Oil Pollution Studies of the Solbergstrand Mesocosms

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Two medium-scale ecosystems (mesocosms) were built on the Oslofjord: one a hard-bottom intertidal system and the other a subtidal soft-sediment system. The hard-bottom mesocosm consists of four basins, two controls and two which were dosed with diesel-oil (129 μg $\mathrm{l^{-1}}$ a high oil (HO) dose and 29 μg $\mathrm{l^{-1}}$ a low oil (LO) dose). Both oil doses caused high mortality of *Mytilus edulis* and growth was reduced in the macroalgae *Ascophyllum nodosum* and *Laminaria digitata*. Recruitment of *Littorina littorea* was also affected by oil so that populations declined over time.

Subtidal benthic communities have been established in the mesocosm and show variations in sediment chemistry within the range found in the field. Although recruitment of benthic macrofauna is reduced, dominant species and species structure remain closely similar to that in the field over six months. Bioturbation effects studied in the mesocosm have shown the important influence of large, rare species in structuring benthic communities, a finding which would not be possible in nature by diving or by the use of submersibles. Preliminary results from a community taken from 200 m depth and established in the mesocosm suggest that it is now possible to do detailed manipulation experiments on communities simulating the whole continental shelf.

INTRODUCTION

Mesocosms are facilities that allow experimentation at scales intermediate between the laboratory and the field. In marine research, mesocosms have been used to enclose large bodies of seawater with their constituent plankton communities (the Loch Ewe experiments in Scotland and Saanich Inlet in Canada, reviewed in Grice & Reeve (1982)), as enclosures linking water column and benthos (the Marine Ecosystem Research Laboratory at Rhode Island U.S.A. (Pilson *et al.* 1977) and the Kiel Bay experiments (von Bodungen *et al.* 1976)), and as enclosures simulating tidal flat communities (the Texel facility in Holland (De Wilde & Kuipers 1977) and the German caissons (Farke *et al.* 1984)). No mesocosms have been used to study intertidal hard bottom communities or subtidal benthic communities. The Solbergstrand facilities cover the last two aspects and are therefore unique.

Mesocosms have been primarily used for studies of effects of pollutants on marine organisms. The advantages of mesocosms over the natural field-habitats are that the environment is usually enclosed and thus easier to experiment in a controlled manner rather than being subject to the vagaries of climate. Experiments with pollutant materials in the natural environment are often uncontrolled (e.g. dosing).

Although effects of oil on marine systems have been much studied, one relatively little-studied aspect is the potential long-term effect of small amounts of oil discharged continuously. Such a scenario would apply to offshore oil platforms, in refineries or indeed at most estuaries.

With financial assistance from British Petroleum (B.P. Norge A/S) it was possible to convert an old trout-farm owned by the Norwegian Institute for Water Research (NIVA) at Solbergstrand on the Oslofjord, Norway into a research facility. A joint research programme was initiated between NIVA, B.P. and the University of Oslo, and has run from 1981 to 1986.

The primary focus of the research has been on long-term effects of small amounts of diesel-oil on individuals and populations of intertidal rock communities (algae, bivalves, gastropods and Crustacea) and on the feasibility of simulating subtidal soft-sediment communities within a mesocosm with the aim of studying effects of, for example, drill-cuttings on natural communities.

The hard bottom mesocosm

Material and methods

Four basins (measuring 8.4 m × 5.0 m × 1.25 m) contain seawater pumped from 1 m depth in the fjord outside the mesocosm (figure 1). During the coldest periods water is pumped from 13 m depth to prevent formation of ice within the basins. Turnover time for the water in each basin is four hours. Over the period July 1982 to October 1984 the minimum monthly mean temperature was 2 °C and the maximum 23 °C. Salinity varied from 14‰ in June 1983 to 31‰ in December 1983 and January 1984. Water flows continuously into the basins at a rate of 10 $m^3 h^{-1}$ and the outflow is adjusted in height by a mechanical pulley system to give a simulated 12 h 25 min tidal cycle. On one side of each basin is a wave generator, running along the full length of the basin, which works mechanically and produces waves of 25 cm in height with a period of *ca.* 2 m. On the opposite side of each basin to the wave generator is a series of steps 42.5 cm in width and 19 cm in height with a slope of 19 cm across the basin. Thus the left-hand side of one step is level with the right-hand side of the step above. The communities were established in 1979 by transporting into each of the four basins stones containing an attached algal flora and constituent fauna. The basins were allowed to develop by natural recruitment, which was large, for three years before oil dosing began. A typical zonation pattern for the sheltered Oslofjord ranging from *Laminaria* through *Ascophyllum* and the genus *Fucus* resulted.

