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THE URQUIOLA OIL SPILL (5/12/76): OBSERVATIONS OF BIOLOGICAL DAMAGE ALONG THE SPANISH COAST

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ABSTRACT

On 12 May 1976, the supertanker Urquiola ran aground, spilling nearly 30,000 tons of Persian Gulf crude along 215 km of Spanish coastline. Quadrat analyses of a sandy tidal flat, a salt marsh, and a mud flat indicated that Cerastoderma edule, the edible cockle, and the marsh gastropod, Littorina littorea, were the macrobenthic faunal residents most vulnerable to the effects of the spilled oil. Other species of bivalves (Scrobicularia plana, Tellina tenuis, Venerupus decussata) suffered lower mortalities ranging from 19-30%. Sub-lethal damage to cockles, small intertidal schooling fish, limpets and nudibranchs was also observed.

It was difficult to assess the effects of oil on annelid and decapod crustacean populations. However, surviving individuals exhibited no indications of sublethal impairment of locomotion or of escape responses.

Some species of macrobenthic fauna are obviously more sensitive than others to the deleterious effects of spilled oil. Physiological differences may account for this fact. However, it is suggested that habitat preferences may also strongly influence species mortality.

INTRODUCTION

On May 12, 1976, during a spring low tide, the supertanker Urquiola ran aground and exploded at the entrance to La Coruña harbor in northwest Spain (Fig. 1). Of the 107,000 tons of Persian Gulf crude on board, only 10,000 tons were later removed. Although most of the oil burned after the explosion, an estimated 25,000 tons eventually contaminated shoreline environments. By June 3, nearly 215 km of coastline had been oiled; 60 km received moderate to heavy accumulations. As part of spill control activities, at least 2000 tons of dispersants were applied around the wreck site. Further information concerning the circumstances of the spill and related cleanup activities is presented by Gundlach and Hayes (1977).

METHODS OF STUDY

Coastal environments affected by the Urquiola spill were studied from 17 May to 19 June 1976. A total of 99 observation stations were set up along the coast (see Gundlach, et al., in press). From 4-10 June 1976, four representative coastal environments were studied in detail (described below) to determine the biological impacts of oil on specific communities. A brief follow-up survey was completed on 1 and 2 May 1978.

This paper describes biological observations at the following locations (Fig. 2): 1. a fine-to medium-grained sandflat at Santa Cristina (Station B1), 2. a salt marsh within the Rio del Burgo estuary (B2), 3. a fine-grained mud flat at Puentedeume (B3), 4. an intertidal rocky shore at Porto Cobo (UQA-9), 5. a rocky shore at Playa de Ber (UQA-20), and 6. a fine-sand beach at Raso (UQA-22). A mud flat within the Ria de Betanzos was surveyed as a control site.

At station B1, four transects were run from low to mid-water marks. At stations B2 and B3, a single transect was completed from low to high water marks. Equidistant sampling sites were established along the transect. At each site, replicate 30 cm x 30 cm x 25 cm volumes of sediment were sieved through 0.8 cm mesh. Macrobenthic fauna were removed from the sieve and placed in polyethylene bags containing 70% ethanol. Examination was performed within 3 hours of capture. Organisms were measured, counted, and examined for degree of damage.

RESULTS

Santa Cristina Sandflat (B1)

The sandflat (100 m x 300 m) at Santa Cristina is located 7 km from the wreck site. Sediments are primarily medium- to fine-grained sand (0.3 - 0.5 mm) with coarser material underlying the surface sediments. At the time of the spill, the flat appeared oil stained, but without thick accumulations. However, along the beach face, a 5 m band of heavily-oiled sediment was present. A sketch of the area at the time is presented in Figure 3. Sand within the tidal flat exuded an oil sheen when rinsed with clear sea water.

