The Effects of Ocean Dumping of Dredge Spoils onto Juvenile Lobster Habitat : A Field Evaluation

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THE EFFECTS OF OCEAN DUMPING OF DREDGE SPOILS ONTO JUVENILE LOBSTER HABITAT: A FIELD EVALUATION

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ABSTRACT

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Two hundred cubic meters of noncontaminated sand-silt-clay sediment were dumped onto a presurveyed juvenile American lobster, Homarus americanus, habitat in Halifax Harbour, Nova Scotia. SCUBA divers carried out five surveys of lobsters and crabs on the dump, the adjacent hard bottom, and on a control area over a 12-mo period. In addition, the divers charted the extensive changes in the topography of the dumped sediment and monitored the invasion of macrofauna and macroflora. Both lobster and crab densities on the dumped sediment remained low, relative to the adjacent hard bottom and the control area, over the postdump monitoring period. The few macrofaunal and macrofloral species invading the dump appeared either sedentary and constrained to settlement on exposed boulders above the spoil, or errant species. We hypothesize that dumping can adversely affect lobsters and crabs by decreasing shelter and prey availability and, thus, increasing inter- and intraspecific competition.

Key words: Cancer, competition, crabs, density, prey, shelter, waste disposal

RÉSUMÉ

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Deux cents mètres cubes de sédiment sable-vase-argile non contaminé ont été déversés sur un habitat de jeunes homards (Homarus americanus), habitat qui avait été préalablement étudié, dans le port de Halifax, en Nouvelle-Ecosse. Des plongeurs autonomes ont effectué, sur une période de 12 mois, cinq relevés de homards et de crabes sur le lieu du déversement, sur les fonds durs avoisinants et sur un site témoin. En outre, les plongeurs ont cartographié les changements importants qui ont pu se produire dans la topographie du sédiment déversé, et ils ont suivi l'invasion de la macrofaune et de la macroflore. Durant la période d'étude d'après déversement, la densité des homards de même que celle des crabes demeurèrent faibles comparativement à celle des fonds durs avoisinants et du site témoin. Les quelques espèces macrofauniques et macroflorales qui envahirent le site du déversement ont semblé être soit des espèces sédentaires, contraintes de s'établir sur des roches exposées au-dessus du déblai, soit des espèces errantes. Nous émettons l'hypothèse que le déversement a des effets nuisibles sur les homards et les crabes en rendant les abris et les proies moins accessibles, augmentant ainsi la compétition inter et intraspécifique.

INTRODUCTION

The American lobster, Homarus americanus, inhabits a wide range of substrate types in inshore waters but is most common on sand with overlying rocks and boulders (Cooper and Uzmann 1980). Although newly settled lobsters (stages IV-VIII) can construct tunnels in mud (Berrill and Stewart 1973; Botero and Atema 1982), stage IV lobster larvae usually prefer a gravel substrate to one of sand or mud, and may delay molting to the benthic fifth stage until "favorable (rocky) conditions are reached" (Cobb 1968). Pottle and Elner (1982) demonstrated that, in the laboratory, early-stage juvenile lobsters (stages VII-X) show a preference for gravel substrate compared to silt-clay deposited over gravel. The presence of juvenile lobsters in the gravel and cobble substrates of inshore areas around the Atlantic coast of Nova Scotia leads to concerns regarding the sensitivity of such "nursery areas" to environmental perturbations. At present in the Canadian Maritime Provinces, spoil dredged from harbors constitutes a major portion of the wastes dumped at sea. Ocean dumpsite selection is based largely on the absence of commercial fisheries and the physical stability of the site. Hence, as juvenile American lobsters appear similar to their European counterparts (Homarus gammarus) in that they may inhabit substrates that are different from their adult conspecifics (Howard 1980), current ocean-dumping practices could result in smothering of habitat occupied by juvenile lobsters. Our study was instigated to field-test aspects of the Pottle and Elner (1982) hypothesis that dumping of dredge spoils may adversely affect juvenile lobster habitat and, over time, have a detrimental influence on recruitment to the fishery.

In the present study, sand-silt-clay sediment was dumped onto an inshore hard bottom which had been previously surveyed for juvenile lobsters and crabs. Subsequently, SCUBA divers mapped the sediment and monitored lobsters and crabs, as well as macrofauna and macroflora, within the experimental area and a control area over a 12-mo period.