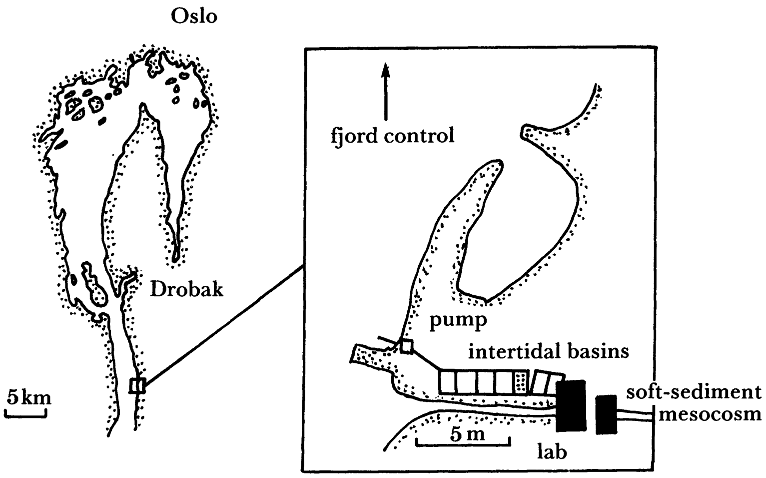

Figure 1. Location of Solbergstrand mesocosms.

Choice of the type of oil to be used in the experiments was the subject of considerable debate. The water-accommodated fraction (WAF) of diesel oil was chosen to ensure consistency of the dose. Our initial concentrations projected were 200 (high oil, HO) and 50 (low oil, LO) $\mu g\ l^{-1}$ total hydrocarbons dosed to two basins. The two remaining basins acted as controls. The dosing system is shown in figure 2. Inflowing seawater was heated to 12.5 °C before being mixed vigorously in the mixing chamber. The separator skimmed off oil droplets and the baffles ensured that only WAF was pumped to the basins†. The concentration of hydrocarbons in the basins was measured routinely by u.v.-fluorescence with periodic checks being made by gas chromatography–mass spectrometry (GC–MS) analyses. After subtracting values for the control basins the added hydrocarbon concentration for the period September 1982 to September 1984 had a mean of 127.3 $\mu g\ l^{-1}$ in the HO basin and 27.9 $\mu g\ l^{-1}$ in the LO basin, giving fourfold dose differences. The background hydrocarbon level was 5.6 $\mu g\ l^{-1}$ (Bakke & Sørensen 1985).

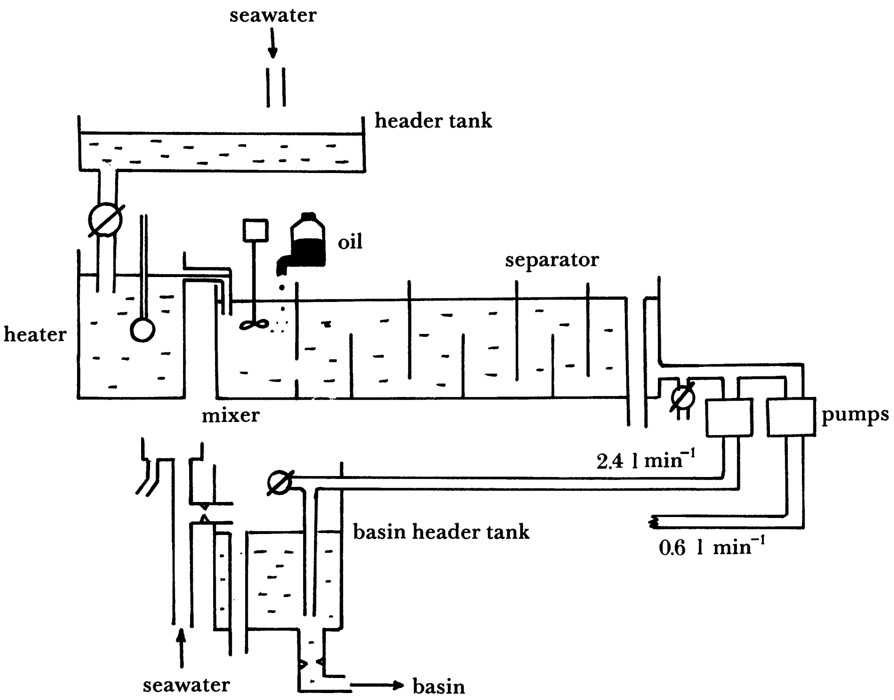

FIGURE 2. Oil dosing system giving 127 $\mu g\ l^{-1}$ (HO) and 27.9 $\mu g\ l^{-1}$ (LO) of water-accommodated fraction (WAF) of oil in dosed basins.

Most studies were done at the individual and population level rather than the community and ecosystem level. Algal communities were studied by placing transects over the steps within each basin and measuring percentage cover for the algae and numbers for the fauna (Bokn & Moy 1987). Growth of individual plants of *Laminaria digitata* and *Ascophyllum nodosum* was studied by marking tips of individual plants. Bokn (1984, 1985) should be consulted for further details.)

The gastropod *Littorina littorea* was a major component of the basins and was studied in detail. Over 3500 individuals were marked with identifying numerical codes and colour codes for catch records, both marks were covered by a cyanoacrylate film before release. Individuals were

† Oil was dosed to the basins from May 1982 to September 1982.

measured with a digital caliper (accuracy ± 0.03 mm) when caught. In addition to the two basin controls a control station was established in Oslofjord near Solbergstrand (figure 1). Sampling was done monthly from July 1982 to September 1983. Data were obtained on individual growth rates, population mortality, recruitment and fecundity. (Details of methods are not presented and will appear elsewhere.)