Infauna of the area consisted primarily of the edible cockle, *Cerastoderma edule*, bivalves, *Scrobicularia plana*, *Venerupus decussata*, *Tellina tenuis*, and polychaetes, *Arenicola* and nereids. Table 1 presents population estimates and percent mortality at Santa Cristina. *C. edule* was by far the most abundant species, having a total estimated population of 4.5 million. The zonation pattern of all species is illustrated in Figure 4. The abundance and distribution of *C. edule* and *S. plana* are illustrated in Figure 5.

Cerastoderma edule, living within the upper 5 cm of sediment, was most severely affected during the spill, exhibiting 70% mortality (3.1 million individuals). Scrobicularia plana, occurring to a depth of 10 cm, suffered a lower mortality (30%) as did Tellina tenuis (19% mortality), whose population was restricted to the more muddy, low intertidal region on the flat. Thousands of oil-stained shells littered the surface of the flat (Fig. 6). Close examination revealed that the siphonal area on the posterior margin of the cockle shells was oil-stained to varying degrees. Dead cockles consistently exhibited a greater degree of staining than did living cockles. When placed in a water-filled trench, surviving cockles pumped slowly and irregularly when observed for a 15 minute period, suggesting sub-lethal impairment of their nervous systems. Nassarius reticulatus, the mud snail, was seen clumped about sub-tidal tubular green macroalgae (Enteromorpha) and suffered no apparent population mortality (Table 1).

The effects of the spill on polychaete populations in the area was difficult to determine. As experimentally observed, the fleshy corpses of these polychaetes decompose within 10 days following death. Since this study began 2 weeks after the initial spill occurred, reliable population estimates were impossible to assess. Surviving macrobenthic polychaetes (the sedentary Arenicola and errant nereids) appeared lethargic in their efforts to burrow back into the sediment, but sub-lethal impairment was difficult to substantiate. No attempt was made to estimate the meiobenthic polychaete population, which may have been the more predominant annelid form on this sand flat.

This area was revisited on 1 May 1978. No oil was observed on or below the surface of the sand flat or beach face. Analysis of 4 replicate samples revealed a reduction in species diversity and population. Where before, an average of 457 individuals of C. edule/m^2 existed, now only 114 per square meter were found. Full results of the second survey are presented in Table 2.

Rio del Burgo Estuary (B2)

Station B2 is a salt marsh environment located within the Rio del Burgo estuary (Fig. 2). Sediments of the area are composed of fine silts and clays. High fringe vegetation consisted of Juncus and Spartina grasses, while Zostera, eel grass, predominated in the lower marsh. At the time of the spill, the area was moderately contaminated by oil. Thick pools of oil accumulated along the high marsh fringe. Oil seeped into crab burrows, penetrating 15-20 cm deep into Spartina-covered mud-mounds at the upper reaches of the marsh. Most of the high marsh grasses were completely oil-blackened. A heavy oil sheen was observed along much of the lower marsh.

Species composition was similar to that of the Santa Cristina sand flat. Table 3 presents the population estimates and percent mortality data for each species at this study site. Species zonation is presented in Figure 7. Again, Cerastoderma edule suffered high mortality, while Scrobicularia suffered a lower (20%) population reduction. Many recently dead littorinid snails accumulated in the lower marsh area. Very few littorinids were found among intertidal

Spartina, where they would be expected to occur. The shore crab, Carcinus maenas, was found in two distinct regions of the marsh. Adult forms occurred at the high marsh region in burrow systems excavated within the Spartina covered mud-mounds; juveniles moved about over the lower muddy regions. Adults were oil coated; while juveniles were not, possibly indicating a recent molt. Surviving crabs seemed to suffer no impairment of locomotor function, and escape responses seemed to be unaffected.

Nereid population densities were nearly 40% lower than in the Betanzos control area. Nereids extricated from the heavily-oiled silty substrate writhed vigorously when placed in water containing an oil sheen, but exhibited normal locomotor rhythm when placed in clear water.

