THE IMPACT OF CRUDE OIL AND OIL DISPERSANTS ON THE MARINE OLIGOCHAETE *MARIONINA SUBTERRANEA*

by

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Résumé

Action du pétrole brut et des dispersants sur l'Oligochète marin *Marionina sublerranea.*

La survie de l'Oligochète interstitiel ubiquiste *Marionina subterranea* (Knöller) (Enchytraeidae) au cours d'expériences courtes, à l'action du pétrole brut de l' « Arabian Light » a correspondu à la haute résistance de cette espèce dans le milieu naturel : des concentrations de 1 **000** ppm sont nécessaires pour produire un faible effet négatif. Tandis que des solutions de l'ancien dispersant Marlophen 86.5 F sont très toxiques même à de faibles concentrations, leur toxicité est en partie limitée dans le pétrole brut. Avec les agents modernes (Corexit 76G4, Finasol **OSR-2** et **OSR-5), la** mortalité était généralement très **faible,** mais augmentait dans des mélanges contenant **du** pétrole **brut.** Les combinaisons de plusieurs dispersants semblent produire une sommation des effets toxiques. Sur **la** base de ces résultats, l'effet des marées noires sur les conditions de vie de **la** méiofaune sont considérés.

Introduction

The rich literature dealing with effects of crude oil and dispersants on macrofauna is in striking contrast to the almost complete lack of results on littoral meiofauna, although the tidal shores are usually most severely affected by oil spills. The few case studies focussing on meiobenthic species (Rützler and Sterrer, 1970; Wormald, 1976) have not been supplemented by experimental work. The field studies after the large spill of the "Urquiola" in Spain 1976 (Giere, 1979) showed that among the various meiofauna groups oligochaetes and especially *Marionina subterranea* survived fairly well. Therefore, laboratory experiments should differentiate the response of this species to the same type of oil and to dispersants used in that spill.

Material and Methods

In order to assess data on acute (primary) toxicity, each time 20 adult and fully active worms were transferred into tightly capped finger bowls and exposed to the following agents:

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1) ”Arabian Light” crude oil, in different concentrations.
2) ”Marlophen 86.5 F”, a main component of various ”old-type” dispersants some of which were used also after the ”Urquiola”—spill (Gundlach and Hayes, 1977).
3) ”Corexit 7664” (Esso), ”Finasol OSR-2” and «Finasol OSR-5» (Fina), widely used modern dispersants.
4) Combinations of Corexit 7664 and Finasol OSR-5.
5) Mixtures of the above dispersants with ”Arabian Light”.

The animals were considered dead and removed when they did not react to light or tactile stimuli. Experiments were discontinued after 14 days in order to exclude possible secondary effects (e.g. lack of bacterial food; noxious metabolic wastes). Results submitted here base on average data of 2-5 replicates and are expressed as lethal time for 50 percent of the initial animal number (LT 50) or as percent survival.

After initial experiments with various components of oil/water mixtures (surface oil film, aqueous phase underneath the oil film), in later tests 5ml-samples pipetted from fresh dispersions in natural filtered and pre-aerated sea water (18 ‰ S) were used (intensive stirring for 1 h, depth of vortex about 3/4 of water column in the jar).

Although in these ”static tests” the initially homogeneous dispersions will soon change their chemical composition and form gradients of different concentrations (Anderson *et al.*, 1974; Wilson, 1977), it has to be realized that physical and chemical alteration and segregation processes occur also in the natural beach sediments.

RESULTS

The high toxicity of the unstirred superficial oil layer in test A (Table 1), pipetted from the surface after 5 min standing, is in sharp contrast to its almost 10-times reduced noxious effect in B, where just one hour of stirring sufficed to change its chemical composition substantially (see below and Fig. 1). However, test C demonstrates how massively this relatively favourable result can be reversed by a dispersant of the old phenole-glycolether-type : even if added in minimal concentration (1ppm), the oily surface was now highly toxic (LT=28h) despite the same stirring procedure as in B. In contrast to these results with films pipetted from the water surface, life conditions in the water column underneath the oily surface are far less adverse regardless whether or not the solution was stirred or treated with dispersants.

