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Short-term effects of an oil spill on the West coast of the Cape Peninsula, South Africa

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Abstract. In 1994, the sinking of the 'Apollo Sea' off the West coast of South Africa led to the deposition of ca. 2 500 tons of heavy fuel oil over 150 km of coastline. The impact of the spill on rocky shore invertebrates, rock-pool fish fauna and rock lobsters was assessed by conducting surveys shortly after the spill, and again two months later. Where possible, results of these surveys were compared with existing data from before the sinking of the Apollo Sea. Among the fish fauna of rock-pools, changes in total density of fishes were largely due to changes in the abundance of *Clinus superciliosus* and were within the range of natural variation for the species and the community as a whole. Community structure of the rock-pool fish fauna also remained unaffected.

At three of four impacted rocky shore sites no changes could be detected in overall benthic community structure, although the winkle *Nodilittorina africana* was affected. At the fourth site, a boulder beach, statistical analysis showed distinct differences in community structure between heavily and lightly contaminated areas, as well as between all areas compared with previously existing data. There were also significant changes in the lightly oiled areas between the first and second surveys after the spill.

Oil-fouled lobster were found at one of three sites investigated. Ca. 7 % of the seabed in this particular area was polluted. Antennae and forelegs of almost all lobsters in the vicinity of the oil were fouled. Examination of the gut-contents confirmed that oil inhibits the ability of lobster to feed. Although there was no evidence that mortalities of lobster were caused by the spill, growth rates may be reduced by the decreased feeding rate. Overall, the impact of the spill was strikingly less than might have been predicted from the effects of other oil spills.

Keywords: Fish; Invertebrate; Pollution ; Rock lobster; Rocky shore.

Nomenclature: Names of fish species follow Smith & Heemstra (1986).

Introduction

The structure of intertidal communities is determined by a combination of physical and biological interactions. While most of the physical factors governing community structure are predictable (e.g. tidal, diurnal and seasonal changes), unpredictable stochastic events also occur (Branch et al. 1990). Harsh conditions, including extreme temperature variations, exposure to wave action and the demands of withstanding desiccation for at least part of the day mean that intertidal organisms are adapted to changing conditions. Nonetheless, these stochastic events are often catastrophic due to their unpredictability: their rarity means that organisms can never adapt to them. Many such events, including floods (Branch et al. 1990) and earthquakes (Castilla 1988), occur naturally, but increasingly they are of anthropogenic origin. Among the most common human-induced events is the pollution of marine areas. In particular, the spillage of petroleum products on the shorelines of the world is a frequent occurrence. The effects of these products on marine organisms have been documented in many cases. Inundation with oil frequently causes large mortalities and reduces community diversity (Suchanek 1993), as well as having sub-lethal toxic effects and causing physiological changes that are difficult to detect (Conan 1982; Southward 1982). However, there is evidence that the effects of oil spills may be more transient than had previously been supposed (Ritchie 1995).

South Africa lies on one of the world's busiest sea routes for the transport of crude oil, with an estimated 327 million tons passing the Cape of Good Hope in 1982 (Jackson & Lipschitz 1984). Given South Africa's exposed coastline and strong seas, there is a considerable threat of oil pollution. Indeed, there have been large spills of oil on the country's coastline, notably following the grounding of the tanker Wafra near Cape Agulhas (Day et al. 1971) and the collision of the Venoil and the Venpet in 1977. Despite this, the Western Cape's coast has escaped relatively unscathed.

A considerable body of data exists documenting the effects of oil spills in other parts of the world, most notably from the Torrey Canyon spill in 1967 (Southward & Southward 1978) and that of the Amoco Cadiz off the coast of Brittany in 1978 (Hess 1978; Conan 1982). In both these cases huge ecological impacts on the affected coasts were reported. Smaller spills such as that in Buzzard's Bay, Massachusetts, also caused large-scale ecological changes (Blumer et al. 1971). Almost without exception, oil spills have been reported as having had severe ecological impacts.

On 20 June 1994 the vessel Apollo Sea sank off the West coast of South Africa. Between 22 and 30 June 1994, ca. 2500 ton of heavy fuel oil from the Apollo Sea was deposited on the Atlantic coastline of the Cape Peninsula. The most intense oiling occurred on the seaward sides of Dassen Island and Robben Island, and on the Cape Peninsula West of Cape Town, while light fouling occurred along most of the Peninsula (Fig. 1). Isolated patches were also recorded in False Bay on the bay's western shore (Moldan 1994). By far the worst oiling occurred in relatively sheltered embayments. Day et al. (1971) recorded similar concentrations of oil in bays after the grounding of the Wafra. In light of past events, pollution from the Apollo Sea was expected to be damaging, although the oil spilled from the Apollo Sea is known to be less toxic than crude or diesel oils.

Amid reports in the press of an 'ecological disaster', a monitoring program was established to assess the ecological effects of the spill on the fish and benthos of the Peninsula's intertidal shores. After the discovery that some oil had settled on the sublittoral seabed, and that rock lobsters, *Jasus lalandii*, had been affected, an investigation of the effects on the lobsters was added to the original program. This species is commercially important; it forms the basis of export-oriented fishery. Lobsters are vulnerable to over-exploitation, and harvesting is presently controlled by a limited annual catch, a minimum size limit, closed seasons, and by several reserves along the coast. Reports by divers that lobsters had been fouled by oil that had settled subtidally in the area of Justin's Caves off Oudekraal, which is within a lobster reserve, was therefore cause for concern. In particular, it was thought that fouling by oil would impair the ability of the lobsters to feed. In the light of this, surveys were undertaken to determine the extent of the subtidal oil and its effect on the frequency of feeding by lobsters.

Effects on birdlife were severe, with some 7500 jackass penguins (*Spheniscus demersus*) treated at the South African National Foundation for the Conservation of Coastal Birds, of which ca. 63 % survived until release (Moldan 1994). Mortality of penguins after release has been shown to be low (Underhill et al. in press). A separate, specific study was undertaken on the penguins.

Methods

Surveys were carried out shortly after the spill and again two months later. Since no major effects were visible, further sampling was considered unnecessary.

Fish

The fish fauna of intertidal pools at Mouille Point and Sea Point (Fig. 1) on the West coast of the Cape Peninsula was sampled using the ichthyocide rotenone, as described by Prochazka & Griffiths (1992). Samples were collected ca. one week and two months after oil was first washed up on 22 June 1994. Sampling dates were 1/7/94 (11 pools sampled) and 21/8/94 (12 pools sampled) at Mouille Point, and 11/7/94 (9 pools sampled) and 22/8/94 (8 pools sampled) at Sea Point. Four shore zones were identified, and representative pools sampled within each zone on each occasion. These zones were constituted by the Cochlear zone at the lowest intertidal level, Lower and Upper Balanoid zones in the mid-shore region, and the Littorina zone, the highest zone in the intertidal range (see Stephenson & Stephenson 1972; Branch & Branch 1982 for diagrammatic representations of these zones). Unfavourable sea conditions precluded working in the Cochlear zone at Mouille Point on 1/7/94. Data from previous studies in these two areas (Prochazka 1994; Prochazka 1996) provided information on the composition of the fish fauna before the oil spill: previous data for the Mouille Point site were collected between May and November 1992, and data for Sea Point were collected between December 1992 and May 1993.

Care was taken to ensure that the same pools were not sampled on the first and second sampling dates after the spill. This reduced the possibility of any effect of the sampling procedure on subsequent samples, since fish show fidelity to particular pools and only fully recolonize denuded pools after periods of several months (Marsh et al. 1978; Fowler 1994). Data are presented as density/m^2 rather than density/m^3, since the fish were all benthic dwellers.