MATERIALS AND METHODS

The experimental and control areas were located close to shore in Ferguson's Cove, on the western shore of the approaches to Halifax Harbour, Nova Scotia (Fig. 1). The two areas were selected because they showed similar biological and physical characteristics while being far enough apart (300 m) to minimize the likelihood of exchange of dumped sediment. The natural substrate of the two areas was a hard bottom comprised of boulders and cobbles on a sand-clay base.

Each area was 1000 m^2 (40 x 25 m) and ranged in depth from 5-12 m. Area boundaries were defined by markers on shore and with anchored buoys. Two hundred cubic meters of noncontaminated sediment, originating from the channel adjacent to a wharf in Eastern Passage (Fig. 1), were dumped from a barge over the experimental area on March 3, 1982. The composition of the dumped sediment was 41-50% sand, 41-43% silt and 9-16% clay.[2]

[2]Analysis by MacLaren Plansearch Ltd., Dartmouth, Nova Scotia.

TOPOGRAPHIC SURVEY

The experimental area was surveyed by SCUBA divers, using a grid method on March 10, July 7, and August 25, 1982, and February 19 and March 21, 1983. The divers laid bottom transect lines at 5-m intervals within the experimental area, perpendicular from the southern boundary to the edge of the dumped sediment. The depth of the dumped sediment was measured with a graduated probe at 5-m intervals along each of the transects. In addition, 10 permanent markers were randomly positioned in the experimental area on March 10, 1982, to assist in monitoring changes in the dumped sediment profile. Each marker consisted of a heavy iron base plate resting on the original substrate, with an attached plastic meter stick protruding vertically through the dumped sediment. Thus, divers could directly assess sediment depth at a marker by reading the meter-stick scale at the sediment-water interface. However, vandals removed the markers from the area between March and July 1982.

A computer program[3] was used to illustrate the topography of the dumped sediment from the transect data.

BIOTIC SURVEY

A predump biotic survey of both the experimental and control areas was conducted during daylight hours on February 3, 1982. A 5-m transect line was randomly laid out along the bottom and two SCUBA divers searched a 1-m wide strip for lobsters and crabs on each side of the line. Lobsters and crabs that could be captured were brought to a support boat on the surface for species identification and measurement. We determined lobster size by measuring carapace length (CL) from the posterior edge of an eye socket to the posterior edge of the carapace parallel to the longitudinal axis. Crab size was determined by measuring the carapace width (CW) between the tips of the distal marginal teeth. The sex of each animal was also recorded. Captured animals were released in their home area immediately after recordings were completed. Lobsters and crabs that divers located on a transect but failed to capture were noted for inclusion in estimates of density. Further biotic surveys in the experimental and control areas were conducted during daylight hours on the same dates as the topographic surveys. A total of 93, 10-m^2 transects were sampled in the study period February 3, 1982-March 21, 1983. In addition, macrofauna and macroflora present in each area were recorded by divers meticulously searching the bottom along random paths on each sampling occasion.

RESULTS AND DISCUSSION

The 200 m^3 of sediment dumped onto the experimental area in March 1982 were subject to considerable flux, likely from storm and tidally-induced water movements. In consequence, substrate smothered by the initial dumping was subsequently uncovered and conversely, substrate originally missed became smothered. The substrate covered by dumped sediment within the experimental area was estimated to be 400, 360, 270, 350, and 488 m^2 in

[3]BGRIDØ1: A surface generation program for representing nonuniform three-dimensional data. G.A.P. Black (1981), Biological Station, St. Andrews, New Brunswick.

March, July, August 1982, and February and March 1983, respectively. The maximum depth of the dumped sediment decreased from 0.60 m in March 1982 to 0.21 m (July 1982) to 0.11 m (August 1982), increased to 0.35 m (February 1983) and then decreased to 0.24 m (March 1983). Changes in the distribution and profile of the sediment over the course of the study are shown in Fig. 2. Between the March 10, 1982, and the July 7, 1982, surveys the surface of the dumped sediment changed with the original gray-colored material becoming covered by a thin layer of fine brownish silt. SCUBA divers observed that the silt was also deposited on macroalgae and substrates in shallow areas untouched by the dumping.