The considerable discrepancies in survival emerging from table 1 correspond well to chemical differences of the various test solutions, as displayed by infra-red spectrograms (Fig. 1): Already after 1 h of stirring (B), the originally fresh oil (A) had lost a marked amount

TABLE 1

LT 50-values of *Marionina subterranea* in mixtures of seawater (18 ‰ S) with 1000 ppm "Arabian Light" crude oil.

	tests with	
	surface film	**aqueous phase underneath surface**
A no stirring; 5' standing	25^{h}	$>14^{d}$
B 1' stirring; 5' standing	9^{h}	$>14^{d}$
C 1 ppm Marlophen 86.5 F added; 1^{h} stirring; 5' standing	28^{h}	$>14^{d}$
D control: untreated seawater	>14	

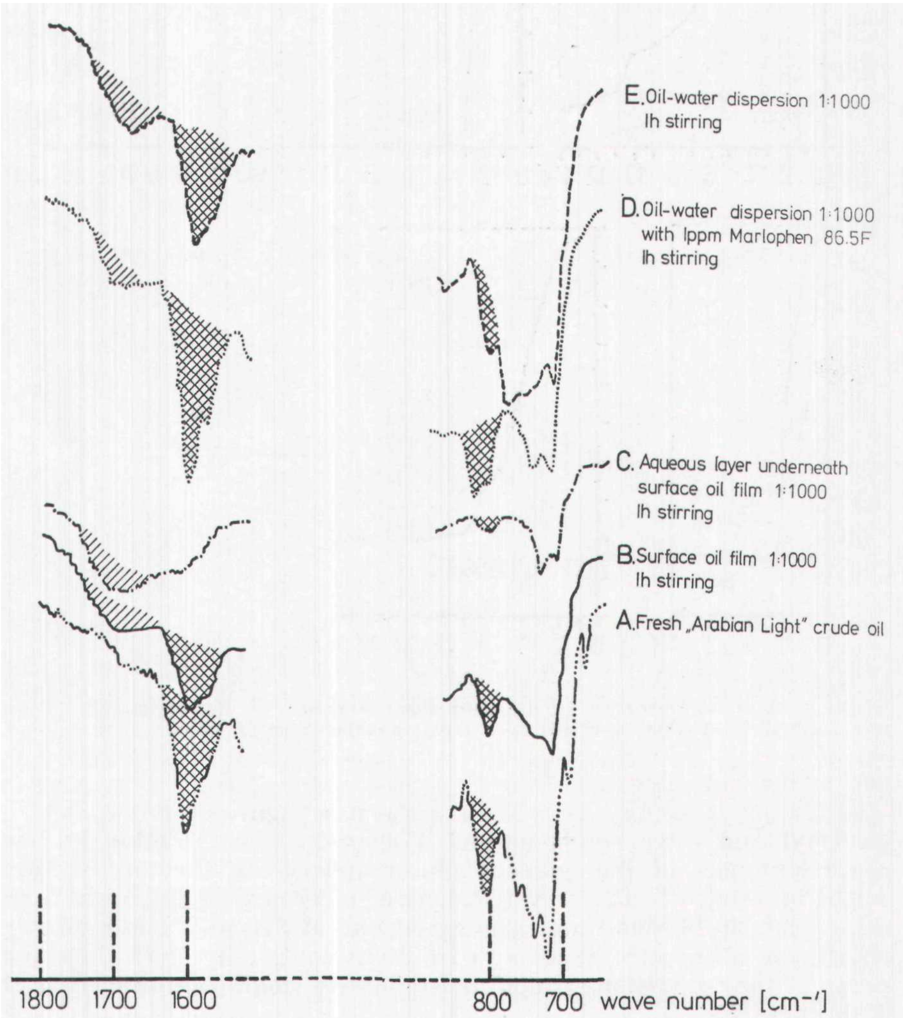

FIG. 1

Relevant sections of infra-red spectrograms from the various test media compile;! in table 1.

of the highly toxic aromatics by evaporation (e.g. smaller peaks at wave numbers 810cm-[1] and 1600cm-[1]) and some unsatured components have been oxidized (hump around wave number 1700cm-[1]). This aging of oil (Anderson *et al.,* 1974) was evident also in curve E, monitored from a well-stirred oil-in-water dispersion (peak of the