Rocky shores

Four sites were selected for investigation of rocky shores: Three Anchor Bay, Camps Bay, a boulder beach near Oudekraal and Hottentot's Huisie at Oudekraal (Fig. 1). Oudekraal forms a distinct bay on the coast and is markedly different from the other sites in being a boulder beach, and relatively protected from wave action. Of all the sites Oudekraal was the most heavily oiled, with a layer to 30 cm deep accumulating between the boulders. Oil deposition was concentrated high on the shore towards the centre of the bay. This allowed samples to be taken on two transects where the oil was heaviest, and two where it was lighter. Because earlier surveys had been undertaken at the same site, using the same methods, it was possible to make direct before-and-after comparisons at this locality.

The remaining three sites comprised rocky platforms. At these sites, the oil formed a slick of ca. 1 - 20 mm thick, again concentrated on the high shore and in more sheltered embayments. At each site, two transects were run across heavily and two across lightly oiled areas, attempting to compare areas which were physically similar. However, at Camps Bay, the lightly oiled site was subject to much stronger wave action than the heavily oiled area. Since wave action is known to profoundly influence community structure (McQuaid & Branch 1985), this particular comparison must be treated with caution. No directly comparable data regarding community composition were available for these three sites before oiling. Nevertheless, specific information was available for the population structures of particular species before oiling, and was used to make comparisons. Additional information was also available for these species for other sites within the region of oiling. Normal 'controls' in the form of comparisons with unaffected sites were not possible because the area of the spill covered an entire biogeographic sub-province, so that the only uncontaminated sites fell in other biogeographic regions (Emanuel et al. 1992). This meant that comparisons would have been flawed by biogeographic considerations.

At each transect, data were collected by counting all organisms in three replicate 0.5-m^2 quadrats at each of five to eight regular intervals up the shore between the level of low-water spring tides and the Littorina zone at the top of the shore, the number of intervals used depending on the width of the intertidal zone at each site. Mobile organisms were counted individually, while seaweeds and sessile organisms were scored as percent cover of the quadrat area. Data were later converted into whole wet-weights, using conversion factors. Data for each species were taken as the average for the quadrats covering the zone in which the species occurred.

The four sites were surveyed shortly after the oil spill (July 1994) and again two months later. Unpublished data from C.D. McQuaid for the boulder beach at Oudekraal, from G.M. Branch & R. Bustamante for mobile species at various sites, and from A. Leeb for mussels at Camps Bay provided information about conditions prior to the spill.

Because the only truly comparable before-and-after data were limited to Oudekraal, more detailed multivariate analyses were undertaken for this site. The data for individual quadrats were pooled for each transect (for both before and after) and an agglomerative cluster analysis was conducted based on Bray-Curtis similarity

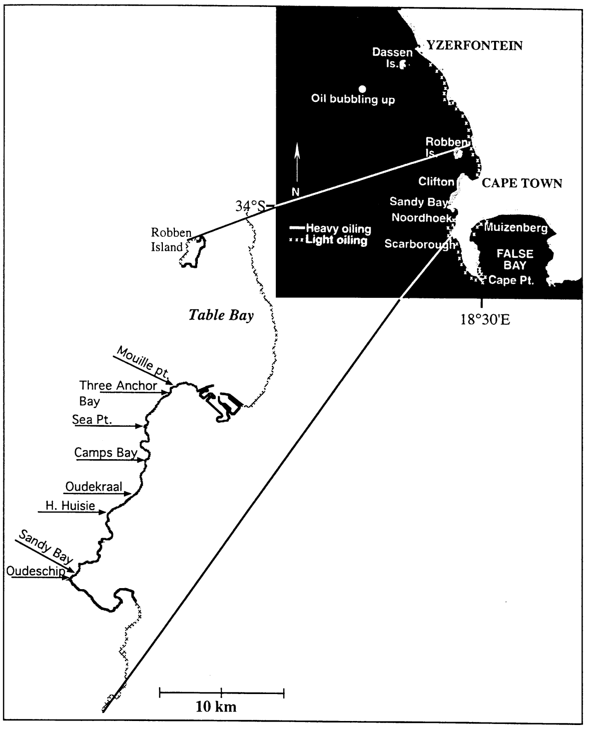

Fig. 1. Map of the southwestern Cape showing the study sites. The solid black line represents areas which were not oiled, the cross-hatching represents light oiling, and the shaded line represents heavy oiling. Inset map from Moldan (1994).

values between samples. An ordination of the same material was performed with non-parametric multidimensional scaling (MDS) (Clarke 1993). The similarity between samples is approximately proportionate to the distance between them on the ordination plot; the stress value calculated by the program is indicative of the difficulty of representing the multidimensional community data in a two-dimensional figure. A test with program ANOSIM (Analysis of Similarity) indicates the statistical significance of differences between transects (Clarke 1993).

Rock lobster

In July 1994 a survey of three areas within the vicinity of Justin's Caves at Oudekraal was carried out to assess the extent of the oiling. At a site where fouled lobsters were present, two 50-m long transects were established. Divers swimming along the transect lines measured the proportion of oiled to unoiled substrate in 1-m strips on either side of the transect. 15 oiled and 15 unoiled lobsters, all of approximately similar size (80 -85 mm carapace length) were collected from the Oudekraal area. 12 of each group were examined for gut contents and the rest were kept alive in aquaria for observation on survival and behaviour.

Results

Fish fauna

In total, 1189 fish were collected from 40 intertidal pools at Mouille Point and Sea Point. At Mouille Point, the density of fish over the whole shore increased slightly, from 16.17 fish/m^2 in the surveys undertaken before oiling, to 18.20/m^2 on 1/7/94 and 17.98/m^2 on 21/8/94 (Table 1). At Sea Point, however, the density increased markedly from 13.01/m^2 before the oiling to 20.00/m^2 on 11/7/94 before decreasing again to 9.21/m^2 on 22/8/94 (Table 1). None of these densities were lower than the average figure of 7.75/m^2 previously reported for the West coast of the Cape Peninsula (Bennett & Griffiths 1984), or the values of 5.49/m^2 and 8.11/m^2 reported by Prochazka & Griffiths (1992) for two other sites on the Cape West coast. No major shifts in species composition were evident at either the Mouille Point or Sea Point site (Table 2). *Clinus superciliosus* made up ca. 20 to 40 % of the total numbers of fish present at both sites on all occasions. *C. agilis*, *C. cottoides* and *M. dorsalis* all contributed > 5 % of the total numbers at both sites on all occasions, while *C. acuminatus* represented > 5 % of total numbers in all samples except the 11/7/94 one at Sea Point.

The only species whose density changed significantly between the initial and subsequent samples at Mouille Point were *M. dorsalis*, and *Chorisochismus dentex*. The density of *M. dorsalis* was lower on 1/7/94 than before the spill (t = 2.073; P = 0.048; t-test). However, its density increased significantly from 1.61/m^2 on 1/7/94 to 4.27/m^2 on 21/8/94 (t = –2.311; P = 0.036; t-test). Density of the clingfish, *C. dentex*, declined significantly between the initial samples and the last sampling date (t = 3.289; P = 0.002; t-test).

At Sea Point, the density of *M. dorsalis* was significantly lower on 22/8/94 than before the oil spill (t = 2.410; P = 0.021; t-test). Although the density of *C. acuminatus* at this site increased from 0.97/m^2 (Table 1) in the original samples to 1.03/m^2 on 11/7/94, this difference was not significant. However, the density declined to 0.03/m^2 on 22/8/94 (t = 4.807; P = 0.0001; t-test). These density figures are, however, similar to the range of natural fluctuations recorded previously over six months for this species at this site (0.05/m^2 to 2.32/m^2; Prochazka 1994). Although the density of *C. heterodon* remained the same between the initial samples and those collected on 11/7/94, it had decreased substantially by 22/8/94 (t =2.261; P = 0.032; t-test).