Mytilus edulis was also a common component of the basins and population dynamics were studied by separating the initial basin population into size classes, placing them in nylon-mesh tubes (as used in mussel culture) and attaching the tubes to ropes strung across the basins. Regular sampling was done to assess growth, mortality and fecundity.

Population genetics studies on enzyme polymorphisms were done on *Littorina littorea*, *Mytilus edulis* and *Semibalanus balanoides*.

Finally, physiological studies of scope for growth, feeding rates, respiration rates and excretion rates and biochemical studies of lysozymal enzymes and membrane structures were done on *L. littorea* and *M. edulis* by IMER & NIVA scientists (see Moore, this symposium; Bakke 1985).

Results

Macroalgae community structure (data from Bokn (1984); Bokn & Moy (1987)) showed surprisingly little variation over time as a result of exposure to oil. Figure 3 shows that *A. nodosum* had almost constant population size over time and there were no differences between basins. *Fucus serratus* showed seasonal growth patterns with slightly less cover in the HO basin whereas *L. digitata* showed seasonal patterns but with no differences between basins. The understorey algae *Phymatolithon lenormandii*, *Chondrus crispus*, *Cladophora rupestris* and *Ulva lactuca* showed significantly greater growth in the LO basin than in the other three basins, (figure 3).

Individually marked *L. digitata* and *A. nodosum* showed clear reductions in growth rate in both oiled basins when compared with the controls (figure 4), but only in the second and third years of growth (Bokn 1985).

L. littorea populations showed over 12 months of exposure to oil a statistically significant decline in population density in all basins (figure 4). Calculations of mortality (table 1) showed that the absolute mortality rate (M) was significantly greater in HO than LO but the LO population showed no differences from the controls.

The basins were not closed populations and some recruitment could have occurred from outside. To investigate this, measurements were taken of the numbers of *L. littorea* eggs in the inlet and outlet of each basin. Between 16 and 30 % of recruits came from outside the basins and the total numbers discharged clearly related to the population size within the respective basins. Basin C4 had the greatest number of larvae discharged and the highest population density as estimated by mark and recapture data. Throughout the study period the high-oil basin (HO) had the least number of individuals less than 6 mm in length, followed by the low oil (LO) and the two controls had greatest numbers. Survival of the smallest individuals was poorest in the oiled basins.

The growth rate pattern of an individually marked *L. littorea* is shown in figure 5. Maximal growth occurs from July to September. Figure 5 shows that growth rate is lower for individuals of similar starting size in HO and LO than in C2. The growth rate in C4 and in the fjord control with higher population densities than in the other basins was, however, even less. The K value from fitted von Bertalanffy curves (table 2) shows that for all individuals measured in July 1983 no clear differences were found between oiled and control basins. The growth rate studies show

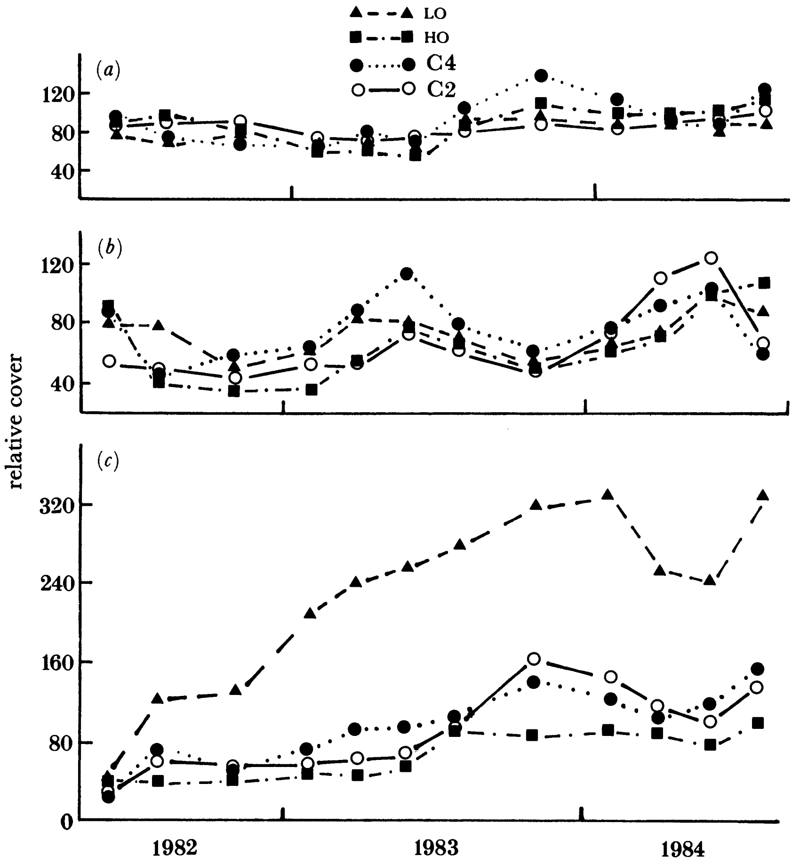

FIGURE 3. Macroalgae cover after addition of oil (WAF) at 127 $\mu g\ l^{-1}$ (MO) and 27.9 $\mu g\ l^{-1}$ (LO). C2 and C4 are two control basins. (Data from Bokn (1985).) (*a*) *Ascophyllum nodosum*. (*b*) *Laminaria digitata*. (*c*) *Phymatolithon lenormandii*.