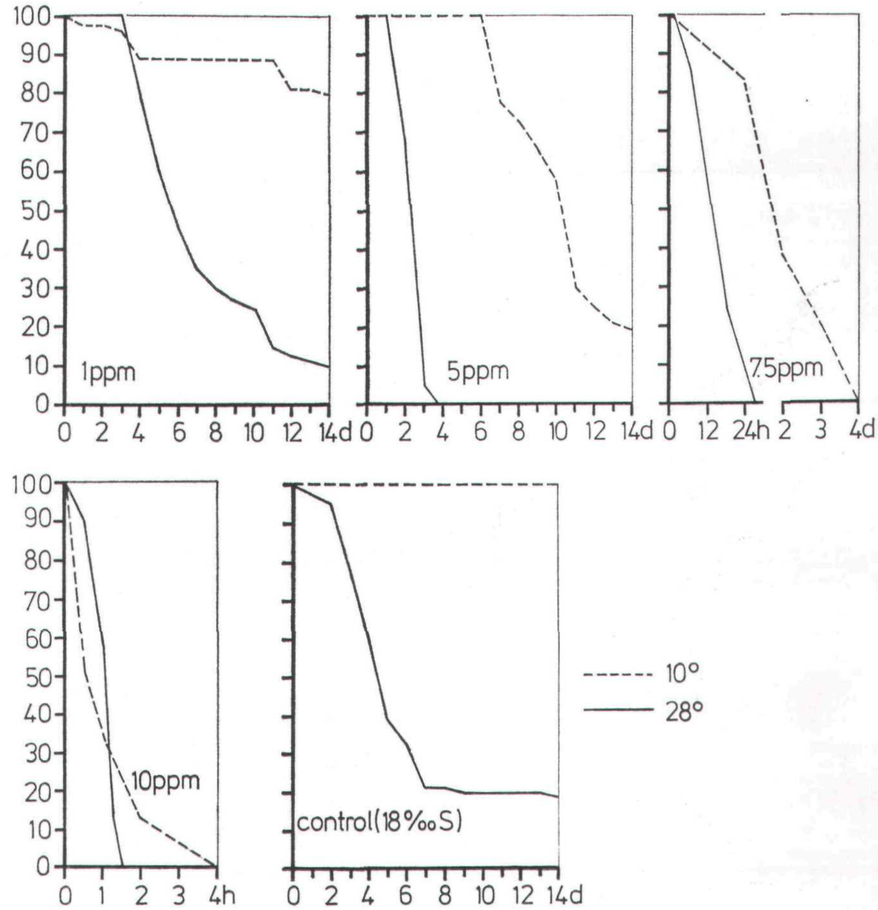

FIG. 2

Survival of *M. subterranea* in different concentrations of Marlophen 86.5 F at 10°C and 28°C—Y-axis: survival (per cent); x-axis: time in days.

carbonyl and ester bands around 1700cm-[1]). The strinkingly less adverse impact of the aqueous phase underneath the oily surface might be related to the very low content of aromatics (in curve C no clear peak at 1600cm-[1] and a minimal one at 810cm-[1]). Interstingly enough, in all spectrograms with solutions containing Merlophen, the peaks of the "oxidation groups" are relatively small (compare curve D with curve E).

The biological impact of Marlophen is compiled in figure 2. Even at favourably low temperatures (10°C) and concentrations

(5 ppm), Marlophen proved to be highly toxic to *M. subterranea*. If high temperatures (28 °C) act as an additional stressor, survival is even lower. This is particularly evident in concentrations below 10 ppm, whereas 10 ppm kill the worms at any temperature almost instantaneously. The lethal thresholds of Marlophen found here are in the same order as reported for other old-type agents from tests with various marine invertebrates (Kühl and Mann, 1967; Portmann and Connor, 1968; Sprague and Carson, 1970). Only concentrations of 1 ppm were found not to affect the animals demonstrably. Here,