The macrofauna and macroflora present on the control area, hard bottom, and dumped sediment portions of the experimental area over the six sampling occasions are shown in Table 1. Generally, we found the macrofauna on the control area and hard bottom of the experimental area to be similar. However, macrofaunal and macrofloral diversity appeared considerably attenuated on the dumped sediment. The green sea urchin, Strongylocentrotus droebachiensis, subjectively assessed as the dominant epifaunal organism in terms of numbers and biomass before the dumping, disappeared entirely and was replaced as dominant by the starfish, Asterias vulgaris, throughout the postdump monitoring period. Other macrofauna that disappeared included molluscs, polychaetes and crustaceans frequently encountered in the natural diets of crabs and lobsters (Scarratt and Lowe 1972; Scarratt 1980; Elner 1981). Excepting Agarum sp., which adhered to boulders protruding through the shallow layer of sediment at the periphery of the dump in February and March 1983, no macroalgae were found on the dumped sediment despite their presence in the predump survey and continued presence on the remaining hard bottom. Similarly, Metridium senile, a sedentary coelenterate present on the dump from the first sampling onwards, was located exclusively on protruding boulders. Buccinum undatum, Cancer sp., Pagurus sp., A. vulgaris and Ophiopholis aculeata were the only macrofauna present on the hard bottom to invade the dumped sediment proper. The sole lobster on the dump was found at its extreme edge. Lunatia heros, a gastropod, and Pseudopleuronectes americanus, the winter flounder, were noteworthy in that they were found only on the dumped sediment. In general, with the exception of the supension feeders M. senile and O. aculeata, most macrofauna found on the dumped sediment in the experimental area could have been transients in search of food rather than residents.

The mean size and range of lobsters and four crab species sampled on the areas over time are shown in Tables 2-6. There was no statistical difference (t-test, $p > 0.01$) between the mean sizes of lobsters from the experimental area and the control area in the predump survey. Similarly, for any subsequent sampling occasion following dumping, there were no statistical differences (t-test, $p > 0.01$) between mean lobster sizes from the two areas. The mean size of rock crabs, Cancer irroratus, did not differ significantly between areas for any given sampling in 1982 (t-test, $p > 0.01$). However, in February 1983, rock crabs from the control area were significantly larger (t-test, $p < 0.01$) than those from the hard bottom of the experimental area; no rock crabs were found on the dumped sediment. In March 1983, rock crabs found on the dump were significantly larger (t-test, $p < 0.01$) than those on either the control area or the hard bottom of the experimental area. There was no statistical difference (t-test, $p > 0.01$) between mean sizes of rock crabs from the two hard bottoms in March 1983. The reason for the differences in mean rock crab size in February and March 1983 is unclear. Overall, male:female ratios were 0.53:1 and 1:0.96 for lobsters and rock crabs, respectively. Statistical analyses on mean sizes of jonah crab, Cancer borealis, green crab, Carcinus maenas, or toad crab, Hyas coarctatus, were not performed because of the small sample sizes involved.

Prior to the dumping, the densities of lobsters on the experimental and control areas were $0.24/m^2$ and $0.07/m^2$, respectively. Subsequently, except for a single lobster found in the first survey following dumping, no lobsters were located on the dumped sediment (Table 7). Lobsters were not found on the hard bottom of the experimental area until August 1982; afterwards, densities closely mirrored those of the control area. Separate predump densities of rock crab and jonah crab are unavailable as these species were classified only to genus. Rock crabs were rare on the dumped sediment compared to both the control area and hard bottom of the experimental area throughout the study period (Table 7). Similarly, jonah crab densities, although lower than those for the rock crab, were much reduced on the dump compared to the hard bottoms (Table 7). In general, densities of Cancer crabs on the hard bottom of the experimental area were higher than on the control area. However, given that predump densities of Cancer crabs were also higher on the experimental area than on the control area, more fundamental ecological factors than an indirect impact of the dumping may account for the differences in Cancer densities between the hard bottoms. Both green crabs and toad crabs were found only on hard bottom (Table 5,6). Figure 3 illustrates the lobster, rock crab and jonah crab density patterns over the study period and, notwithstanding the variability, reflects the prolonged depressive impact of the dumping on the density of these decapods.

The range of lobster densities in our study are comparable with estimates for Nova Scotia, the Northumberland Strait and Rhode Island but fall below that given for the substrate supporting the greatest concentrations of juvenile and adult lobsters in the Gulf of Maine (Table 8). The densities of rock crab on hard bottoms in our study were, generally, higher than that found in a survey of the Northumberland Strait but less than the estimated rock crab density in a kelp bed off Callahan Island, Nova Scotia (Table 9).