The density of all species combined in the Cochlear zone at Mouille Point (Table 3) varied only slightly between the initial situation (20.80/m^2) and the last sampling date (21.79/m^2). The contributions of the dominant species relative to the zonation are shown in Table 5. Community structure remained relatively constant with *C. agilis* contributing ca. 25 %, *M. dorsalis* 28 %, *C. cottoides* 17% and *C. heterodon* 5 - 10 % of the total numbers on both occasions. The only noticeable change was in the contribution of the clingfish, *Chorisochismus dentex*, which made up 12.1 % of the initial samples, and < 5 % of the sample on 21/8/94. Density of this species was 1.97/m^2 initially, but only 0.60/m^2 on 21/8/94 (Table 3). This final density is within the range of natural variation for this species in this zone at Mouille Point (0.18 - 1.42/m^2, Prochazka 1994).

Total density in the Cochlear zone at Sea Point was considerably greater on 11/7/94 (39.78/m^2; Table 4) than initially (18.76/m^2), but was lower on 22/8/94 (9.61/m^2). Although most species always contributed > 5% each to the total numbers present (Table 6), small differences in community structure were evident between sampling

Table 1. The density in fish/m^2 of intertidal fish over the whole shore at Mouille Point and Sea Point on the West coast of the Cape Peninsula before the oil spill (Prior), and ca. 1 week (1/7/94; 11/7/94) and two months (21/8/94; 22/8/94) after. Values are means, with standard errors in small font. Significant differences (p < 0.05) are indicated as follows: * value significantly different from that obtained on the previous sampling occasion; # the value is significantly different from that obtained prior to the oil spill.

	Mouille Point						Sea Point					
	Prior		1/7/94		21/8/94		Prior		11/7/94		22/8/94	
Clinus superciliosus	3.67	0.47	7.60	2.01	3.15	0.85	4.49	0.39	5.83	1.60	2.94	1.01
Clinus agilis	3.74	0.72	2.38	0.78	4.85	1.88	1.32	0.24	6.56	2.83	1.97	1.32
Clinus cottoides	2.49	0.33	5.01	2.87	2.94	0.86	1.15	0.19	2.10	0.77	1.84	0.51
Muraenoclinus dorsalis	2.79	0.36	*1.61	0.44	*4.27	1.07	1.58	0.34	1.49	0.73	0.54	0.27
Clinus acuminatus	1.42	0.29	1.97	0.81	1.49	0.89	0.97	0.19	1.03	0.83	0.03	0.03
Chorisochismus dentex	0.85	0.15	0.31	0.25	#0.15	0.15	1.64	0.31	0.93	0.39	0.97	0.41
Clinus heterodon	0.82	0.20	1.75	1.44	0.47	0.34	1.24	0.21	1.24	0.50	0.56	0.21
Other species	0.42	0.11	0.10	0.10	0.65	0.39	0.61	0.18	0.83	0.56	0.37	0.20
Total	16.17	1.35	18.20	5.04	17.98	3.68	13.01	0.87	20.00	5.49	9.21	2.41

Table 2. Percentage numerical contribution of the seven most important species to the fish fauna of intertidal rock pools over the whole shore at Mouille Point and Sea Point prior to the spill and ca. one week (1/7/94 & 11/7/94) and two months (21/8/94 & 22/8/94) after. Only species which constituted at least 5 % of the community are shown individually. Bold: highest value in a row; italics: highest values in a column.

	Mouille Point			Sea Point		
	Prior	1/7/94	21/8/94	Prior	11/7/94	22/8/94
Chorisochismus dentex	5.6	<	<	9.8	5.1	11.1
Clinus acuminatus	11.2	13.0	13.5	9.3	<	10.6
Clinus agilis	21.6	17.2	*23.2*	11.4	***34.8***	11.6
Clinus cottoides	15.2	20.3	16.1	8.4	7.7	18.1
Clinus heterodon	<	<	<	7.1	6.6	<
Clinus superciliosus	*25.7*	*34.9*	21.3	***40.9***	29.9	*34.7*
Muraenoclinus dorsalis	15.7	8.9	21.3	10.7	7.5	5.5
Other species	5.1	5.7	4.5	2.3	8.3	8.5

occasions. *C. agilis* contributed 16.6 % to the community initially, 42.8 % on 11/7/94, and only 8.5 % on 22/8/94, while the contribution of *C. superciliosus* was 19.5% initially, 25.1 % on 11/7/94, and 40.4 % on 22/8/94.

Density in the Lower Balanoid zone at Mouille Point was 20.08/m^2 initially but was higher (26.81/m^2) on 1/7/94, and on 21/8/94 (27.88/m^2; Table 3). Four species contributed > 5 % to the total number of fish caught in this zone before and after the oil spill (Table 5). At the Sea Point site, density in this zone was 15.54/m^2 initially (Table 4), and remained in the region of 9 - 12/m^2 thereafter. Species that contributed > 5 % to the community on all occasions (Table 6) included four *Clinus* species. *C. heterodon* contributed > 5 % initially and on 11/7/94, but failed to make up > 5 % of the community on 22/8/94, and density of this species on that date (0.67/m^2) was lower than in the previous two samples (Table 4). However, this was within the range of natural variation for this species at this site (0.20 - 1.55/m^2; Prochazka 1994).

Density of all species combined in the Upper Balanoid zone at Mouille Point varied from 14.67/m^2 initially to 18.70/m^2 on 1/7/94 and 11.01/m^2 on 21/8/94 (Table 3). *C. superciliosus*, *C. agilis*, *C. cottoides* and *M. dorsalis* all contributed substantially to the total number of individuals present (Table 5), although *C. superciliosus* contributed 51.0 % initially, 36.8 % on 1/7/94 and only 22.9 % on 21/8/94, while *M. dorsalis* contributed ca. 10 % initially and on 1/7/94, and 33.3% on 21/8/94. Density of *M. dorsalis* remained relatively constant over the sampling period (Table 3). However, the decline in density of *C. superciliosus*, the most common species mirrored the decline in total density (Table 3). At Sea Point total density (Table 4) remained relatively constant between the initial samples (10.48/m^2) and 11/7/94 (8.52/m^2), but was lower on the last sampling occasion (5.63/m^2). Again, this decline could be attributed to a decline in the density of *C. superciliosus* (Tables 4 and 5).

Within the Littorina zone at Mouille Point, total densities of fish one week (10.25/m^2) and two months (11.26/m^2) after the oil spill were slightly higher than previously recorded (7.73/m^2: Table 3). No changes in community structure were evident in this zone at this site (Table 2), with *C. superciliosus* contributing 35.8 - 40.0 %, and *C. acuminatus* contributing 50.0 - 53.7 % to the total numbers present. However, some change in community composition was evident in this zone at the Sea Point site. Here *C. superciliosus* contributed almost 60 % to the total numbers initially, but only ca. 25 % after the oil spill (Table 5), and density of this species declined from 3.44/m^2 initially to 2.94 and 1.79/m^2 on 11/7/94 and 22/8/94 respectively (Table 4). Although total density in this zone was similar (6.63/m^2) initially and 8.32/m^2 on 11/7/94, it decreased to 1.79/m^2 on 22/8/94.