By the end of the first survey on 10 June 1976, new growth was visible on much of the previously-blackened marsh grass. By the second survey in 1978, most of the high marsh grasses appeared normal. However, the 1-2 m fringe area along the tidal flat/marsh interface had not fully recovered. Only short stubs of dead grass were present. A light oil sheen was still visible along much of the fringe. Several oil globs, 10 x 15 cm, were found in one previously-oiled area.

Puentedeume Marsh/Tidal Flat (B3)

Station B3 is a mud flat having a band of fringing marsh grasses. Its location is depicted in Fig. 2. Sediments consist mostly of silts and clays. Juncus and Spartina predominated in the high marsh fringe. Zostera grew over the entire lower mud flat.

Oil deposition was heavy along the fringing marsh. All grasses were oil blackened. An oil coating of 2-3 cm was commonly observed at the base of these grasses. Tidal flat sediments rinsed in clear sea water exuded an oil sheen. As the tide flooded the area, small oil globules and an oil sheen were observed to rise out of the sediment and become mobilized by tidal currents.

While community structure at Station B3 was similar to that observed at Santa Cristina and Rio del Burgo, species composition was distinctly different (Fig. 8). Species diversity was higher here than at any other station. In addition to the genera and species indicated in Table 4, thirteen other molluscan species were identified from sub-tidal samples (Table 5). At Puentedeume, as at Rio del Burgo, Cerastoderma edule and Littorina littorea suffered the highest mortalities. Scrobicularia plana, the predominant bivalve in this habitat, suffered 25% mortality (comparable to its mortality at other stations). Mortality in the gastropod, Hydrobia, was difficult to assess in the field because of their minute size (less than 6 mm). Observation of lomotion and orientation responses in polychaetes and crabs suggested that these organisms were unharmed. Small elvers (6.5 cm), which would be expected to be highly sensitive to spilled oil because of their high rate of oxygen consumption and high rate of metabolism (see Vernberg, 1972), were apparently unharmed.

Two years later, after returning to the station, a narrow (1 m) band of destroyed marsh grass was evident. Grasses previously only oil-blackened recovered fully. An oil sheen was apparent on the marsh surface, and minor traces of mousse could still be found. No algae were present on the mud flat, probably due to seasonal differences rather than the effects of the oil spill.

Porto Cobo (UQA-9)

The station at Porto Cobo is comparable to a typical New England rocky intertidal habitat. Sediments consist of mixed sand and gravel with outcropping bedrock along the low-tide terrace. Oil coverage at the time of the spill was heavy along the upper intertidal zone and on the rocks.

The effects of the spill were not as dramatically apparent here as compared with other stations but were still important. Shore crabs, Carcinus maenas, were oil blackened, but still exhibited normal shadow- and escape-responses. A school of small fish, seen swimming nearshore, exhibited variable behavior. While most fish swam, changing direction sharply and in a well-coordinated fashion, several individuals lost contact with the main school and became stranded on shore. When returned to the water, these individuals swam about, changing direction erratically, indicating sub-lethal damage. Nudibranchs, numerous within lightly-oiled tidepools, showed no response upon being prodded with a blunt instrument. The limpets, Acmea sp., Patella intermedia, and Patella aspera, were loosely attached to the rocks, being easily removed by hand. The oil seemed to interfere with their adhesive capability.

Playa de Ber (UQA-20)

Playa de Ber is a relatively exposed, fine-sand beach with outcropping bedrock on the low-tide terrace (Fig. 2). On our first visit during the spill, a large oil pool covered the low-tide terrace and much of the beach face. Sediment on the low-tide terrace was totally saturated with oil. Rocks were completely oil blackened on their shoreward face but generally free of oil on the side exposed to wave activity. Barnacles, limpets and intertidal macroalgae were oil covered. Mortality in amphipods was dramatic. Their bodies accumulated at the high tide swash line in high concentrations.