We believe that the dearth of lobsters on the dump was most likely due to the lack of suitable shelter afforded by the soft sediment. Shelter is facilitated by the presence of embedded stones, overlying rocks, gravel or other solid objects for lobsters to use as "hides" or as supporting structures for their tunnels (Berrill and Stewart 1973; Cooper and Uzmann 1980; Pottle and Elner 1982). Although early-stage juvenile lobsters are adept at tunnelling into cohesive mud (Berrill and Stewart 1973), the density of lobsters in mud substrates without surface objects tends to be relatively low (Cobb 1971; Cooper and Uzmann 1977). The absence of lobsters on the hard bottom of the experimental area over the first two postdump surveys, despite the presence of apparently suitable shelters, suggests that the dumping affected lobsters not only on the actual bottom smothered but also on the adjacent bottom.

CONCLUSIONS

The movement of dredge spoils throughout the study suggests that dumping can have a multiple impact on a series of adjacent habitats over time, the impact of the original spoil material being magnified if it is subsequently redeposited by tidal currents. Our study demonstrates that hard-bottom assemblages that become smothered by spoil from dumping can suffer drastic macrofaunal and macrofloral changes. For the 12 mo following dumping, most invasive macrofauna were either sedentary and constrained to settlement on exposed boulders above the spoil, or errant species. Lobsters and four crab species present on the hard bottoms were absent or relatively scarce on the dumped sediment. We suggest that lobsters and crabs surviving the actual dumping moved away as shelter was destroyed and prey availability reduced. Cancer crabs, green crabs and lobsters are known to overlap in their natural diet and habitat requirements (Cooper and Uzmann 1980; Elner 1981). Thus, the removal of shelter and prey could further increase inter- and intraspecies competition amongst lobsters and crabs in habitats where such resources are limited. A lack of suitable shelter could result in lobsters becoming more vulnerable to predators and suffering a rise in mortality. In addition, lobsters could exhibit a decreased growth rate from reduced food intake, due to decreased availability of suitable prey (Aiken 1980) and from crowding due to spatial competition (Cobb and Tamm 1974; Stewart and Squires 1968). Studies by Scarratt (1968) for H. americanus and Howard (1980) for H. gammarus have suggested that a scarcity of suitable habitat may limit lobster distribution and abundance; if such is the general case, reduction of existing lobster habitats by ocean-dumping practices can only exacerbate the situation. The various postulated effects of ocean dumping on subsequent recruitment into the lobster fishery are summarized in Fig. 4.

In summary, while dredging is vital to the economical operation of most ports in the Canadian Maritime Provinces, our study indicates that spoils should not be dumped either directly onto juvenile lobster habitat or onto sites from which the spoils may become transported onto such habitat. Surveys to monitor the dynamics of the dumped sediment and the succession of species in the Ferguson's Cove experimental area are being continued.

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Table 1. Species of macrofauna and macroflora present on the experimental area and control area during the period February 1982-March 1983.

Species	Experimental area: Hard bottom	Experimental area: Dumped sediment	Control area
Algae			
Agarum sp.	III IV V VI	V VI	III IV V VI
Corallina sp.	III IV V VI		III IV V VI
Desmerestia sp.	III IV V VI		III IV V VI
Fucus sp.	I II III IV V VI		I II III IV V VI
Laminaria sp.	III IV V VI		III IV V VI
Ulva sp.	III IV V VI		III IV V VI
Anthoza			
Metridium senile	I II III IV V VI	II III IV V VI	I II III IV V VI
Amphineura			
Ischnochiton ruber	I II III IV V VI		I II III IV V VI
Gastropoda			
Acmaea testudinalis	I II III IV V VI		I II III IV V VI
Buccinum undatum	I II III IV V VI	II III IV V VI	I II III IV V VI
Crepidula fornicata	I II III IV V VI		I II III IV V VI
Littorina littorea	I II III IV V VI		I II III IV V VI
Lunatia heros		V VI	
Pelecypoda			
Anomia aculeata	I II III IV V VI		I II III IV V VI
Hiatella arctica	I II III IV V VI		I II III IV V VI
Modiolus modiolus	I II III IV V VI		I II III IV V VI
Polychaeta			
Lepidonotus squamatus	I II III IV V VI		I II III IV V VI
Nereis sp.	II III IV V VI		I II III IV V VI
Crustacea			
Balanus balanoides	II III IV V VI		II III IV V VI
Cancer borealis	III IV V VI	II III	III V VI
Cancer irroratus	II III IV V VI	III IV V VI	II III IV V VI
Carcinus maenas	III V VI		IV
Homarus americanus	I IV V VI	II	I II III IV VI
Hyas coarctatus	V VI		
Pagurus sp.	I II III IV V VI	II III IV V VI	II III IV V VI
Echinoidea			
Strongylocentrotus droebachiensis	I II III IV V VI		I II III IV V VI
Stelleroidea			
Asterias vulgaris	I II III IV V VI	II III IV V VI	I II III IV V VI
Henricia sanguinolentea	V VI		III IV V VI
Ophiopholis aculeata	I III IV V VI	II III IV V VI	I
Selachii			
Raja sp.		III	
Pisces			
Anarhichas lupus	IV		
Macrozoarces americanus	I		
Pseudopleuronectes americanus		II III IV V VI	