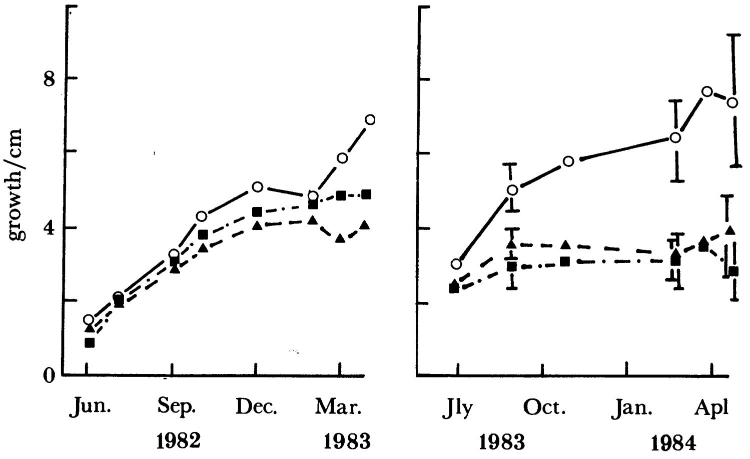

FIGURE 4. Growth of *Ascophyllum nodosum* dosed with oil (WAF). HO = 127 $\mu g\ l^{-1}$, LO, 27.9 $\mu g\ l^{-1}$, C2, control. Symbols as in figure 3.

that oil did not have an appreciable effect and that density differences among the studied populations were more important than oil in affecting growth rate.

Analyses of size–frequency distributions of *L. littorea* suggested that stabilizing selection might have occurred where the modal size is selected at the expense of the smallest and largest individuals (figure 6). A comparison with the controls, however, shows that the populations

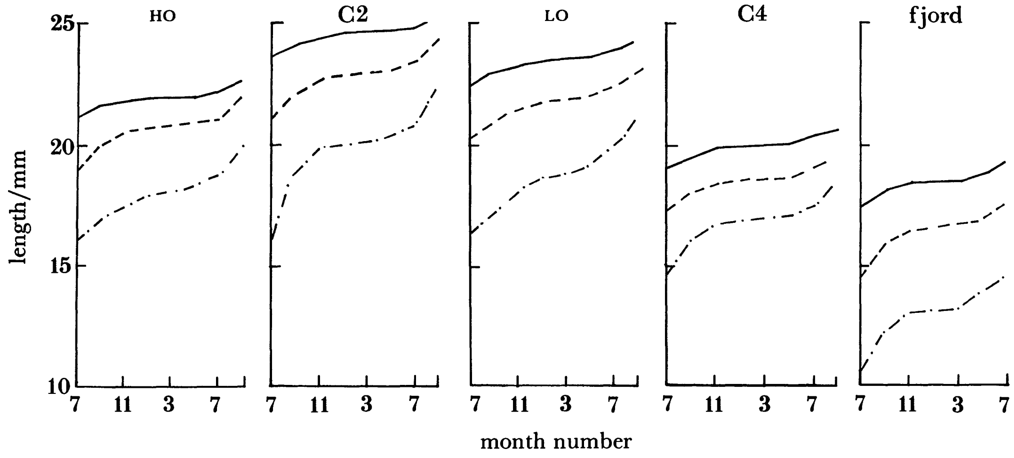

FIGURE 5. Growth rates of *Littorina littorea* exposed to oil (WAF), data from E. Lystad & K. Moe, unpublished results. HO = $127\ \mu g\ l^{-1}$, LO = $27.9\ \mu g\ l^{-1}$. C2 and C4, basin controls; fjord, fjord control. Solid line, year class 3; broken line, year class 2; broken and dotted line, year class 1.

TABLE 1. SURVIVAL AND MORTALITY RANGE OF *LITTORINA LITTOREA* (SEP. 1982, SEP. 1983)

(HO, $127\ \mu g\ l^{-1}$, LO, $27.9\ \mu g\ l^{-1}$; C2 and C4, controls (data from E. Lystad & K. Moe, unpublished results))

	HO	LO	C2	C4
relative survival (S)	0.51	0.66	0.65	0.68
absolute mortality (M)	0.67	0.42	0.43	0.39

TABLE 2. GROWTH RATE OF *LITTORINA LITTOREA* (JULY 1982 TO JULY 1983)

(K values from the Von Bertalanffy equation. HO, $127\ \mu g\ l^{-1}$, LO, $27.9\ \mu g\ l^{-1}$; C2 and C4, controls; fjord, fjord control)

	HO	LO	C2	C4	fjord
K	0.62	0.75	0.53	0.62	0.34

here also showed similar trends. There is no evidence therefore that oil leads to stabilizing selection on *L. littorea*.

M. edulis populations placed in nylon mesh tubes in the basins showed markedly different mortalities among basins. Figure 7 shows that at the high-oil dose 95 % of the 10–15 mm size fraction transplanted were dead after 5 months compared with 50 % in the control basin and 30 % in the fjord control. Mortality rates were less at other size intervals but in HO reached over 95 % in a year. With such marked mortality rates one might expect that survivors would show differences in genetic composition to the initial population.