Rocky shores

Densities of the more abundant species were compared between sites and with data gathered before the oil spill (Fig. 2). Densities of the high shore winkle *Nodilittorina africana* declined at Oudekraal in the heavily oiled areas (Fig. 2a). By the time of the second survey in September, they had completely disappeared from this zone, although there were signs of recovery in the less fouled areas. The same species showed signs of recovery at Three Anchor Bay by September 1994 in both 'heavily' and 'lightly' oiled zones. It should be noted that the oil was removed from the rocks at Three Anchor Bay considerably more promptly than at Oudekraal. At Hottentot's Huisie numbers of *N. africana* were reduced compared with control densities before oiling although, paradoxically, the lowest numbers were recorded at the lightly oiled transects. At Camps Bay this species declined in numbers only in the heavily oiled sites, densities in areas of light oiling being equivalent to those before the spill.

Two other mobile species which occur relatively high on the shore, *Oxystele variegata* and *O. impervia* (grouped together as *Oxystele* spp.) were severely impacted in the heavily oiled transects, their numbers being reduced to about 20 % of those recorded in lightly oiled transects and prior to the oil spill. By September, however, their numbers had also declined in the lightly oiled transects (Fig. 2b). These species are characteristic of sheltered boulder bays, and were accordingly scarce or absent at the other three sites. Data from five sites prior to the oil spill (Fig. 2b) show that its numbers were always low at such sites.

The limpet *Patella granularis*, which ranges from the low shore through to the mid-high shore, initially

Table 3. The density in fish/m^2 of intertidal fish in each of four shore zones at Mouille Point on the West coast of the Cape Peninsula before the oil spill (Prior), and approximately one week (1/7/94) and two months (21/8/94) after. Standard errors are in small font below the means. C = Cochlear zone; LB and UB = Lower and Upper Balanoid zones; L = Littorina zone.

	Prior				1/7/94				21/8/94			
	C	LB	UB	L	C	LB	UB	L	C	LB	UB	L
Clinus superciliosus	1.81	3.06	7.22	2.52	-	5.74	6.62	10.20	0.64	5.55	2.51	3.91
	0.46	1.00	1.17	0.47		1.02	2.34	5.44	0.64	1.87	1.60	1.69
Clinus agilis	5.30	7.12	1.91	0.37	-	3.84	3.59	0.00	6.41	10.56	2.42	0.00
	1.65	2.03	0.42	0.17		0.71	2.08	0.00	3.61	5.47	1.54	0.00
Clinus cottoides	2.65	4.14	2.95	0.02	-	10.15	4.85	0.00	3.71	4.94	2.46	0.67
	0.83	0.63	0.59	0.02		7.43	2.57	0.00	1.86	2.54	0.86	0.67
Muraenoclinus dorsalis	6.27	3.31	1.27	0.09	-	1.76	2.21	1.01	5.93	6.83	3.62	0.71
	1.00	0.39	0.25	0.06		0.83	0.65	0.79	0.39	3.52	1.08	0.38
Clinus acuminatus	0.09	0.00	0.98	4.86	-	0.00	1.21	4.52	0.00	0.00	0.00	5.97
	0.09	0.00	0.33	0.88		0.00	0.42	1.52	0.00	0.00	0.00	2.05
Chorisochismus dentex	1.97	1.25	0.11	0.00	-	0.69	0.22	0.00	0.60	0.00	0.00	0.00
	0.42	0.28	0.07	0.00		0.69	0.22	0.00	0.60	0.00	0.00	0.00
Clinus heterodon	1.35	0.90	0.97	0.00	-	4.35	0.00	0.47	1..88	0.00	0.00	0.00
	0.41	0.33	0.57	0.00		3.90	0.00	0.47	1.11	0.00	0.00	0.00
Other	1.35	0.30	0.00	0.02	-	0.28	0.00	0.00	2.62	0.00	0.00	0.00
	0.37	0.11	0.00	0.02		0.28	0.00	0.00	0.83	0.00	0.00	0.00
Total	20.80	20.80	14.67	7.73	-	26.81	18.70	10.25	21.79	27.88	11.01	11.26

Table 5. Percentage numerical contribution of the most important species to the fish fauna of intertidal rock pools in four shore zones at Mouille Point prior to the spill and approximately one week (1/7/94) and two months (21/8/94) after. Only those species which constituted at least 5 % of the community are shown individually. Bold: highest value in a row; italics: highest values in a column; () no sample.

	Cochlear			Lower Balanoid			Upper Balanoid			Littorina		
	Prior	11/7/94	22/8/94	Prior	11/7/94	22/8/94	Prior	11/7/94	22/8/94	Prior	11/7/94	22/8/94
Chorisochismus dentex	12.1	()	<	6.8	<	<	<	<	<	<	<	<
Clinus acuminatus	<	()	<	<	<	<	5.0	5.7	<	*52.5*	*50.0*	*53.7*
Clinus agilis	25.4	()	26.9	*34.8*	23.4	*39.0*	14.0	20.7	18.8	<	<	<
Clinus cottoides	16.7	()	<	22.1	25.0	19.0	16.2	**26.4**	25.0	<	<	<
Clinus heterodon	5.0	()	9.6	<	7.8	<	<	<	<	<	<	<
Clinus superciliosus	8.3	()	<	12.8	*29.7*	20.0	*51.0*	*36.8*	22.9	40.0	40.0	35.8
Muraenoclinus dorsalis	28.2	()	*28.8*	17.6	7.8	22.0	9.4	10.3	*33.3*	<	7.5	6.0
Other species	4.3	()	**17.3**	6.0	6.3	<	4.4	<	<	7.5	2.5	4.5

showed no response at any of the sites, when compared with densities before oiling. By September its numbers were slightly reduced at Oudekraal and Three Anchor Bay, but did not drop below the range exhibited for control sites. (Fig. 2c).

The low-shore limpet, *Patella cochlear* remained unaffected at all sites (Fig. 2d). This is particularly salient because this species is known to be especially sensitive to stress and experienced heavy mortalities after the oil spill from the Wafra (Day et al. 1971). It should, however, be borne in mind that the Wafra was carrying crude oil, which is more toxic than the heavy fuel oil from the Apollo Sea.

The mussel *Mytilus galloprovincialis* showed little sign of any effects at either Camps Bay or Three Anchor Bay (Fig. 3b). It was scarce at the remaining two sites. Additional information is also available for Kommetjie (which was lightly oiled during the spill) and for Paternoster (which lies north of Saldanha Bay, and beyond the range of the oil spill). At both these sites numbers were comparable before and after the spill, and with our study sites (Fig. 3a). The apparent difference in percentage cover of *M. galloprovincialis* at heavily and lightly oiled sites at Camps Bay (Fig. 3b) is primarily due to the fact that the ‘heavily’ oiled zones were sheltered from wave action, and likely to support smaller numbers of mussels.

Species richness of the benthos (Fig. 4) declined up the shore as is normal for intertidal rocky shores. There were no consistent differences between lightly and heavily oiled areas, nor any obvious differences between samples taken in July and September. At Oudekraal (the only site for which comparable ‘before’ data were available), there was no sign that species richness was reduced by the oil spill.

Table 4. The density in fish/m^2 of intertidal fish in each of four shore zones at Sea Point on the West coast of the Cape Peninsula before the oil spill (Prior), and approximately one week (11/7/94) and two months (22/8/94) after. Standard errors are in small font below the means. C = Cochlear zone, LB and UB = Lower and Upper Balanoid zones, L = Littorina zone.

