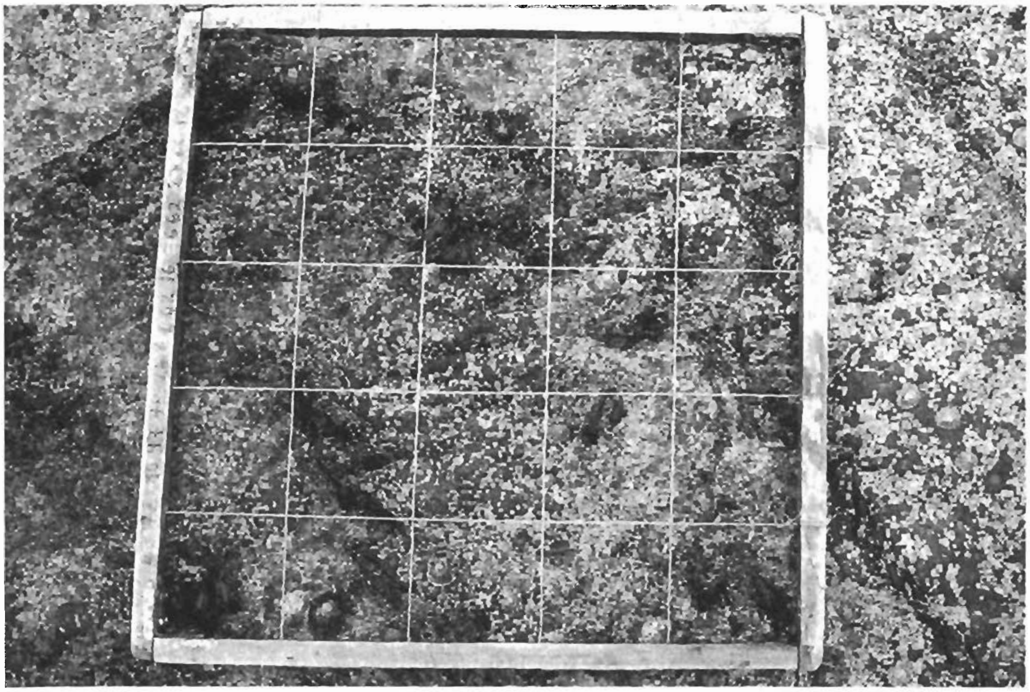

PLATE 7. Quadrat 5 (height 3m) on the West Angle Bay permanent transect, March 1995. showing the typical middle-shore limpet / barnacle community

PLATE 8. Quadrat 5 (height 3m) on the West Angle Bay permanent transect, June 1996. Note the few surviving limpets and extensive growth of the green alga *Enteromorpha* sp.