Note: Period I = February 3, 1982, 4 wk before dumping;
II = March 10, 1982, 1 wk after dumping;
III = July 7, 1982, 17 wk after dumping;
IV = August 25, 1982, 24 wk after dumping;
V = February 19, 1983, 50 wk after dumping;
VI = March 21, 1983, 55 wk after dumping.

Table 2. Size (CL) characteristics of *H. americanus* sampled (animals located but not measured are not included) (see Table 1 for key to date symbols).

	Experimental area								Control area			
	Hard bottom				Dumped sediment							
Period	N	Mean (mm)	± SE	Range	N	Mean (mm)	± SE	Range	N	Mean (mm)	± SE	Range
I	30	39.1	2.3	20-66					7	37.4	3.0	26-50
II	0	-	-	-	1	43.0	-	43.0	8	45.5	4.6	28-65
III	0	-	-	-	0	-	-	-	8	48.8	7.3	26-89
IV	3	89.3	26.1	42-132	0	-	-	-	2	63.5	1.5	62-65
V	1	48.0	-	48	0	-	-	-	0	-	-	-
VI	3	48.7	9.8	31-65	0	-	-		2	48.0	9.9	38-58

Table 3. Size (CW) characteristics of *C. irroratus* sampled (animals located but not measured are not included) (see Table 1 for key to date symbols).

	Experimental area								Control area			
	Hard bottom				Dumped sediment							
Period	N	Mean (mm)	± SE	Range	N	Mean (mm)	± SE	Range	N	Mean (mm)	± SE	Range
I	- *Cancer* samples not differentiated to species -											
II	4	47.8	8.1	26-55	0	-	-	-	4	51.3	3.8	44-61
III	6	65.8	6.3	36-78	2	22.0	3.0	19-25	4	55.3	7.5	33-65
IV	11	67.3	6.5	33-99	1	76.0	-	76	10	66.0	3.6	49-83
V	22	36.4	2.8	18-65	0	-	-	-	9	42.9	5.8	25-78
VI	22	41.1	3.4	21-79	6	61.3	2.8	54-74	21	40.7	3.6	18-73

Table 4. Size (CW) characteristics of *C. borealis* sampled (animals located but not measured are not included) (see Table 1 for key to date symbols).

	Experimental area								Control area			
	Hard bottom				Dumped sediment							
Period	N	Mean (mm)	± SE	Range	N	Mean (mm)	± SE	Range	N	Mean (mm)	± SE	Range
I	- *Cancer* samples not differentiated to species -											
II	0	-	-	-	1	81.0	-	-	0	-	-	-
III	8	42.5	9.6	18-106	1	15.0	-	-	4	66.5	5.8	51-79
IV	1	107.0	-	107	0	-	-	-	0	-	-	-
V	1	52.0	-	52	0	-	-	-	2	88.0	15.0	73-103
VI	5	80.6	9.2	46-100	0	-	-	-	1	18.0	-	18

Table 5. Size (CW) characteristics of C. maenas sampled (animals located but not measured are not included) (see Table 1 for key to date symbols).

	Experimental area											
	Hard bottom				Dumped sediment				Control area			
Period	N	Mean (mm)	+ SE	Range	N	Mean (mm)	+ SE	Range	N	Mean (mm)	+ SE	Range
I	0	-	-	-	0	-	-	-	0	-	-	-
II	0	-	-	-	0	-	-	-	0	-	-	-
III	1	37.0	-	37	0	-	-	-	0	-	-	-
IV	0	-	-	-	0	-	-	-	2	49.0	12.0	37-61
V	2	44.0	3.0	41-47	0	-	-	-	0	-	-	-
VI	1	43.0	-	43	0	-	-	-	0	-	-	-

Table 6. Size (CW) characteristics of H. coarctatus sampled (animals located but not measured are not included) (see Table 1 for key to date symbols).