	Prior				11/7/94				22/8/94			
	C	LB	UB	L	C	LB	UB	L	C	LB	UB	L
Clinus superciliosus	2.82	5.36	6.33	3.44	9.63	3.73	6.48	2.94	3.17	4.97	1.13	1.79
	0.66	0.78	0.79	0.61	3.53	1.77	0.00	2.94	1.92	2.81	1.13	0.00
Clinus agilis	2.14	2.25	0.63	0.10	17.68	1.57	1.30	0.00	0.78	5.66	1.02	0.00
	0.71	0.44	0.21	0.04	1.71	0.56	0.00	0.00	0.17	5.44	0.37	0.00
Clinus cottoides	0.99	1.83	1.53	0.17	2.62	3.62	0.19	0.00	1.32	2.96	2.43	0.00
	0.30	0.29	0.55	0.15	0.74	1.77	0.00	0.00	0.32	0.37	1.78	0.00
Muraenoclinus dorsalis	3.72	2.14	0.28	0.00	3.58	0.27	0.19	0.84	0.93	0.44	0.35	0.00
	0.89	0.68	0.11	0.00	1.64	0.15	0.00	0.84	0.67	0.44	0.35	0.00
Clinus acuminatus	0.00	0.22	1.02	2.78	0.00	0.00	0.19	4.54	0.00	0.11	0.00	0.00
	0.00	0.22	0.38	0.42	0.00	0.00	0.00	3.02	0.00	0.11	0.00	0.00
Chorisochismus dentex	4.57	1.68	0.14	0.00	2.10	0.69	0.00	0.00	1.98	0.54	0.35	0.00
	0.80	0.37	0.10	0.00	0.81	0.13	0.00	0.00	0.77	0.54	0.35	0.00
Clinus heterodon	2.40	1.76	0.53	0.14	1.70	1.97	0.19	0.00	0.82	0.67	0.35	0.00
	0.54	0.44	0.24	0.07	0.97	0.99	0.00	0.00	0.44	0.45	0.35	0.00
Other	2.10	0.30	0.01	0.00	2.48	0.00	0.00	0.00	0.61	0.56	0.00	0.00
	0.57	0.13	0.01	0.00	1.30	0.00	0.00	0.00	0.41	0.56	0.00	0.00
Total	18.76	15.54	10.48	6.63	39.78	11.84	8.52	8.32	9.61	15.90	5.63	1.79
	1.90	1.43	1.14	0.74	6.41	3.04	0.00	6.81	0.36	8.54	2.06	0.00

Table 6. Percentage numerical contribution of the most important species to the fish fauna of intertidal rock pools in four shore zones at Sea Point, prior to the spill and approximately one week (1/7/94) and two months (21/8/94) after. Only those species which constituted at least 5 % of the community are shown individually. Bold: highest value in a row; italics: highest values in a column.

	Cochlear			Lower Balanoid			Upper Balanoid			Littorina		
	Prior	11/7/94	22/8/94	Prior	11/7/94	22/8/94	Prior	11/7/94	22/8/94	Prior	11/7/94	22/8/94
Chorisochismus dentex	<	5.4	17.0	9.1	6.5	8.9	<	<	<	<	<	<
Clinus acuminatus	<	<	<	<	<	<	8.3	<	<	35.5	*67.9*	*74.1*
Clinus agilis	16.6	***42.8***	8.5	16.4	22.8	19.6	6.5	15.9	18.2	<	<	<
Clinus cottoides	6.6	6.3	13.8	12.0	18.5	26.8	12.8	<	*36.4*	<	<	<
Clinus heterodon	11.2	<	6.4	8.6	20.7	<	<	<	<	<	<	<
Clinus superciliosus	*19.5*	25.1	*40.4*	*33.1*	*29.3*	*30.4*	*63.8*	***75.0***	31.8	*59.7*	25.0	25.9
Muraenoclinus dorsalis	**17.5**	9.5	6.4	17.2	<	7.1	<	<	<	<	7.1	<
Other species	5.3	10.9	7.4	3.6	2.2	7.1	8.6	9.1	**13.6**	4.8	7.1	<

Biomass changes up the shore similarly showed little difference between lightly and heavily polluted zones at Three Anchor Bay and Hottentot's Huisie (Fig. 5). At Oudekraal, the heavily oiled areas had considerably less biomass in July than the same area prior to the spill. This was particularly notable in the mid and high shores. The lightly oiled area tended to have intermediate values. By September, the biomass values in the lightly and heavily polluted zones were similar, but both were substantially lower than the recorded values prior to the spill.

At Camps Bay, the biomass was substantially higher in heavily oiled than in lightly oiled transects for both dates. Once again, this is likely to be the result of differences in wave exposure between the lightly and heavily oiled transects, and should not necessarily be seen as an effect of oil pollution.

When the data for biomass were averaged for each transect (Fig. 6), similar patterns emerged. There were no significant differences between lightly and heavily oiled areas at Three Anchor Bay or Hottentot's Huisie and the low biomass at the heavily oiled Camps Bay site once again reflects the sparsity of mussels associated with low wave action. Overall biomass at Oudekraal was significantly lower following the spill compared to that prior to oiling.

Similarity analyses were conducted specifically for Oudekraal, the only site for which data were collected before the spill, and at which the most severe effects were recorded. The dendrogram and ordination plot (Fig. 7) which take diversity into account, confirm the differences shown in Figs. 4 - 6. There were significant community differences between transects in heavily and lightly oiled areas and between these and the communities present