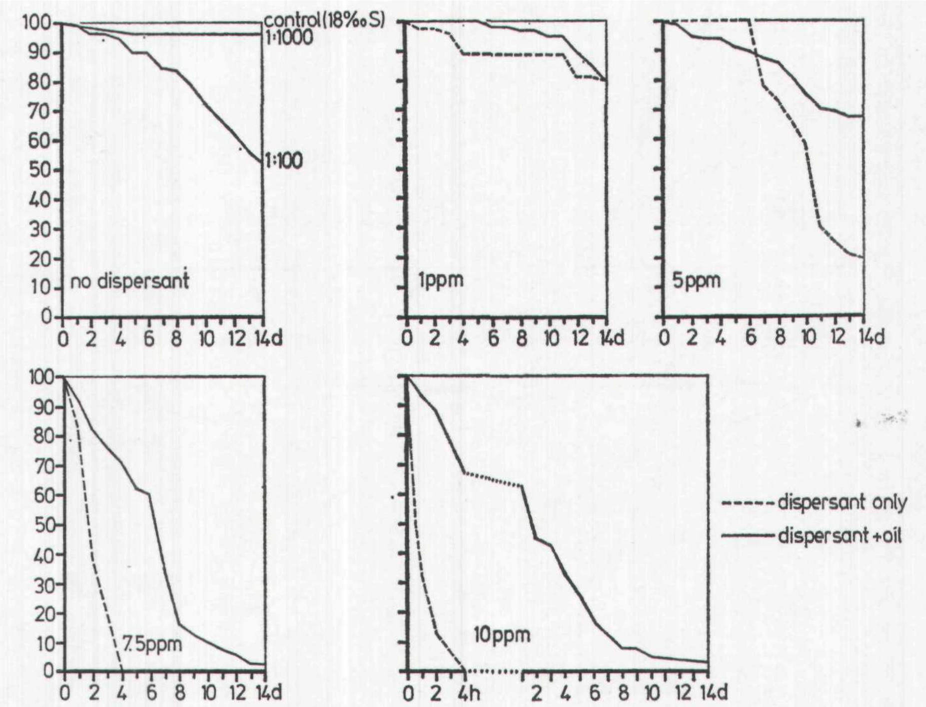

FIG. 3

Survival of *M. subterranea* in different concentrations of pure Marlophen 86.5 F and off combinations with oil 1:1000; 10°C). Scales as in Fig. 2.

oscillations of natural ecofactors like high temperatures might restrict viability more heavily than the chemical impact.

If used in combination with crude oil (Fig. 3), the harmful effect of Marlophen is clearly attenuated. This somewhat surprising result which was most evident in concentrations above 5 ppm, indicates the toxic effect being caused specifically by the dispersant and modified by the added oil. Moreover, figure 3 exhibits the high tolerance of *M. subterranea* to untreated crude oil: concentrations of 1:1000, commonly used in oil experiments and considered by Lindén (1976) as "medium" to "heavy" pollution, do not seem to affect the worms markedly.

The **progress** in developing less toxic dispersants is apparent in the tests with the three anionic agents Corexit 7664, Finasol OSR-2 and

OSR-5 (Fig. 4): even concentrations 100-times higher than those of Marlophen affected the test animals relatively little. Corexit 7664, recommended by Esso specifically for beach clean-up, acted in high

