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Inhibition of Barnacle Settlement by Ekofisk Crude Oil

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ABSTRACT: Inhibition of settlement of the larvae of the barnacle *Balanus balanoides* was observed to result from experimental applications of weathered Ekofisk crude oil to bare rock surfaces in the intertidal zone of a Norwegian fjord. The degree of inhibition appeared to be related to the oil concentration applied. *B. balanoides* settlement on heavily oiled surfaces was initially less than 1 % of that on unoiled squares; squares initially receiving 1/3 this amount of oil showed only a 50 % reduction in barnacle settlement.

INTRODUCTION

Steady expansion of oil exploration and oil production activities into northern latitudes has resulted in increasing attention to the ecological impact of oil spills and the recovery of oil-fouled northern marine ecosystems (Vandermeulen, 1978; Kineman et al., 1980). Following an oil spill, a key factor in the recovery of oil-fouled rocky intertidal communities in northern latitudes will be larval settlement by the intertidal invertebrate species composing such communities. In one of the few published field experiments with oil in rocky intertidal systems, Crapp (1971) has shown some indication that spatfall of the barnacle *Balanus balanoides* may be decreased by oil dispersant runoff, but is largely unaffected by crude oil alone. This paper presents data showing that the presence of crude oil can prevent, almost totally, the once-yearly settlement of the larvae of *B. balanoides*.

MATERIALS AND METHODS

Larval recolonization experiments were carried out in the rocky intertidal zone of a moderately exposed location near the Institute of Marine Biology of the University of Bergen, Bergen, Norway. Fifteen patches, each 0.01 m^2 in area, were scraped to bare rock. Five of the squares served as unoiled controls, 5 were oiled by spraying with 20 ml of Ekofisk crude oil per square (a concentration equal to 2 l m^{-2}), and 5 were oiled on 3 consecutive days with 6.6 ml Ekofisk crude oil per square. A second experiment started with two intact squares, each 0.04 m^2 in area. One of these was sprayed with 80 ml Ekofisk crude (2 l m^{-2}), then both the oiled and the remaining unoiled square were scraped to bare rock after 1 h. The oil used in both experiments was weathered before use; it was subjected to mechanical mixing with seawater for 3 d, allowed to separate, and recovered through a separatory funnel. Larval settlement was monitored photographically. Counts were obtained of *Balanus balanoides* settling in 3 randomly located 9 cm^2 quadrats per settlement square in the first experiment, and in 12 such quadrats per settlement square in the second experiment. Results were compared using one-way analysis of variance.

RESULTS

Significant differences in *Balanus balanoides* settlement were clearly seen after 24 h (Fig. 1), and these differences persisted through the period of larval settlement. *B. balanoides* settlement on the heavily oiled squares initially was less than 1 % of that on unoiled squares, whereas squares initially receiving one-third this amount of oil showed only a 50 % reduction in barnacle settlement. After 3 d, the total amount of oil applied to both sets of oiled squares was the same, yet the squares that had received multiple moderate doses

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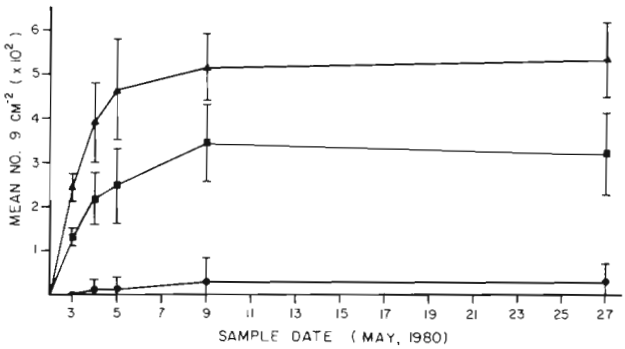

Fig. 1. *Balanus balanoides*. Mean density (± 1 standard deviation) of larvae settling on bare rock surfaces. ▲ = control (no oil); ■ = oiled on each of 3 consecutive days with 6.3 ml day^{-1} square^{-1}; ● = oiled once with 20 ml square^{-1}. All differences between treatments on any sample date are significantly different ($p \ll 0.001$)

of oil showed 250 % greater settlement of barnacles than those squares receiving a single heavy dose. Table 1 indicates that even when oil was applied to the extant community and these animals were removed, sufficient oil remained to significantly inhibit *B. balanoides* settlement (number settling per 9 cm^2: unoiled, 184.8 ± 31; oiled, 111.6 ± 34.2). The degree of reduction in this instance resembled that of the multiple oiling treatment in the first experiment. Both experiments suggest that inhibition of barnacle settlement by crude oil may be directly concentration-dependent.

Table 1. *Balanus balanoides*. Analysis of variance comparing density of settling larvae on oiled and unoiled squares, scraped to bare rock after oiling

Source of variation	df	Sum of squares	Mean square	F value	$F_{0.05}$
Treatments	1	32,120	32,120.2	30.0	4.3
Quadrats	22	23,523	1,069.2		
Total	23	55,643			

DISCUSSION

The results of these experiments relate to the potential impact of oil spills on rocky intertidal communities in northern latitudes. *Balanus balanoides* is a primary component of upper intertidal communities on the Norwegian coast (Brattegard, 1966) and in many other northern areas (e.g. Lewis, 1964). *B. balanoides* reproduces only once annually (Nilsson-Cantell, 1978), mass occurrence of cyprid larvae being noted for only 1–2 weeks (Blom and Nyholm, 1961). The majority of settlement may take place over a period of 5 d (Blom and Nyholm, 1961). As shown by the present experiments, an oil spill during this critical period resulting in concentrations reaching the shore of approximately 2 l m^{-2} (e.g. roughly equivalent to the Dounreay oil spill; Bowman, 1978) could result in an almost total lack of settlement by barnacles in the intertidal zone for that year in the affected area. Such a potentially major effect on larval settlement is in sharp contrast to results of work in progress indicating that similar concentrations of Ekofisk crude oil have little or no effect on survival of adult *B. balanoides* under field conditions. Myers et al. (1980) have recently observed mortality of juvenile *B. balanoides* due to spilled Saudi Arabian crude oil, although they observed similar settlement at oiled and unoiled sites. Whether this apparent lack of inhibition of settlement was due to the difference in oil type or to an insufficient concentration on the shore remains an open question.

Total or partial reduction in *Balanus balanoides* settlement and recruitment might result in significant shifts in the species composition of the community. Indications are that the effects of crude oil on recruitment of rocky intertidal invertebrate species persist for relatively short periods (Crapp, 1971; Straughan, 1971; Chan, 1975; Nelson, unpubl.). The possibility therefore exists that other species reproducing later, and usually being prevented from recruiting by the presence of barnacles, might be more successful during settlement and recruitment. In the intertidal community studied, settlement of several other important species (*Mytilus edulis* and fucoid algae) on barnacles also appeared to be much greater than on bare rock (K. Erstad, IMB, Bergen, pers. comm.). As a result, a failure of barnacle settlement could lead to major modifications of community composition by either pathway, and these changes could persist. Changes in rocky intertidal community structure generated by oil-related perturbations have been shown to persist for as long as 10 y (Southward and Southward, 1978) in England. In colder waters, with shorter seasons of growth and reproduction, conceivably they might persist even longer.

The critical nature of the timing and concentration of oil necessary to produce significant inhibition of larval settlement by *Balanus balanoides* is probably why such inhibition has not been previously reported. It is clear that further controlled field experiments are necessary to identify other potentially important but non-obvious consequences of oil pollution in marine ecosystems.

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