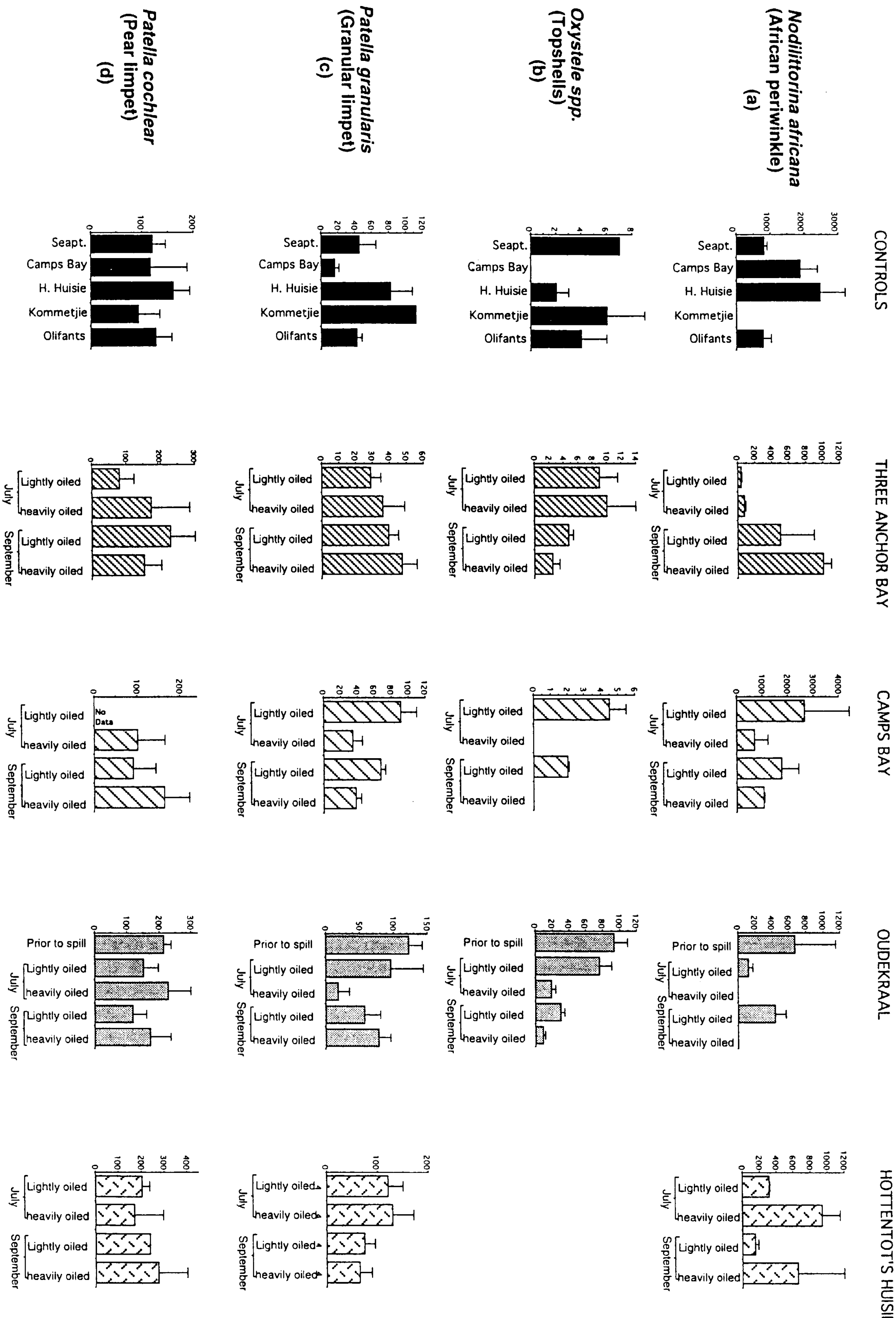

Fig. 2. Densities (no./m^2) of the more abundant benthic organisms at all study sites, compared with control samples from before the spill. All error bars represent the standard errors. Note that scales differ between sites.

prior to the spill. There were also differences between July and September surveys. It is nonetheless striking that despite these differences, all transects at this site had similarity indices of above 60 %, as shown by the dendrogram in Fig. 7.

Similarity analysis (Table 7) confirms that there were significant differences between prior and heavy, prior and all September results, light and heavy, and between July and September.

Extent of subtidal oiling

Oil was found in only one of the three areas investigated at Oudekraal. At this locality almost all the lobsters seen had oil on their mouthparts and legs, although oil covered only 7 % of the seabed. Oil on the rocks and sandy substrata consisted of globules ranging in diameter from 30 cm to 1.5 m, and was concentrated in sheltered gullies, and in the lee of rock pinnacles.

Examination of gut contents

The fore-guts of 12 oiled and 12 non-oiled lobsters were dissected out and the contents examined. Guts were classified as full, liquid or empty, giving a qualitative index of the time since the animal last fed. The difference between the two groups was considerable:

Oiled lobsters:	gut contents full: 0	liquid: 3	empty: 9
Non-oiled lobsters:	10	1	1

All the lobsters kept in aquaria survived. Those which had been fouled had cleaned all signs of oil from their legs and mouthparts within one week and were in apparent good health.

Discussion

Rock-pool fish fauna

The majority of fish species that occur in rock pools on the West coast of the Cape Peninsula are restricted to the intertidal zone and are not found in deeper water. 22 species have been captured from intertidal pools on the Cape Peninsula West coast (Bennett & Griffiths 1984; Prochazka 1994; Prochazka 1996), but only seven contribute more than 5 % to the total fish abundance in the area. These include six species of klipfish and the clingfish (Tables 5 and 6).

Among intertidal organisms, fish have relatively high metabolic requirements and are thus sensitive to changes in oxygen levels in intertidal pools. This makes them good indicators of pollution in the intertidal environment (Moring 1983).

Only a single species, *Chorisochismus dentex*, de-

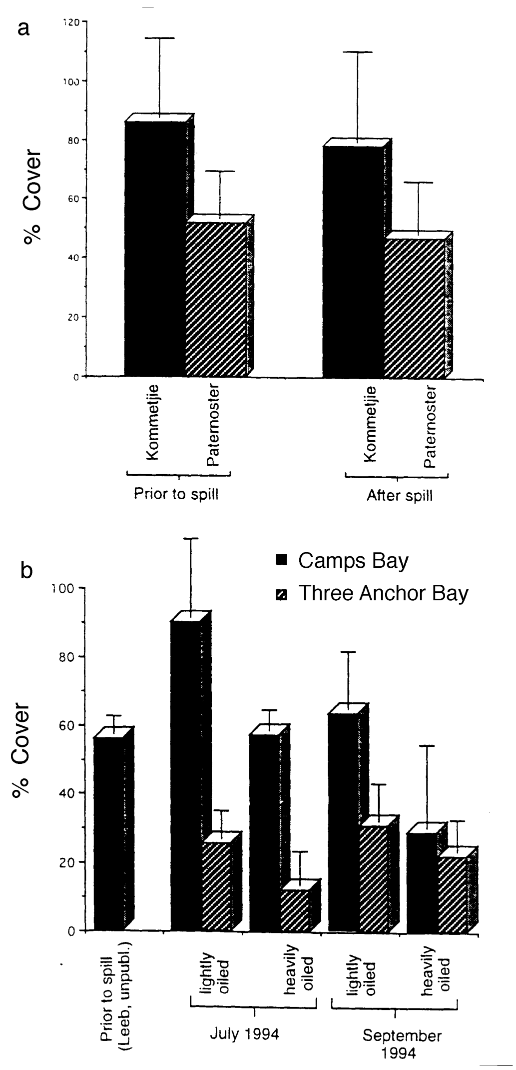

Fig. 3. Percentage cover of *Mytilus galloprovincialis* (Mediterranean mussel) at two control sites (**a**) and at Camps Bay and Three Anchor Bay (**b**) before and after the spill. No data prior to the spill were available for Three Anchor Bay. Error bars represent the calculated standard error of the data.

Table 7. Results of Analysis of Similarity (ANOSIM) at Oudekraal, based on the abundance of intertidal organisms.

Groups compared	Statistical value	Significance level
Prior vs Light	0.130	0.34
Prior vs Heavy	0.852	0.02
Light vs Heavy	0.510	0.05
Prior vs July	0.241	0.25
Prior vs September	0.556	0.02
July vs September	0.542	0.02