Electrophoretic analyses on enzyme polymorphisms showed that *M. edulis* had an average heterozygosity of 11.5 ± 3.7 % for 30 loci studied (Fevolden & Garner 1986). Fevolden and Garner's analyses showed no significant deviation from Hardy–Weinberg expectation indicating that Oslofjord is inhabited by one single randomly mating stock. Six polymorphic loci were compared among basin populations and with the fjord control. A classification analysis of the polymorphic gene loci showed (figure 8) that between the basin and fjord populations

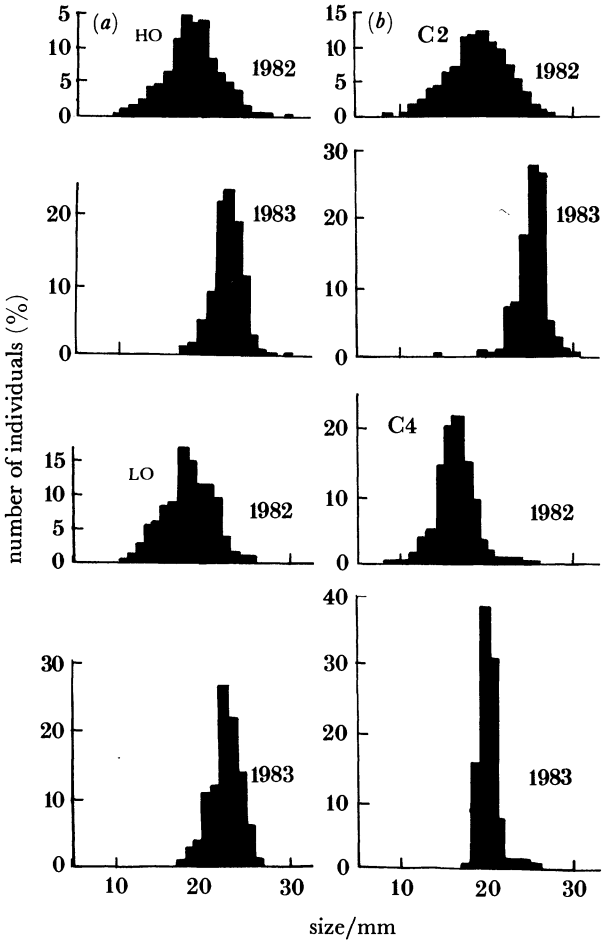

FIGURE 6. Size-frequency distribution of *L. littorea* exposed to oil (WAF) over 12 months, data from E. Lystad & K. Moe (unpublished results). (*a*) HO, 127 $\mu g\ l^{-1}$, LO, 27.9 $\mu g\ l^{-1}$. (*b*) C2, C4, control basins.

adults differed at the *LAP*-3 and *PGI* loci, whereas the new recruits differed at the *IDH*, *LAP*-2 and *PGM*/*C*-3 loci in one year, but not in the next year. One locus, *IDH*, showed differences between oiled and non-oiled recruits in 1983 but not in recruits in 1984. Thus year to year variations in allele frequencies are probably more important than effects of oil.

Genetic studies done on *L. littorea* (S. E. Fevolden, unpublished data) and *Semibalanus balanoides* (Fevolden & Sigurdsson, unpublished data) show similar results with little evidence that oil leads to dramatic short-term selection on the enzymes studied.

Extensive studies have also been done on the physiology, biochemistry and cell biology of *M. edulis* and *L. littorea* by scientists from IMER (see M. N. Moore *et al.*, this symposium, for a detailed discussion of results). The suspension-feeding rate of *M. edulis* was 67 % of the control in LO and only 34 % of the control in HO. Food-absorption efficiency was also less in exposed animals. Oxygen consumption did not, however, vary among exposed and control animals whereas ammonium excretion was greater in HO but the same as the controls in LO (Widdows & Donkin 1985). Lysosomal membrane stability was reduced in digestive cells of *M. edulis* and *L. littorea* at both HO and LO (Moore *et al.* 1984). NAPDH–neotetrazolium reductase, a cytochrome marker for NAPDH–cytochrome P-450 reductase, a component of the microsomal

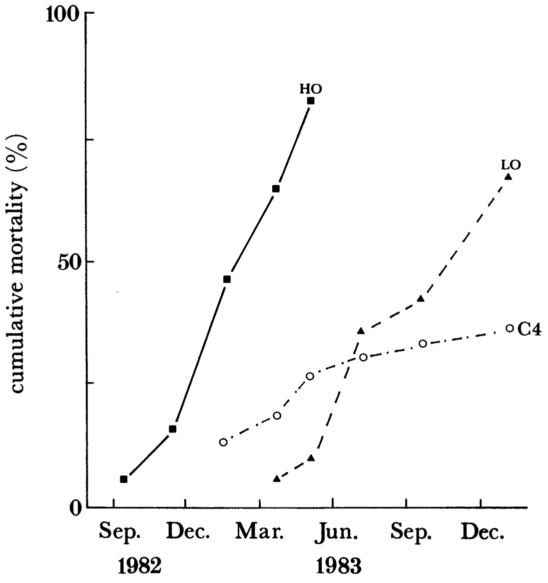

FIGURE 7. Mortality of *Mytilus edulis* transplanted into basins, following exposure to oil over 12 months, data from Walday & Thome (unpublished data). HO, 127 μg l^{-1}; LO, 27.9 μg l^{-1}; C4, control.