	Experimental area											
	Hard bottom				Dumped sediment				Control area			
Period	N	Mean (mm)	+ SE	Range	N	Mean (mm)	+ SE	Range	N	Mean (mm)	+ SE	Range
I	0	-	-	-	0	-	-	-	0	-	-	-
II	0	-	-	-	0	-	-	-	0	-	-	-
III	0	-	-	-	0	-	-	-	0	-	-	-
IV	0	-	-	-	0	-	-	-	0	-	-	-
V	1	9.0	-	9	0	-	-	-	0	-	-	-
VI	3	15.0	2.08	11-18	0	-	-	-	0	-	-	-

Table 7. Estimates of density (no./m^2) of *H. americanus*, *C. irroratus*, and *C. borealis* sampled in the experimental and control areas at Ferguson's Cove over time. ( ) = number of lobsters; animals located but not measured are included (see Table 1 for key to date symbols).

	Experimental area						Control area		
	Hard bottom			Dumped sediment					
Period	*H. americanus*	*C. irroratus*	*C. borealis*	*H. americanus*	*C. irroratus*	*C. borealis*	*H. americanus*	*C. irroratus*	*C. borealis*
I	0.24(31)	0.25					0.07(7)	1.60	
II	0	0.13	0	0.03(1)	0	0.03	0.13(8)	0.07	0
III	0	0.30	0.40	0	0.04	0.02	0.18(9)	0.08	0.08
IV	0.08(4)	0.22	0.02	0	0.03	0	0.08(3)	0.25	0
V	0.03(1)	0.55	0.04	0	0	0	0	0.18	0.04
VI	0.05(3)	0.37	0.08	0	0.10	0	0.07(4)	0.35	0.02

Table 8. Estimates of density (no./m^2) of H. *americanus* in inshore areas along the northwestern Atlantic coast.

Month	Area	Type of bottom	Sampling method	No./m^2	Mean CL (mm)	Source
May-Aug.	Northumberland Strait	Flat bedrock; Boulder-rock substrate	SCUBA	0.007; 0.11	39.7	Scarratt (1973)
	Gulf of Maine	Sandy substrate with overlying flattened rocks	-	3.25	40.0	Cooper and Uzmann (1980)
July	Rhode Is.	Rocky bottom; Mud-shell/rock	"	0.10; 0.16	-	Cobb (1971)
Aug.-Oct.	McNutts Is., N.S.	Boulders on sand/gravel base	"	0.11	~20.0	Bernstein and Campbell (1983)
March	Ferguson's Cove, N.S.	Dumped sediment	"	0.03	43.0	Present study
Feb.-March	Ferguson's Cove, N.S.	Boulders, cobbles on sand-clay base (hard bottom, experimental area)	"	0-0.24	44.2	Present study
Feb.-March	Ferguson's Cove, N.S.	Boulders, cobbles on sand-clay base (control area)	"	0-0.18	45.9	Present study

Table 9. Estimates of density (no./m^2) of C. *irroratus* in various inshore areas along the northwestern Atlantic coast.

Month	Area	Type of bottom	Sampling method	No./m^2	Mean CW (mm)	Source
June	Northumberland Strait	Sand	SCUBA	0.02	84.1	Scarratt and Lowe (1972)
"	" "	Boulders	"	0.04	72.3	"
"	" "	Bedrock	"	0.02	65.3	"
Sept.-Oct.	" "	Sand	"	0.003	112.0	"
"	" "	Boulders	"	0.11	49.0	"
"	" "	Bedrock	"	0.05	57.0	"
July-Sept.	Callahan Is., N.S.	Kelp bed on bedrock	Traps	0.50	>45.0	Drummond-Davis et al. (1982)
March-March	Ferguson's Cove, N.S.	Dumped sediment	SCUBA	0-0.10	58.5	Present study
March-March	Ferguson's Cove, N.S.	Boulders, cobbles on sand-clay base (hard bottom, experimental area)	"	0.13-0.55	46.6	Present study
March-March	Ferguson's Cove, N.S.	Boulders, cobbles on sand-clay base (control area)	"	0.07-0.35	48.5	Present study

