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Effects of sunken oil on the feeding of plaice on brown shrimps and other benthos

by

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Introduction

The current development of low-toxicity oil dispersant concentrates will increase ten-fold the spraying time of vessels at sea. Nevertheless, because of the difficulties of deploying sufficient spraying vessels at short notice in European waters, the movement of a very large oil spill may have to be halted by sinking it with sand.

Previous work at this laboratory (Blackman, 1972) had established that sunken crude oil was ingested by brown shrimps (Crangon crangon) and remained in the foregut until the next moult. It was also found that the presence of sunken oil could reduce the rate of feeding of shrimps on normal foods. This paper describes experiments to assess whether the presence of oil in the prey of demersal fish, or on the bottom of tanks in which these fish were held, would interfere with their predation of shrimps and other benthos.

Materials and Methods

Topped Kuwait Crude oil (200 degrees C residue) was sunk in plastic bins using an apparatus to simulate oil-sinking at sea, built by the Warren Spring Laboratory of the Department of Trade and Industry. The resulting layer of sand and sunken oil was removed to a separating funnel and washed by passing sea water upwards through it. The required quantities of washed oil were then spread on the floors of the experimental tanks or cages.

(a) Feeding on oiled substrates: Plaice (Pleuronectes platessa) of average length 15cm were trawled from the Crouch estuary, and healthy and undamaged animals were placed singly in 10 litre perspex tanks for 2-3 days and their faeces collected and examined under a binocular microscope. Faeces characteristically contained remains of either polychaete worms, small bivalve molluscs and hydrobiid snails, or small brown shrimps, crabs and amphipod crustacea. Fish producing faeces containing the former assemblage were placed on a substrate of mixed sieved sand and estuarine mud to a depth of 2.5-3cm; fish producing the latter assemblage were placed on a substrate of clean sieved sand to the same depth. The plastic tanks used had a capacity of 56 litres and a bottom area of $0.28m^2$, and were supplied with aeration and with sea water at 100-250ml/min. Sunken topped oil was added to these substrates to give a concentration of $60ml/m^2$ of tank floor. A selection of prey organisms removed from estuarine mud during sieving was added to the mud substrates and small brown shrimps were added to the sand substrates. Tank water temperatures ranged from 17 to 21 degrees C during the experiment (July-October 1973).

When isolated fish had ceased to produce faeces they were placed in the test tanks for 2 days to feed. They were then removed, examined and wiped carefully with damp tissue to remove any adhering substrate or oil. Only very light smearing with oil was ever noticed and this was easily removed due to the external mucus layer. Fish were then returned to oil-free 10 litre perspex tanks, receiving filtered sea water, for 2 days. The faeces were collected and examined for evidence of prey and ingested oil. This sequence was carried out twice, after which the fish were killed, dissected, and the gut contents and buccal cavity examined for oil.

Results

Examination of faeces showed that partially digested brown shrimps and numbers of the empty or partially digested hydrobiid snails contained oil droplets. Examination of prey from the oiled substrates showed that many shrimps had indeed ingested oil, but examination of over 70 hydrobiid snails, together with polychaetes and small bivalves, revealed no visible oil droplets. It appeared that oil found in the faeces of fish on sand substrates was present in the prey when ingested, but that oil which appeared in the faeces of fish on mud substrates was directly ingested either alone or together with the prey.

In another experiment four fish were therefore placed on the sieved mud with oil substrates but without prey organisms, and the same procedures followed as above. One of these four produced faeces containing oil droplets and when killed and examined had smears of oil on its buccal crushing plates.

Table 1 summarizes the results of these tests. Using the Exact Chi^2 test, fish on a mud substrate were significantly more likely to have oil in their faeces than fish on a sand substrate (at $P = 0.002$), and were significantly more likely to have oil on their crushing plates (at $P = 0.01$).