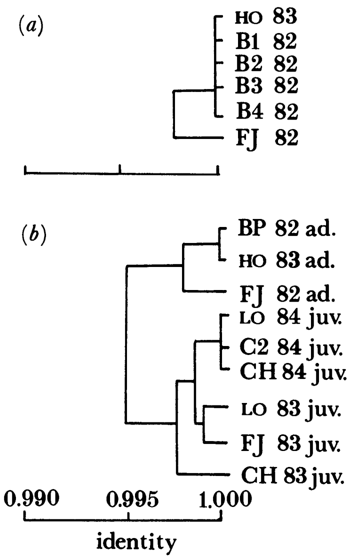

FIGURE 8. Classification analyses of population genetics data on *Mytilus edulis* using Nei's unbiased identity coefficients (Nei 1978). Data from Fevolden & Garner (1986). (*a*) Comparison of 20 gene loci in adult *M. edulis* from basins (B1–B4) and fjord (FJ) before oil exposure (82, 83, 1982, 1983). (*b*) Comparison of polymorphic gene loci after exposure to oil for 12 months. BP, pooled basin samples; HO, 127 μg l^{-1}; LO, 27.9 μg l^{-1}; C2 and C4, controls; FJ, fjord control; ad., adult; juv., juveniles.

detoxification–toxification system was elevated in *M. edulis* and *L. littorea* at both oil doses (Moore *et al.* 1984). Yet although the negative effects occurred rapidly, in one day, recovery was possible with lysosomal stability being restored in 3–4 d.

Effects on hard-bottom system

The results of the exposure of intertidal systems to chronic doses of oil over a period of 25 months showed that except for the high mortalities in populations of *M. edulis*, effects were not dramatic. The macroalgal community structure remained fairly constant with no change in *A. nodosum* or in *L. digitata*. *F. serratus* showed a slightly decreased population density in the higher-dosed basin. These findings are in keeping with known effects on algal communities. After the *Torrey Canyon* oil-spill there was no evidence of a severe and direct impact of oil on intertidal or subtidal algal communities (Chasse 1980). Similarly in Milford Haven, an area subject to continual small oil-spills, no changes that could be attributed to oil were observed in macroalgal communities over a 20 year period (Dicks & Hartley 1982).

Some algae, notably the *r*-selected opportunist species (*P. lenormandii*, *C. crispus*, *C. rupestris* and *U. lactuca*) in fact increased in abundance in the low-oil dose. This increase could not be related to a smaller population density of the herbivorous gastropod *L. littorea* as no comparable increase occurred in the control basins (Bokn & Moy 1985). Small amounts of oil probably directly enhance growth in these species although the mechanism of enhancement is unknown.

At the individual level there were marked effects of oil on growth rates of *A. nodosum* and *L. digitata*. Thus effects of chronic oil-pollution are likely to be found after many years of exposure and could lead to severe problems where commercial exploitation of these species occurs, as in the Norwegian alginate industry, where there is an annual harvest of 150 kt from a standing stock of 1.8 Mt (Bokn 1985).

At the high-oil dose there was increased mortality in *L. littorea* populations compared with the controls and the low-oil basin. However, in all basins the populations declined indicating that there is a direct effect of enclosing the system within the mesocosm. Lower recruitment was the primary cause of the decline but in addition to this effect the high-oil dose had a significantly lower level of recruitment. *L. littorea* showed large mortality after the *Torrey Canyon* oil-spill where an estimated 54% of the population was killed (Chasse 1980). However, no measurable changes in populations occurred in Milford Haven with irregular oil-spills over a 20-year period, suggesting that recruitment was not reduced. In the oiled basins *M. edulis* did not secrete byssus threads and fell to the floor where they were eaten by *Carcinus maenas*. The lack of byssus secretion was oil-induced and mortality was not just an effect of predation as caged animals not exposed to crab predation also suffered high mortalities (IMER, personal communication). This high *M. edulis* mortality was induced at a dose of only 27.9 μg l^{-1}. This response has been noted previously by Linden (1977), who found reduced secretion of byssus at oil concentrations of 130 μg hydrocarbons l^{-1} equivalent to the highest dose used in our experiments.

M. edulis is a major component of the fouling community of North Sea oil rigs and platforms and greatly increases stress on metal structures by giving greater surface area for wave impingement. Perhaps a solution to this problem is to discharge small amounts of oil continuously at concentrations up to 130 μg l^{-1} (that used here) so that byssus secretion is inhibited and high mortality occurs.

With this high mortality it was surprising to us that there was no evidence of short-term genetic selection. Correlations between balancing selection and allozyme or genotype frequencies in *M. edulis* have been demonstrated in response to salinity (Koehn *et al.* 1976, 1980*a*, *b*; Thiesen 1978; Gartner-Kepkay *et al.* 1983), to temperature (Koehn *et al.* 1976, 1980*a*; Levinton & Suchanek 1978) and degree of exposure (Gosling & Wilkins 1981). Battaglia *et al.* (1980) found that the Mediterranean mussel, *Mytilus galloprovincialis*, had higher frequencies of the alleles for 6-phosphoglucosedehydrogenase and *PGI* along a pollution gradient in the lagoon of Venice. This was not the case with the Oslofjord data for *M. edulis*, *L. littorea* or *S. balanoides*. It is possible, as Nei (1983) suggested, that there was not sufficient genetic variability on which selection could operate, or alternatively it may be that although a wide range of enzymes (30) were tested, others not tested were selected.