Revisiting the area two years later, we found minor repopulation of the sheltered rocks by intertidal fauna. Barnacles and limpets were not commonly observed. Patchy tar remained on the sheltered side of outcropping rocks. A large percentage of the exposed rock surfaces was covered by Enteromorpha, a tubular green alga. Living mussels and limpets were also observed on the wave-exposed rock surfaces. Between the rocks, a 4 m x 2 m x 30 cm patch of heavily-oiled sediment remained, possibly providing a source of continuous low-level hydrocarbon contamination to the adjacent areas.

Raso (UQA-22)

Raso is a flat, fine-sand beach located within the Ria de Ares. At the time of the spill, a 1 cm thick coat of oil covered the entire intertidal zone (Fig. 9a). As a result of the oiling, the high tide swash line was littered with thousands of dead amphipods (Fig. 9b). We estimate that over 125,000 amphipods were killed at this particular beach.

Our follow-up survey two years later, uncovered no trace of oil. However, eight quadrat analyses along the upper beach face revealed only two amphipod individuals. Apparently, repopulation of this area is very slow.

DISCUSSION

This study was limited by the short time given for preparation and field work and the unfortunate lack of baseline data. It should also be noted that the extensive offshore use of dispersants complicated evaluation of the singular effects of spilled oil. Biological damage could have been caused by the spilled crude oil, a mixture of oil and dispersant, or, though unlikely, the dispersant alone.

In our field study, quantitative examination of the Santa Cristina sand flat, the Rio del Burgo marsh, and the Puentedeume mud flat revealed a basic similarity in these mollusc and polychaete dominated communities. Quadrat sampling and analysis revealed that *Cerastoderma edule* was the macrobenthic species most susceptible to the lethal effects of spilled oil, suffering from 56-70% mortality. During the *Torrey Canyon* spill, *Cerastoderma* similarly suffered the greatest mortality among affected biota (Smith, 1968).

We consistently observed that *S. plana*, a deeper burrowing bivalve, suffered only a 20-30% population reduction. In addition, *L. littorea*, a high marsh species living on *Spartina* blades, was completely eliminated in the Rio del Burgo, while the sub-tidally occurring *N. reticulatus* showed high survivorship. It appears then that molluscs living at the water/sediment interface (*C. edule*, *L. littorea*) suffer the highest mortalities. Burrowing organisms living deeper below the sediment (*S. plana*, *V. decussata*, *T. tenuis*) or those living sub-tidally (*N. reticulatus*) seem to survive the effects of spilled oil to a greater degree than do surface-dwelling organisms. Therefore, while vulnerability to oil may appear species-specific, it may also be influenced by habitat preference. This hypothesis can be supported by a comparison of the size class versus the number dead for *C. edule* (Fig. 10). The pattern is similar on both graphs. The number of dead cockles is proportional to the number of individuals comprising that size class interval. If death in *C. edule* were due to disruption of some physiological process, then the pattern would not be similar. Smaller individuals, metabolizing at a much higher rate than larger individuals of the same species (Vernberg, 1972) would be expected to suffer higher mortalities. Since this is not the observed pattern, some other factor must be responsible for the death of *C. edule*. The physical clogging of respiratory membranes by oiled sand particles is suggested by the fact that dead cockle shells consistently appeared more heavily oil-stained in their siphonal region than did living cockles (see Nelson-Smith, 1972).

The impact of oil on polychaete populations is unclear because of a lack of previous baseline studies for each area and the rapidity with which fleshy bodies decompose in the marine environment. But it seems

9. The pre-spill structure of polychaete communities is difficult to assess because of rapid body decomposition following death. However, surviving lugworms (Arenicola) and nereid worms seemed to suffer no long-lasting impairment to locomotion.

10. Marsh grasses were subjected to heavy oil cover during the spill. Two years later, complete recovery was observed except for a narrow band of fringing marsh where the oil originally formed thick pools.

11. Two years after the spill, oiled rocky intertidal areas generally showed no signs of oil contamination. However, at de Ber, tar patches remained, and the number of organisms observed was low.