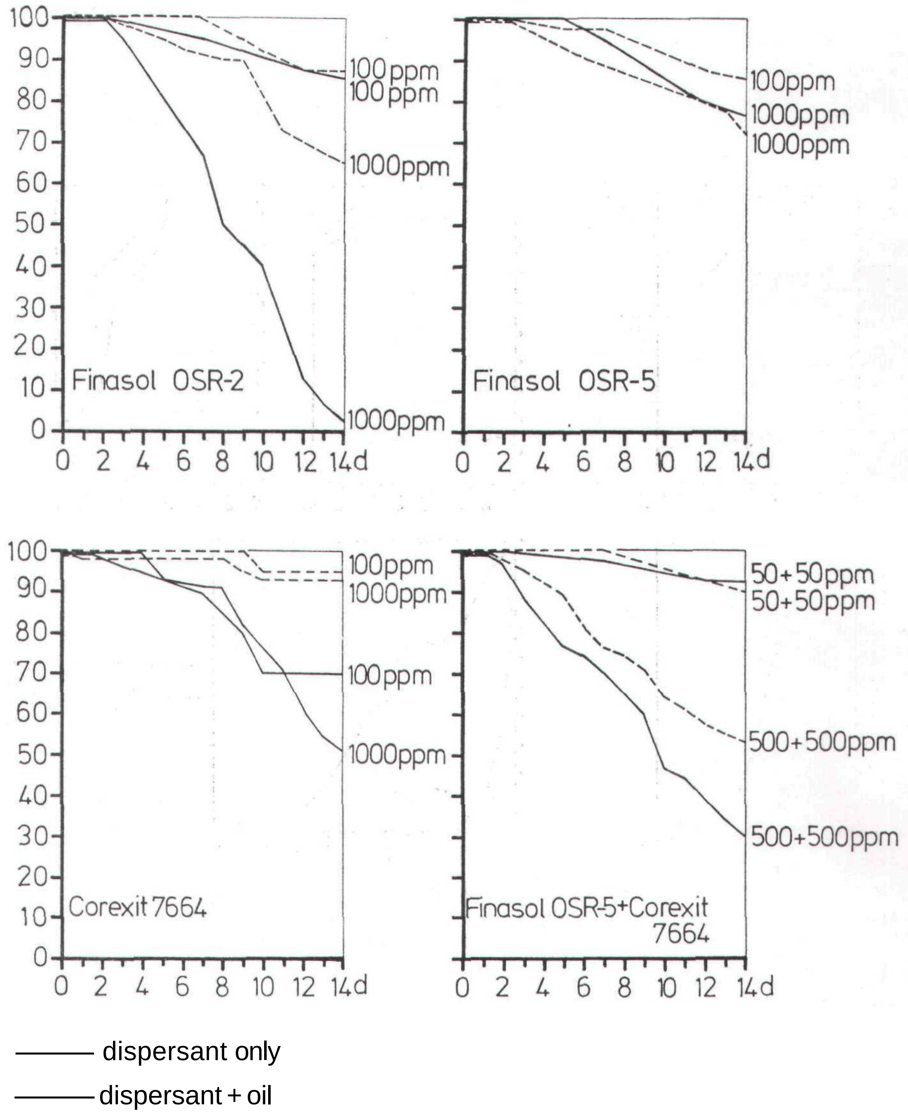

FIG. 4

Survival of *M. subterranea* in different modern dispersants and in mixtures of dispersant + oil (oil concentration always. 1:1000; 10°C). Scales as in Fig. 2.

concentrations which easily occur in superficial sand layers after spraying (1000 ppm) clearly less harmful than the two Finasols.

These modern dispersants in combination with oil (in the recommended 1:10-relation of detergent: oil) cause, at least in higher concentrations, an additive deleterious effect compared to that of the resp. detergent (Fig. 4) and the pure oil (Fig. 3) per se: The toxicity of 100 ppm pure Finasol OSR-2 (Fig. 4; 12 percent mortality) and of a 1:1000 crude oil/water mixture (Fig. 3; 4 percent mortality) was increased to 15 percent mortality in the resp. combination.

Despite the modern chemical formulation of Corexit 7664 and Finasol OSR-5, combinations of these dispersants seem to cause a synergistic noxious effect, illustrated in the last graph of figure 4. Both in pure solutions and in mixtures with oil, 1000 ppm concentrations of the combined detergents in equal parts caused a markedly higher mortality than 1000 ppm of one single dispersant. This result is relevant since, in the case of an oil spill, it was common to use several products at hand for clean-up ("Torrey Canyon", "Urquiola").

DISCUSSION

Although the restricted validity of oil pollution tests with just one species and one sort of crude oil is recognized, *M. subterranea*, world-wide abundant in the "hygropsammal" beach zone and typically adapted to life in the interstitial system, might serve as a good example for meiobenthic littoral fauna.

The specificy of littoral interstitial habitats renders comparisons with results from other biotopes problematical. The tests, performed here, show that oil films covering the beaches threaten meiobenthic life far more than corresponding oil-in-water dispersions would suggest. Test A in table 1 would roughly answer a situation where oil had reached the shore shortly after a leakage and the fresh oil film would be deposited at the high-water line, the zone of highest meiofauna abundance, leaving black sediments and, in medium to coarse sand beaches, contaminating the fauna down to considerable depths (Blumer, Ehrhardt and Jones, 1973; Giere, 1978; Wormald, 1976). The direct contact to oil rapidly exterminates even relatively hardy species (Branch, 1973; Brown, Baissac and Leon, 1974).