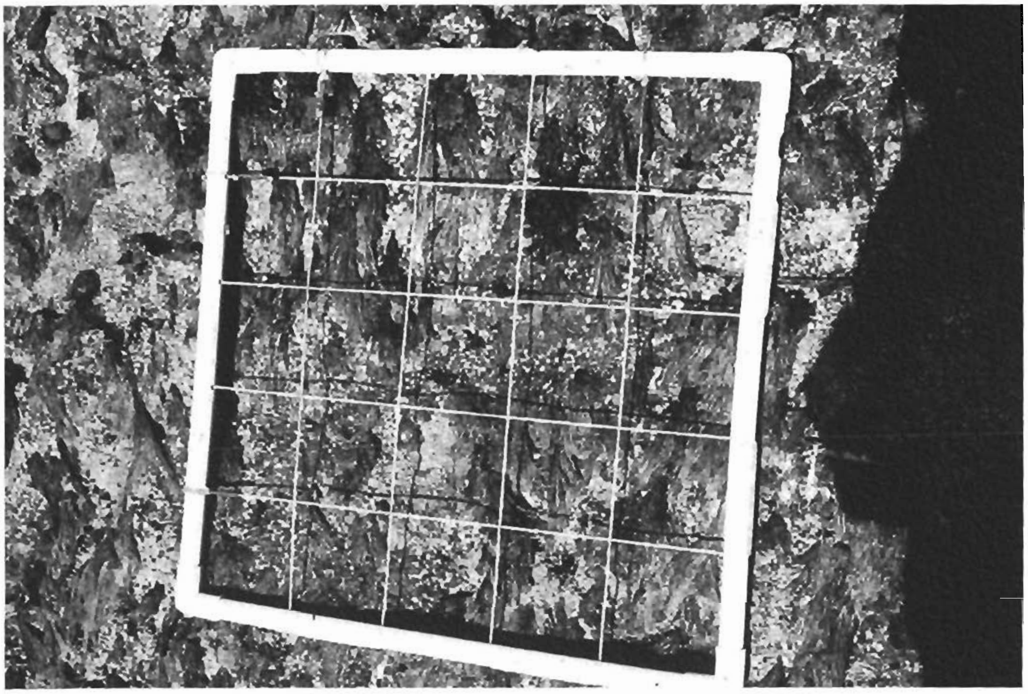

PLATE 9. Quadrat 5 (height 3m) on the West Angle Bay permanent transect, September 1996. Note a reduction in *Enteromorpha* sp. and heavy growth of laver; the red alga *Porphyra* sp.

PLATE 10. Quadrat 5 (height 3m) on the West Angle Bay permanent transect, May 1997. Note the second green phase caused by *Enteromorpha* sp. and the 60% cover of bladderless bladder wrack, *Fucus vesiculosus* var. *linearis*

PLATE 11. The green phase on the West Angle Bay permanent transect, April 1996.

PLATE 12. The green phase on the West Angle Bay permanent transect, July 1996. Note the grazing effect of the surviving limpets

PLATE 13. The *Porphyra* phase on the West Angle Bay permanent transect, September 1996. Note the *Enteromorpha* on limpet shells and the 1996 growth increment (ribbed outer ring) on the central limpet's shell

PLATE 14. The brown phase on the slop adjacent to the West Angle Bay permanent transect, May 1997. The rock is almost completely covered by *Fucus vesiculosus* var. *linearis*.

PLATE 15. Severe oiling by "chocolate mousse" in Manorbier Bay, 24th February 1996

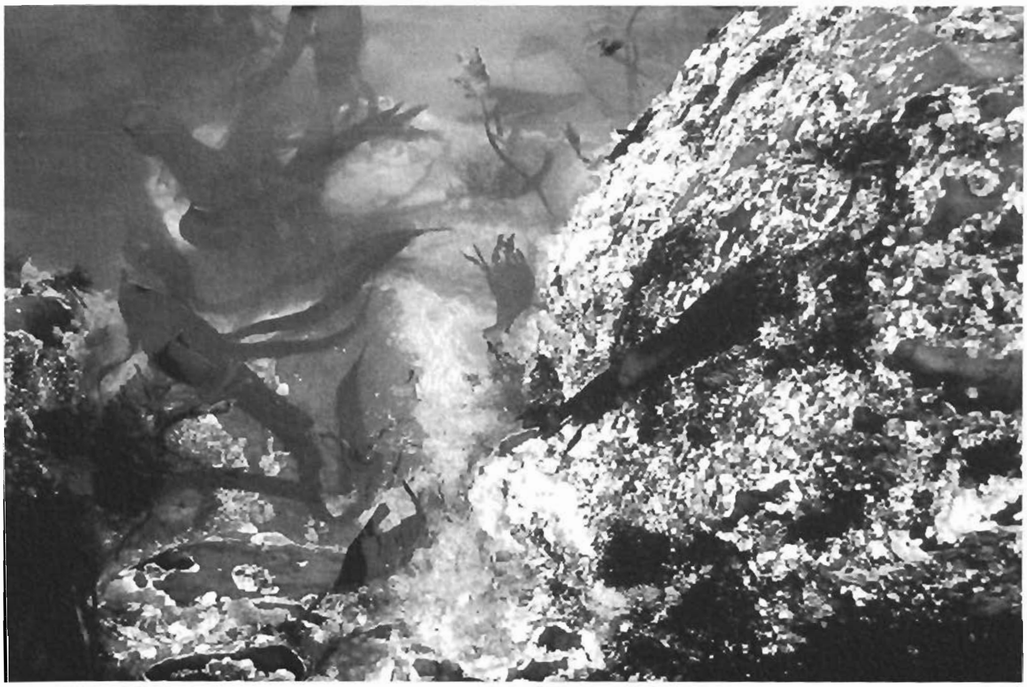

PLATE 16. Bleached coralline red algae (usually pink in colour) in Manorbier Bay, 28th February 1996.