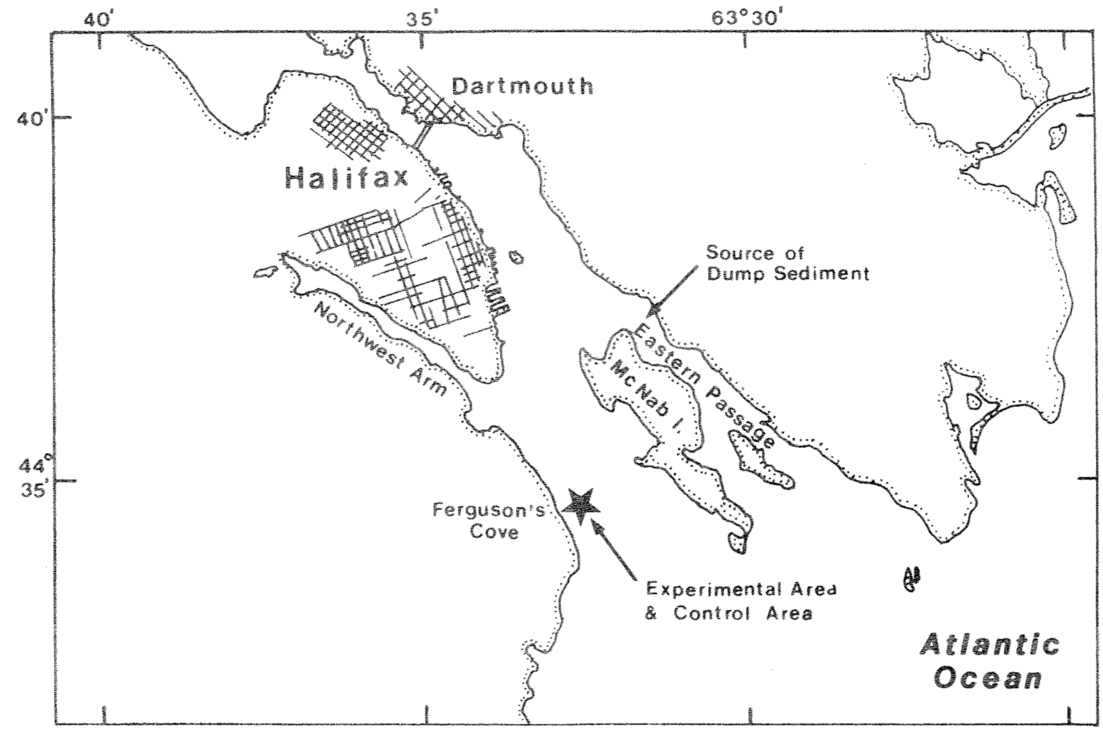

Fig. 1. Locations of experimental area, control area and source of dump sediment.