(b) Feeding on oiled shrimps in clean conditions: 12 plaice of 24-30 cm length were maintained in a tank of 216 litres and bottom area $0.72m^2$ for at least 7 months, supplied with flowing aerated water and fed solely on clean brown shrimps. Before the experiment, fish were isolated in 56 litre tanks and transferred to a 216 litre tank for feeding trials. Tank water temperatures fell from 17 to 10 degrees C during the experiment (October-December 1973).

Brown shrimps were isolated in 15 plastic mesh cages per 10 litre perspex tank of bottom area $0.1m^2$, supplied with aeration and with flowing sea water at 100-150ml/min. All were fed clean food, consisting of 3 parts macerated *Mytilus* tissue to 1 part macerated *Gadus* tissue bound with gelatine, until they moulted. They were then left unfed for 4 days for the new cuticle to harden, and placed in cages containing sunken topped oil at a concentration of $600ml/m^2$ of tank floor. After 10 days they were examined alive for ingestion of oil and if this had occurred the cage was tagged and the shrimps were used in feeding trials. Control shrimps were kept under similar conditions, but were not placed on sunken oil and were marked by punching a small hole in each exopodite. The wound tissue which formed was black and readily visible in the tanks. Where excessive wound tissue formed, or the exopodite was torn, the shrimps were discarded.

A fish was placed in the large trial tank and then 10 clean and 10 oiled shrimps were added simultaneously at the opposite end of the tank. The tank was observed continuously for 5-6 hours and at frequent intervals thereafter over 3-4 days. The times at which chases and catches of clean and oiled shrimps occurred were recorded over the former period, and the numbers of clean and oiled shrimps surviving were noted at frequent intervals over the latter period. A chase was defined as the final rush towards a shrimp with the mouth opened; slow preliminary approaches were ignored. A catch was recorded only when the shrimp was taken into the mouth of the fish. When trials were repeated, each fish was starved for 2-3 days previously. Trials were also run with 20 clean shrimps and the same procedures followed.

Results

Only 6 of the 12 fish chased and caught more than 10 shrimps over a 3-4 day period (Fish A-G in Table 2). The other 6 fish were therefore excluded from the assessment. Time permitted repeated tests with only 2 fish (A and B in Table 2). Table 2 gives a summary of the results of the feeding trials. The first entry is that at the time when the first recorded clean shrimp was caught;

the second entry is that after a period of approximately the same duration, recorded throughout the trials; the third entry is that of the last recorded capture.

Results for the 3 trials with fish A were combined, giving 56 chases directed at oiled shrimps and 44 directed at clean shrimps. Thus oiled shrimps were not chased significantly more often than clean shrimps, but it must be pointed out that fish A was very active in moving around the tank and this result may not hold for largely stationary fish. However, of the 56 chases of oiled shrimps, 14 were successful, whereas of the 44 chases of clean shrimps, only 6 were successful. Although not significant by the Exact Chi^2 test, the results suggest that oiled shrimps were more easily caught than clean shrimps, and the pattern of catches with time supported this. In only one trial did the total of clean shrimps caught exceed the total of oiled shrimps caught at any recorded time within the first 15 catches of the trial. It was considered that when less than 5 shrimps were available, the chances of the fish encountering one of the remaining oiled shrimps were small enough to outweigh any relative ease of their capture.

(c) Observations: During the periods of continuous observation the behaviour of the shrimps was noted. Oiled shrimps frequently performed backward circling movements or complete somersaults when retreating or escaping. They were liable to swim to the water surface and along the tank walls just below the surface, unlike the clean shrimps which tended to move about more on the bottom or to remain in the corners of the tank. The movements of the oiled shrimps rendered them more likely to encounter a stationary fish and induce its feeding activities, or to become the target of feeding activity of slowly moving fish. The atypical behaviour of the oiled shrimps led to an investigation of the effects of ingested oil on their buoyancy.