Life conditions improve substantially, as displayed in test B, if the drifting oil had weathered for some time before it contaminated the fauna, loosing much of its original toxicity (Anderson *et aï.*, 1974; Hellmann and Müller, 1975).

The generally reported decreased toxicity of modern dispersants (Swedmark, Granmo and Kollberg, 1973; Wilson, 1977) corresponds well with the results on *M. subterranea* (Fig. 4). Records on toxic levels of dispersants in combination with oil are far less uniform (Wilson, 1977): dispersions of oil with Marlophen exerted a similarly reduced mortality of test animals (Fig. 3) as reported by Portmann and Connor (1968) for the old-type agents Gamlen and BP 1002. The dispersing effect of modern detergents seems to be far more biologically neutral (Connor, 1972; Dalla Venezia and Fossato, 1977; Sprague and Carson, 1970; Swedmark, Granmo and Kollberg, 1973; Wilson, 1977), thus, mortality of *M. subterranea* in oil/dispersant mixtures was usually only slightly higher than that of the oil per se (Fig. 4).

Judging from literature (Carr and Reish, 1977; Fauchald, 1971; George, 1971; Kasymow and Aliev, 1973; König, 1968; Nelson-Smith, 1972; Rossi, Anderson and Ward, 1976; Wharfe, 1975), there are among littoral annelids many species which tolerate oil pollution fairly well. For meiobenthic annelids, this conclusion is based not only on the experimental results on *M. subterranea* reported here, but is also supported by additional field research on this and other oligochaete species after the "Urquiola"-spill (Giere, 1978).

Considering this relatively low susceptibility for crude oil and modern dispersants and realizing, on the other hand, the immense dilution of oil in the sea (Canevari and Lindblom, 1976), one could doubt the realistic value of many high-concentration tests. But, in littoral beaches, extremely high concentrations of oil are not unrealistic (Bleakley and Boaden, 1974; Renzoni, 1973). If treated with dispersants, as still recommended by leading companies, a deleterious effect would result even to relatively insensitive species.

Moreover, flats and beaches are exposed to additional stress factors like extreme abiotic fluctuations (e,g. temperature, see Fig. 2) or high concentrations of other pollutants which would aggravate the negative impact of oil on littoral meiofauna.

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Summary

Survival of the ubiquitous marine interstitial oligochaete *Marionina subterranea* (Knollner) (Enchytraeidae) in short-term experiments with ”Arabian Light” crude oil was in correspondance with the fairly high resistance of the species in field studies: concentrations of 1 000 ppm crude had only little negative effect. Whereas pure solutions of the old-type dispersant Marlophen 86.5 F were highly toxic even in low concentrations, their toxicity was somewhat lowered in dispersions with crude oil. In modern agents (Corexit 7664, Finasol OSR-2 and OSR-5), mortality usually was very low, but increased in mixtures with oil. Combinations of several modern dispersants seem to cause synergistic noxious effects. Based on these results, effects of oil spills on life conditions of littoral meiofauna are considered.

Zusammenfassung

Der Einfluß von Rohôl und Öldispergatoren auf den marinen Oligochaeten *Marionina sublerranea*

Die Ùberlebensrate des ubiquitären interstitiellen Oligochaeten *Marionina subterranea* (Knöllner) (Enchytraeidae), die in Kurzzeitexperimenten mit «Arabian Light» Rohôl getestet wurde, entsprach der im Freiland gefundenen hohen Resistenz dieser Art gegenüber Ölverseuchung. So hatten Konzentrationen bis zu 1000 ppm Rohöl nur einen gering negativen Effekt. Dagegen waren Lösungen des (veralteten) Dispergators ”Marlophen 86,5 F” auch in niedriger Konzcntration hochgiftig, in Kombination mit Rohöl wurde die Toxizität allerdings leicht abgeschwiieht. Dispergatoren neuen Typs wie «Corexit 7664», «Finasol OSR-2»

und «OSR-5» verursachten in realistischen Konzentrationen kaum Mortalitat, in Dispersion mit Rohöl erhöhte sich jedoch ihre Schadwirkung. Kombinationen mehrerer moderner Dispergatoren wiesen —offenbar synergistisch— eine gesteigerte Toxizität auf. Auf der Grundlage dieser Resultate wurden die Auswirkungen von Ôlunglucken auf die Lebensbedingungen der littoralen Meiofauna erötert.

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