The physiological and biochemical data show that sublethal effects do occur in both *M. edulis* and *L. littorea* but that these effects are reversible on return to clean seawater.

THE SOFT SEDIMENT MESOCOSM

The advantages of a subtidal soft-sediment mesocosm are probably greater than those of an intertidal, in that experiments cannot be done in a controlled manner in the subtidal even by diving and by the use of submersibles. Only the MERL system (Pilson *et al.* 1977) includes subtidal sediment but at MERL the design is for an integrated water-column sediment system and sampling of the benthos is done blindly through a 5.5 m high water-column. The Solbergstrand system is designed to establish benthic communities at medium scales (i.e. 0.25 m^2 boxes) where the surface of the sediment can be sampled at fine scales without disturbing adjacent areas.

The mesocosm consists of two indoor concrete basins each coated with epoxy resin (4.9×21.5 m and $4.6–5.0 \times 21.5$ m). Each basin is further divided into three sections by removable vertical walls. Across each basin runs a moveable bridge to facilitate loading of sediment boxes in the basins. Seawater from 42 m depth in the fjord flows into each section by a horizontal pipe with 2.5 mm holes placed 5 cm apart, 60 cm above the tank bottom. Water flows in a laminar fashion across the basin to a horizontal outflow pipe with 4.5 mm diameter holes, 5 cm apart. The outflow pipe has adjustable height and water depth can be varied from 0 to 1.7 m. Water flow across the basins is approximately 1 cm s^{-1}. Over the first two years of operation the salinity was never below 30‰ and the temperature varied from 5 to 11 °C. Light can be varied from 0 to 0.2 μE m^{-2} s^{-1}† and follows a natural light–dark cycle.

Initially experiments were designed to clarify the amount of food material that needed to be added to keep the benthic community alive and functioning approximately normally. Powdered *Ascophyllum nodosum* was added at two levels equivalent to 50 and 200 g C m^{-2} with untreated boxes left as controls. Sediment was obtained by sampling with a 0.25 m^2 box-corer (a modified USNEL spade-corer built by Adolf Wuttke, Hamburg). The sediment was placed in plastic boxes (0.54 m^2 surface area, depth 20 cm) with the result that much disturbance of the surface occurred.

In the second experiment a removable liner was placed within the box-corer which enclosed the sample. On retrieving the sampler the liner was placed on a bottom plate for transport and placement within the basins. Samples obtained with the liner usually contained a 30 cm depth of undisturbed sediment and a supernatant water layer of 10 cm. In this experiment natural plankton was added in suspended form to the sediment four times over a six-week period giving total doses of 5 g C m^{-2} and 20 g C m^{-2}. Three boxes were used for each treatment and three remained as controls.

Samples were taken for analysis of sediment and water chemistry, bacteria, meio- and macrofauna.

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† 1 Einstein = 1 mol photons; 1 μE = 6×10^{17} photons.

Results

With the addition of *A. nodosum* powder there was little difference between the experiment and the field in relation to profiles of water content, carbon and nitrogen (figure 9). The change at 4–6 cm depth can undoubtedly be related to disturbance of the sediment on filling the boxes. The high dose of *A. nodosum* led to a marked decrease in *Eh* and pH (down to 2.0) compared with the field. In the natural phytoplankton addition, pH remained between 7.2 and 7.4. Oxygen consumption measured by bell-jar experiments was 214, 262 and 438 μmol m^{-2} h^{-1} in the control, 5 g C m^{-2}, and 20 g C m^{-2} respectively (M. Schaaning, unpublished data).

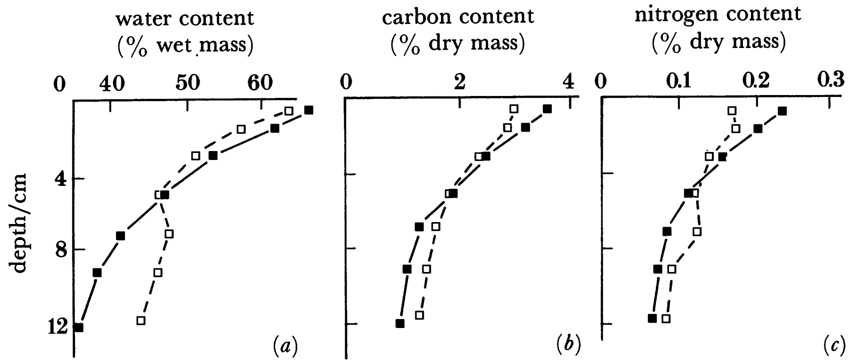

FIGURE 9. Profiles of (*a*) water content, (*b*) carbon and nitrogen content of sediment in mesocosm (broken line) one year after transplantation without using a core liner, compared with the field (solid line), data from M. Schaanning (unpublished results).