(d) The specific gravity of oiled shrimps: The specific gravity of clean and oiled shrimps of comparable carapace length was measured by placing them in sea water in a wide graduated tube. Concentrated brine (300 g/l) was added slowly as the mixture was stirred. When the shrimp floated in the middle of the water column a sample of the mixture was withdrawn and measured with a specific gravity bottle. No shrimps were used that had recently moulted, but no account was taken of sex, lipid content or previous feeding regime. 12 oiled shrimps of mean carapace length 11.73mm (SE 0.017) had a mean specific gravity of 1.085 (SE 0.003), while 13 clean shrimps of mean carapace length 11.50mm (SE 0.016) had a mean specific gravity of 1.109 (SE 0.003). There is no significant difference between the mean carapace lengths, but the mean specific gravities are significantly different (at $P < 0.001$).

Discussion

The experiments with plaice confirm that they will catch and eat oiled shrimps and continue to search for and eat burrowing benthos in oiled substrates. The fact that under laboratory conditions shrimps and plaice ingested sunken oil at seabed concentrations over 30 times lower than those calculated as being likely to follow immediately after oil-sinking activities at sea (data from Van Dixhoorn, Van Angeren and Menagie, 1970) indicates that the potential problem of tainting of commercial catches may persist after considerable dilution of bottom oil concentrations by dispersion and burial. It would also appear that plaice, like shrimps, ingest sunken topped oil as a potential food, rather than ingest oil unintentionally while catching and swallowing prey, but that the feeding habits of a demersal fish will affect the amounts likely to be eaten.

The feeding trials with oiled and clean shrimps indicate that the former may be eaten preferentially, not because they are more attractive, but because ingestion of oil renders shrimps more likely to encounter a predator or to be more easily caught once chased. It is not clear whether the effects of ingestion of oil, which lead to more encounters with fish and less success at escaping, stem from interference with behaviour or sensori-motor control or result entirely from increased buoyancy and instability.

Summary

1. The ingestion of sunken topped crude oil renders brown shrimps more easily caught by a predatory fish.
2. Shrimps that have ingested sunken oil have a reduced specific gravity.
3. Plaice will eat oiled shrimps on an oiled sand substrate, but fish searching for food in an oiled mud substrate are more likely to ingest sunken oil.
4. Sunken oil may be eaten by plaice as a potential food, and not merely by accident while catching and swallowing prey on an oiled substrate.

References

BLACKMAN, R. A. A., 1972. Effects of sunken crude oil on the feeding and survival of the brown shrimp (Crangon crangon). ICES, C.M. 1972/K:13.

VAN DIXHOORN, I. R. J., VAN ANGEREN, H. F. A. and MENAGIE, H. M., 1970. Report of an oil control trial with the Shell sand sink method on Wednesday 8 April 1970 in the North Sea. Government Department of Water Control and Public Works, Harbour Mouths Division, Hook of Holland.

Table 1 The numbers of plaice showing evidence of ingested sunken oil

	Oil in faeces and on buccal plates	Oil in faeces alone	Oil on buccal plates alone	No evidence of oil	Total
Fish on a mud substrate + prey	6	1	2	3	12
Fish on a sand substrate + prey	0	0	1	5	6
Fish on a mud substrate with no prey	1	0	0	3	4

Table 2 A summary of the results of trials of feeding plaice with oiled or clean shrimps

	No. of oiled shrimps caught	No. of clean shrimps caught	Time (Mins)
FISH			
A (test 1)	2	1	123
	8	4	1295
	9	5	1625
A (test 2)	3	2	106
	8	8	1410
	9	9	1590
A (test 3)	5	1	245
	9	5	1380
	10	8	2620
B (test 1)	1	2	160
	4	3	1380
	5	8	8200
C	3	1	270
	4	4	1380
	9	10	4400
E	1	2	1110
	1	2	1590
	8	4	11360
F	2	1	65
	4	3	1260
	8	6	8550
G	4	2	235
	5	3	1380
	7	6	7140
Clean shrimps only			
FISH			
A (test 4)		1	2
		18	1500
B (test 2)		1	2
		19	470