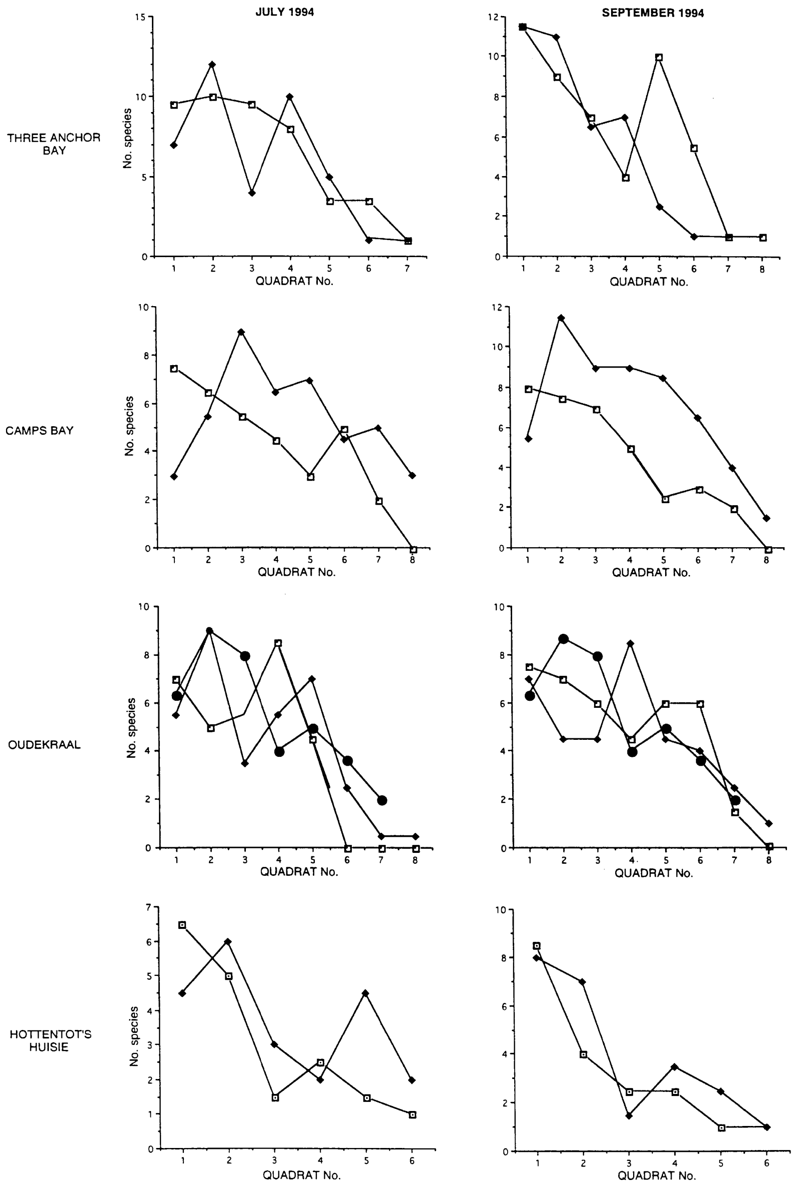

Fig. 4. Species richness of macrofauna and macroflora in relation to height on the shore of four sites. ● = Prior to spill, ◆ = Lightly oiled, □ = Heavily oiled. Quadrats run from low water spring tide (1) up the shore to the Littorina zone (8).

clined significantly during the sampling period whereas the density of one species, *Muraenoclinus dorsalis*, increased at Mouille Point after the spill. The dominant species, *Clinus superciliosus*, did not vary significantly throughout the sampling period. Since the natural variability in densities of fish in intertidal pools may be substantial and declines in densities were not significant for all other species, it is likely that most observed differences simply reflect natural inter-pool variation.

Marked changes in intertidal fish density occurred in the Upper Balanoid zone at both Mouille Point and Sea Point and in the Littorina zone at Sea Point, due to lower densities of *C. superciliosus* being captured in these areas. However, Prochazka (1996) indicated that a decline in the density of this species at the time of year when the surveys were conducted is not unusual. Although small changes in community structure were evident, these were probably due to natural fluctuations and slight differences in the size and available cover of pools sampled before and after the spill, especially at Mouille Point.

Moring (1983) suggested that oil coats the skin and gills of fish, thus impairing their normal physiological functions. This was, however, not evident in the inter-

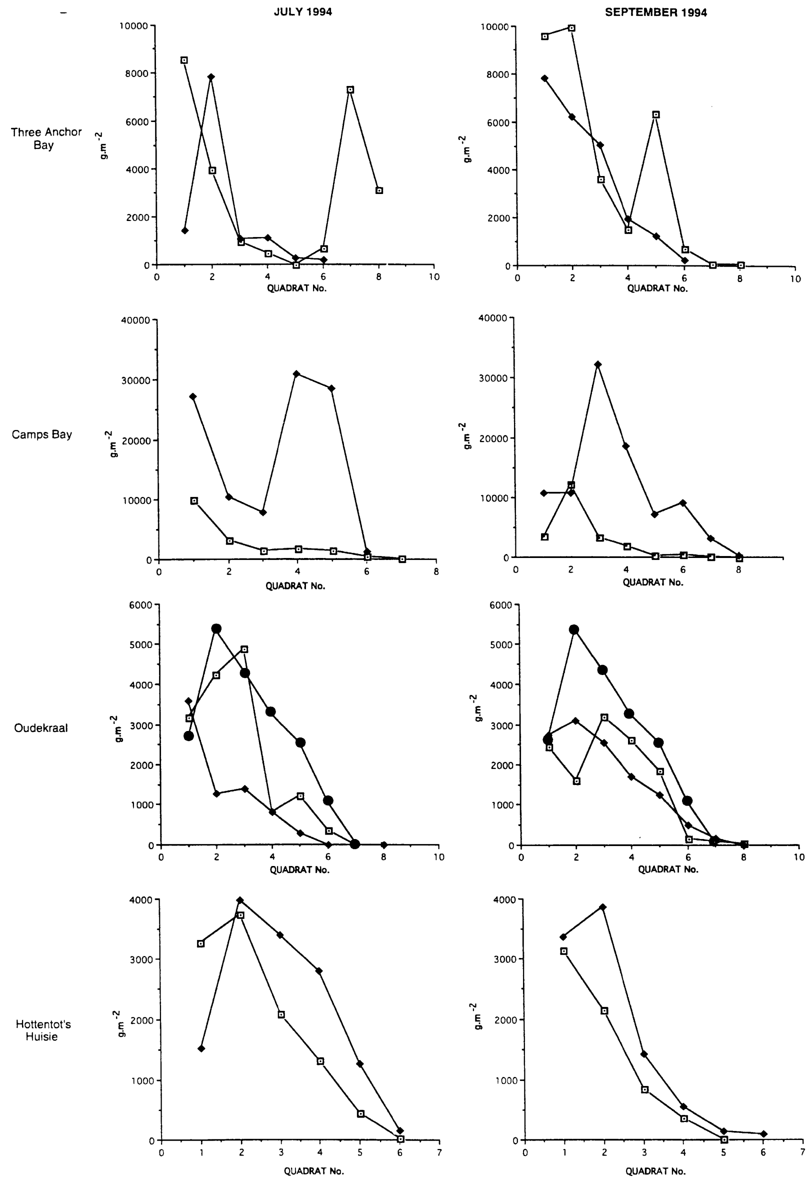

Fig. 5. Total biomass in relation to height on the shore at four sites. ◘ = Prior to spill, □ = Lightly oiled, ◆ = Heavily oiled. Quadrats run from low water spring tide (1) up the shore to the Littorina zone (8).

tidal fish on the Cape Peninsula West coast, possibly as the oil was heavy and formed cohesive lumps rather than a filmy coating. In addition, the strong seas and onshore winds that prevailed during the worst of the oil wash-up caused most of the oil to be deposited higher up the shore than the rock pools sampled. Thus, the oil spill from the Apollo Sea on the West coast of the Cape Peninsula had little apparent effect on the density or community structure of the resident rock pool fish fauna. This is a striking result, given the sensitivity of fish fauna of intertidal pools as pollution indicators.

Rocky shores

There were no visible effects on any organisms in the low rocky shore intertidal, but the impact of the oil increased with height up the shore. The species most affected were the African periwinkle *Nodilittorina africana* and two species of topshell, *Oxystele*. The decline in abundance of *N. africana* contrasts with the behaviour of a closely related species, *Littorina littorea*: the abundance of this species was unaffected in oiled areas of Nova Scotia and its individuals were even longer (Thomas 1978). The two most affected species

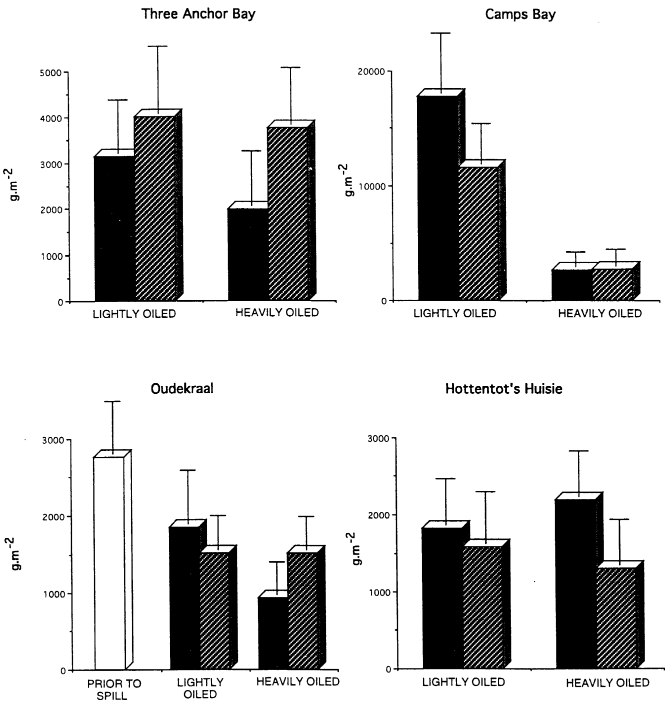

Fig. 6. Average biomass per transect at all sites. Solid bars represent July 1994, shaded bars September 1994. Error bars indicate the calculated standard error of the data.

were already showing signs of recovery at three of the four sites investigated by September 1994, though not at Oudekraal, the most heavily oiled site, where changes in intertidal community structure were most apparent.