Bacterial production as measured by [^{3}H]thymidine incorporation into bacterial DNA showed no significant difference between field and mesocosm over a six-month period (G. M. Skeie, personal communication).

Four box-core samples were taken at 30 m depth in Bjornhodebukta, Oslofjord in December 1984. Two were immediately sieved through a 1 mm sieve and the remaining two sieved after six months in the mesocosm. Table 3 shows that 50 % of the total number of species found occurred in both field and mesocosm. The 31 % found only in the field represented only 2 % of the number of individuals. The 10 % found only in the mesocosm represented only 1 % of the number of individuals. Figure 10 shows the relation between densities in field and mesocosm. The dominant species show similar abundances in both, whereas motile species such as the amphipods, *Ophiura affinis* and two sedentary spionid polychaetes were less abundant in the mesocosm. Surface and subsurface deposit feeders have almost identical abundances in field and mesocosm whereas filter feeders and carnivores had only 50 % of the field abundance in mesocosm (Berge *et al.* 1986).

TABLE 3. COMPARISON OF MESOCOSM, SEVEN MONTHS AFTER ESTABLISHMENT, WITH FIELD DATA

(Data from two replicate 0.25 m^2 box-core samples.)

	species	individuals
in mesocosm and field	41 (50 %)	2752 (97 %)
in mesocosm only	10 (12 %)	29 (1 %)
in field only	31 (38 %)	59 (2 %)
total	82	2840

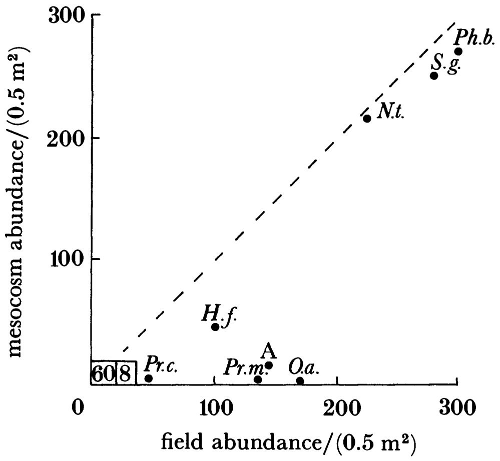

Figure 10. Comparison of faunal abundances in field and mesocosm. The numbers within boxes indicate the number of species found at corresponding densities. The dotted line shows perfect similarity. Abbreviations: *Ph.b.*, *Philomedes brenda*; *S.g.*, *Sosane gracilis*; *N.t.*, *Nuculoma tenuis*; *H.f.*, *Heteromastus filiformis*; *Pr.m.*, *Prionospio malmgreni*; *Pr.c.*, *Prionospio cirrifera*; *O.a.*, *Ophiura affinis*; A, Amphipoda.

Over 19 months in the mesocosm 30 species recruited compared with 66 in a similar box placed in the field, whereas only 77 individuals recruited to the mesocosm compared with 891 individuals in the field.

In addition to the above, studies of local-scale bioturbation on meiofauna by the large-sized but rare polychaete *Streblosoma bairdii* have been done (Warwick *et al.* 1986). These studies showed that the tentacle feeding area of the deposit feeder had a reduced population density and a higher diversity of meiofauna compared with the unaffected sediment. The nematodes in the unaffected sediment were primarily diatom feeders whereas bacterial feeding nematodes were confined to feeding mounds. Time-lapse studies of *S. bairdii* feeding patterns have been done and a paper is in preparation (Rumohr *et al.* 1987).

We conclude from these results that the observations on sediment chemistry in the sediment transported to the mesocosm are within the range of variation found in the natural environment. Although recruitment of macrofauna is reduced, the benthic community in terms of the dominant species and community structure closely follows that of the natural environment. The huge advantage of the mesocosm is the ease of sampling and manipulation of the communities in an almost undisturbed state. The important role that bioturbation plays in the flux of nutrients and pollutant materials to and from the sediment can be studied in detail. The system is now being used to simulate and experiment on communities taken from 200 m depth, giving us the possibility of assessing effects of pollution over analogue communities to the whole continental shelf. For the first time effects can be studied directly and not be subject to the inefficiency of remote and blind sampling with subsequent *a posteriori* data interpretation.

CONCLUSIONS

Use of enclosed meso-scale systems for the study of effects of pollutants allows examination of effects of controlled doses of pollutants over long-time periods in a manner not possible in the natural environment. Care must be taken, however, to ensure that the effects of enclosing the system are carefully documented. Although recruitment of macroalgae was not affected in the Solbergstrand hard-bottom mesocosm, molluscs were affected. Moreover, the basins were not identical in faunal and floral composition at the outset of the experiments with the result that controls were different and results hard to interpret. Nevertheless, clear long-term effects occurred as a result of oil pollution, notably on algal growth, recruitment of *L. littorea* and byssus secretion of *M. edulis*, all of which factors in the natural environment would lead to severe consequences for the communities concerned.

In the soft-sediment mesocosm, after reliable methods for establishing the community were established, it was possible to hold alive for periods of six months communities simulating the continental shelf. Thus unique opportunities are now available for assessing effects of pollutants on important processes such as fluxes of material into and out of the sediment, the effects of bioturbation on sediment processes and the role of key organisms in controlling community structure and processes.

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