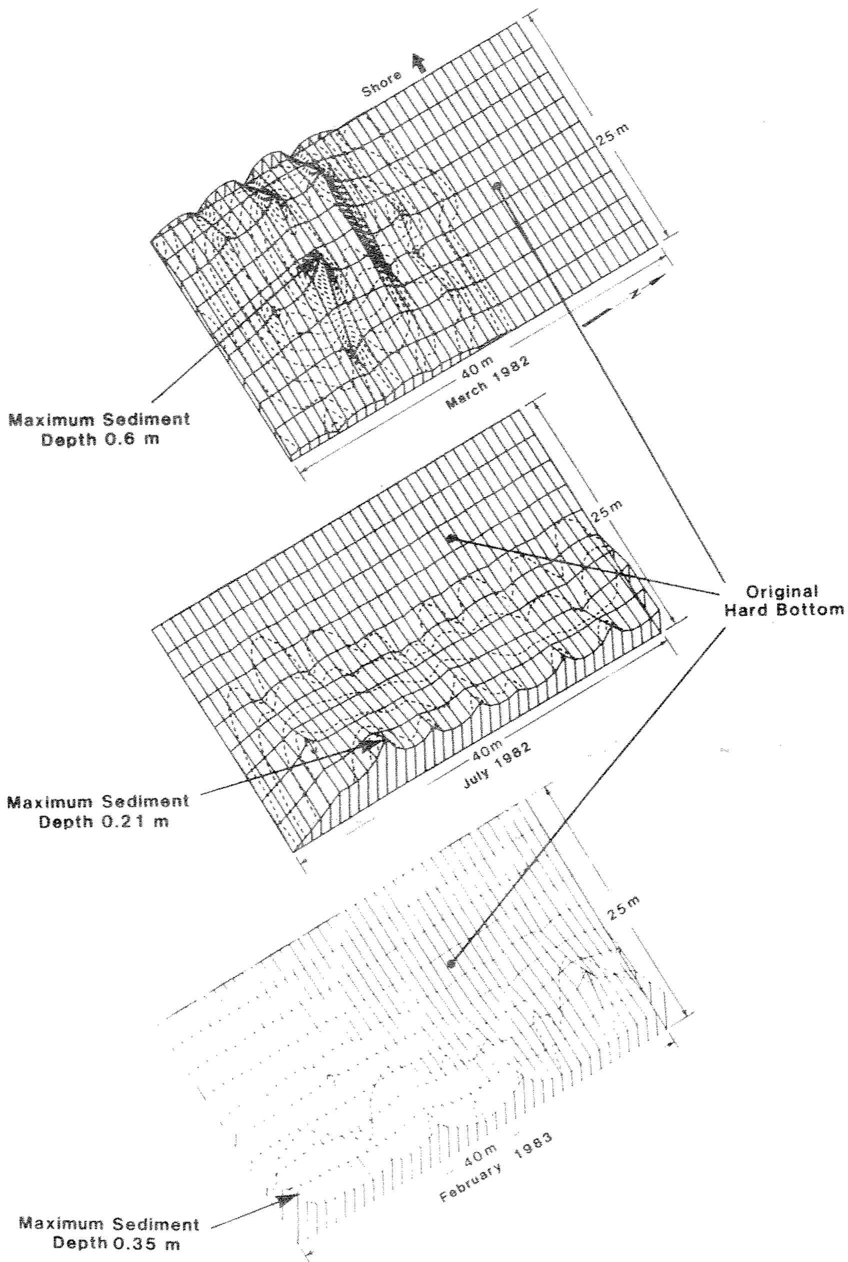

Fig. 2. Topographic changes of the dumped sediment on the experimental area over the study period.

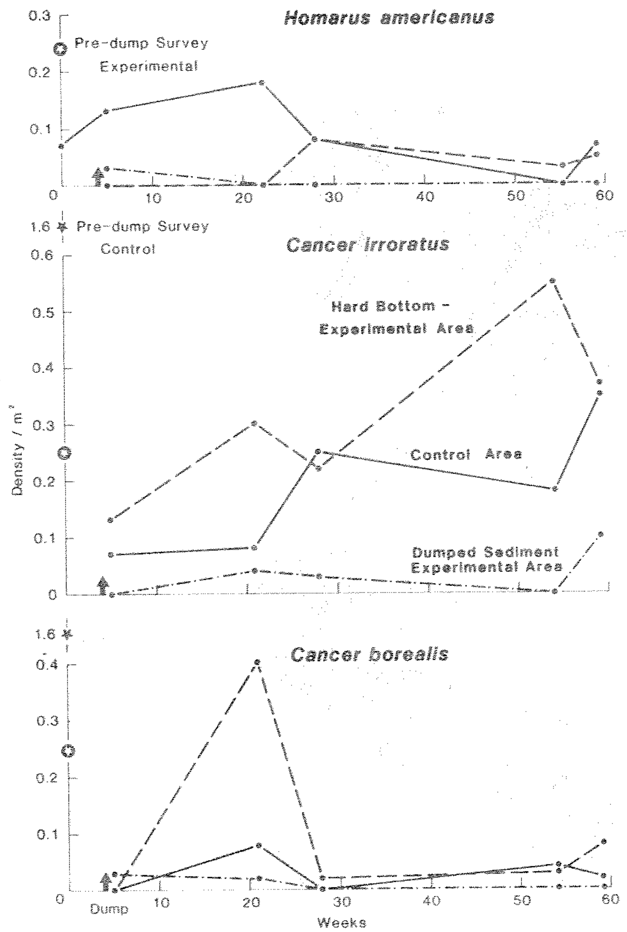

Fig. 3. Estimates of density of lobsters, rock crabs, and jonah crabs on the hard bottom and dumped sediment portions of the experimental area and the control area over the period February 1982-March 1983. (Predump densities for Cancer are for both species combined.)

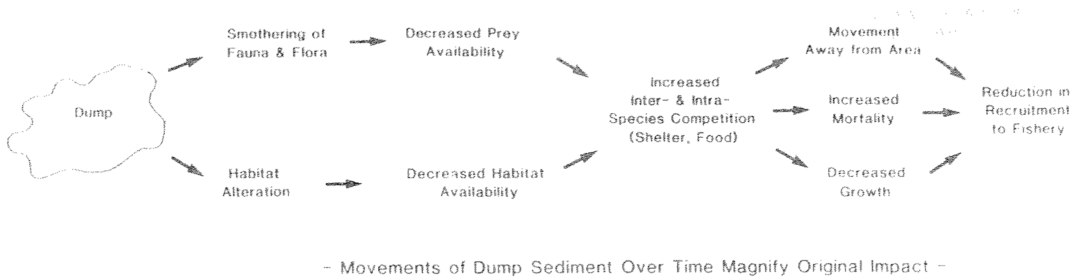

Fig. 4. Schematic to illustrate the various postulated effects of the impact of ocean dumping on lobsters.