With the exception of this site, earlier impressions that there had been little damage caused to the intertidal zone seem to have been borne out. This contrasts with other recent catastrophic events, such as the black tide of April 1994, or the Orange River flood of 1988, which caused huge mortalities of many species and resulted in intertidal communities becoming largely dominated by opportunistic algal species, such as *Ulva* and *Enteromorpha*, following high mortalities of grazers (Branch et al. 1990). In the current case, more deleterious effects may have been prevented by some factors, such as the type of oil: heavy fuel oil, rather than crude oil – although lighter types of fuel oil may be more toxic than crude oil (Blumer et al. 1971; Neff & Anderson 1981). Also, the oil had had several days of weathering before it reached the shore and stormy weather deposited the oil high in the intertidal zone, largely missing the low-shore species. Intertidal animals are known to be resistant to stress; the height at which a species occurs on the shore is correlated with its physiological tolerance (Branch et al. 1990), and the

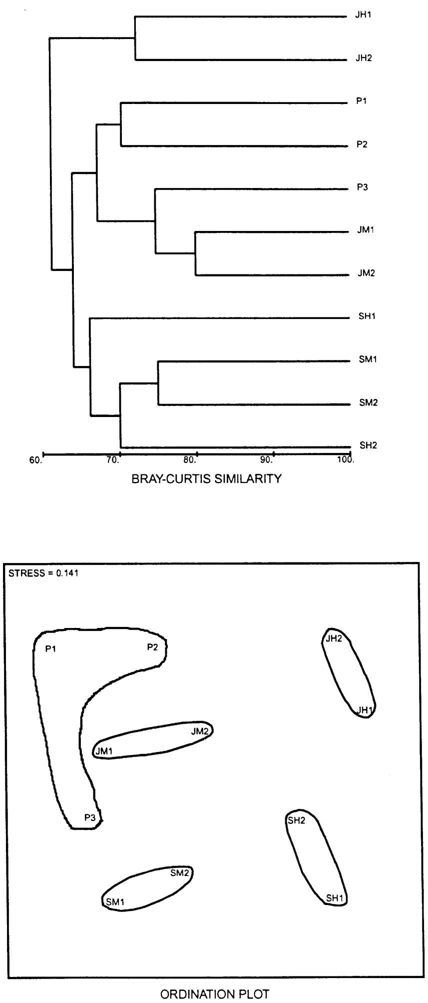

Fig. 7. Dendrogram and ordination for pooled samples from Oudekraal. P = prior tot he spill (three transects P1 - P3); J = July, S = September; JM1,2 and SM1,2 = two moderately oiled in July and two in September, JH1,2 and SH1,2 = two heavily oiled in July and two in September.

species that bore the brunt of the oil were thus likely to have been those best suited to withstand it.

A major factor contributing to the damage caused by oil pollution has been the application of chemical dispersal agents. In the aftermath of the Torrey Canyon spill, the dispersants may have caused more damage than the oil itself (Southward & Southward 1978), and 10 years after the spill some rare species had not recolonized areas where dispersants had been heavily applied. In the present instance, all cleaning of the intertidal areas was done by more benign, mechanical means. Finally, at 2 500 tons, the spill was relatively small, although a similar size spill of fuel oil caused considerable ecological damage at West Falmouth, Massachusetts, USA. (Blumer et al. 1971). However, the size of an oil spill alone is generally a poor determinant of the amount of ecological damage it causes, relative to other factors.

Rock lobsters

Inhibition of feeding by lobsters in the presence of oil was previously documented for the American lobster, *Homarus americanus* (Atema & Stein 1974; Atema 1976). Different types of oil, and different fractions had varying effects that ranged from acute toxicity to an increase in the time taken to find food. The latter effect was attributed to the impairment of sensory abilities. Concentrations as low as 10 ppm of oil in the water were sufficient to induce feeding responses in some cases. Strangely, these authors also found that some fractions of oils, in particular kerosene, acted as attractants to the lobster, and resulted in increased feeding initially, followed by depressed activity, and complete cessation of feeding for several days afterward. These observations would account for patterns seen in this survey. In the field, lobsters remained fouled approximately six weeks after the spill, but when held in aquaria, they lost all traces of oil after one week, implying that they were being repeatedly oiled *in situ*. Since the oil covered a relatively small area of the seabed, it is possible that the lobsters were actively attracted to the oil. The absence of food in the guts of oiled lobsters is also consistent with the results of Atema (1976).

The fuel oil from the Apollo Sea had no apparent lethal effects on *Jasus lalandii*. All oiled lobsters held in aquaria survived, and there were no indications of oil-induced mortalities in the field. Lobsters are able to survive for several months without feeding (Cockroft pers. comm.), and the lack of feeding was therefore also unlikely to result in mortalities. However, it is possible that growth rates of lobsters would be reduced if they were unable to feed for lengthy periods. This is of concern since the growth rates of *J. lalandii* have been depressed over the past several years (Castilla et al. 1994). Further, depressed activity, as reported by Atema (1976), might render the animals vulnerable to predation. Sub-lethal effects of oil pollution on marine organisms are also known to include decreased fecundity in some cases. While the scope of the present study did not cover such eventualities, the potential effect of reduced fecundity in a commercially important species is clearly an important consideration. Finally, fouling of lobsters with oil makes them unsuitable for marketing for human consumption. In the present instance, the oiling of lobsters occurred in an area too localised to significantly affect the population as a whole. Moreover, much of the oil had disappeared from the seabed by mid-November, 1994. However, the potential for population-wide effects in the event of a large oil spill is very real.

Conclusion

Taken collectively, the above results seem to indicate that little lasting ecological harm was inflicted on the coastal areas by oil pollution from the Apollo Sea, particularly in comparison with damage caused by other documented spills, many of which involved highly toxic crude oil. Nonetheless, assessment of the impact of the pollution was hampered by the absence of reliable baseline data before the event in many of the areas surveyed. It is also important to note that the current study was designed to assess only the short term consequences of the spill - in effect the mortalities caused soon after the spill by toxicity, smothering or ‘dislodgement’. Any sub-lethal, long-term effects would have gone unnoticed, despite the fact that the reduction of reproductive potential of populations is regarded as one of the most important criteria for assessing the ecological effect of pollution events (Brown 1985).

There is little doubt that initial reports in the press of an ‘ecological disaster’ were without foundation, with the exception that birds, particularly penguins, were severely impacted. Expected mass mortalities and associated extreme changes in community structure of the rocky shores did not materialise, and in this sense the effect of the spill was minor. Indeed, this is the most salient feature of the study. All previous reported oil spills have led to substantial changes in intertidal communities. The limited impact recorded in this case contrasts strikingly with impacts reported after most oil spills, but is not surprising in view of the relatively low toxicity of the heavy fuel oil. However, the assertion of little ecological damage needs to be made with some caution, especially in view of the absence of data on sub-lethal effects of the pollution.

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