ACKNOWLEDGEMENTS

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clear that survivors suffered no short sub-lethal damage, as was observed in cockles and small, low-intertidal fish.

It was also difficult to assess the effects of the spill on the crab populations since exoskeletons of dead crabs may be transported by tidal currents and aggregate at the high water line. However, surviving crabs seemed to suffer no sub-lethal impairment to their normal behavior patterns. The fact that juvenile crabs conspicuously lacked the black coating that typified their older conspecifics may merely reflect that molting occurred during the interim between inital oiling and our investigations.

High mortality in L. littorea may have occurred as a result of the interference of oil with this species' ability to successfully adhere to its substrate. After death, these organisms might then be translocated within the estuary by the motion of the tide (Nelson-Smith, 1972). This would explain the large accumulations of L. littorea at the low water line in the Rio del Burgo marsh. Many limpets (Acmea sp., Patella spp.) affected by the oil may have been able to remain in position on the rocks though loosely attached because of their location in a generally low-wave energy environment.

CONCLUSIONS

From our observation of coastal environments affected by the Urquiola spill, we are able to conclude the following:

1. Edible cockle (Cerastoderma edule) populations suffered consistently high mortality ranging from 50-70% after the spill, probably as a result of the physical clogging of respiratory membranes by oiled particles.

2. Surviving cockles exhibited irregular pumping rates and a conspicuous absence of normal burrowing behavior.

3. Other bivalves (Scrobicularia plana, Tellina tenuis, Venerupus decussata), exhibited mortalities ranging from 19% to 30%.

4. Sub-lethal impairment of adhesive capability was observed in L. littorea and several species of limpets.

5. Sub-lethal impairment, in terms of orientation responses, in small, low intertidal fish was observed.

6. Sub-lethal damage to nudibranchs was evidenced by their complete lack of tactile responses when prodded by a blunt instrument.

7. Surviving decapod crabs and polychaete annelids seemed to be unaffected by the spilled oil.

8. Amphipod populations at the two fine-sand beaches, Playa de Ber and Raso, were completely destroyed by the oil, probably as a result of smothering. Limited recovery was observed 2 years later.

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Table 1. Population and Percent Mortality
Santa Cristina, 1976

	Population Density (No./Sq. m)	Mortality (%)
Cerastoderma edule	457	70
Scrobicularia plana	85	30
Nassarius reticulatus	48	0
Tellina tenuis	17	23
Venerupus decussata	5	19
Hydrobia	--	--
Arenicola	4	--
Nereis	2	--

Table 2. Population and Percent Mortality
Santa Cristina, 1978

	Population Density (No./Sq. m)	Mortality (%)
Cerastoderma edule	114	0
Scrobicularia plana	3	0
Carcinus maenas	3	0

Table 3. Population and Percent Mortality
Rio del Burgo, 1976

	Population Density (No./Sq. m)	Mortality (%)
Cerastoderma edule	200	56
Scrobicularia plana	89	20
Nereis	44	--
Carcinus maenas	38	38
Littorina littorea	15	100
Venerupus decussata	11	0
Hydrobia	11	--

Table 4. Population and Percent Mortality
Puentedeune, 1976

	Population Density (No./Sq. m)	Mortality (%)
Hydrobia	800	--
Nereis	75	--
Scrobicularia plana	70	25
Carcinus maenas	14	--
Littorina littorea	10	50
Anguilla anguilla	7	0
Cerastoderma edule	5	50
Mytilus edulis	3	0

Table 5. Molluscan Species also found at Puentedeume.

Barnea candida

Donax vitalis

Gibbula magus

Littorina littorea

Monodonata lineata

Mytilus edulis

Nassarius reticulatus

Natica catina

Ocenebra erinacea

Ostra edule

Spisula solida

Tellina tenuis

Trivia monacha

Venerupus decussata

Venerupus pallustra

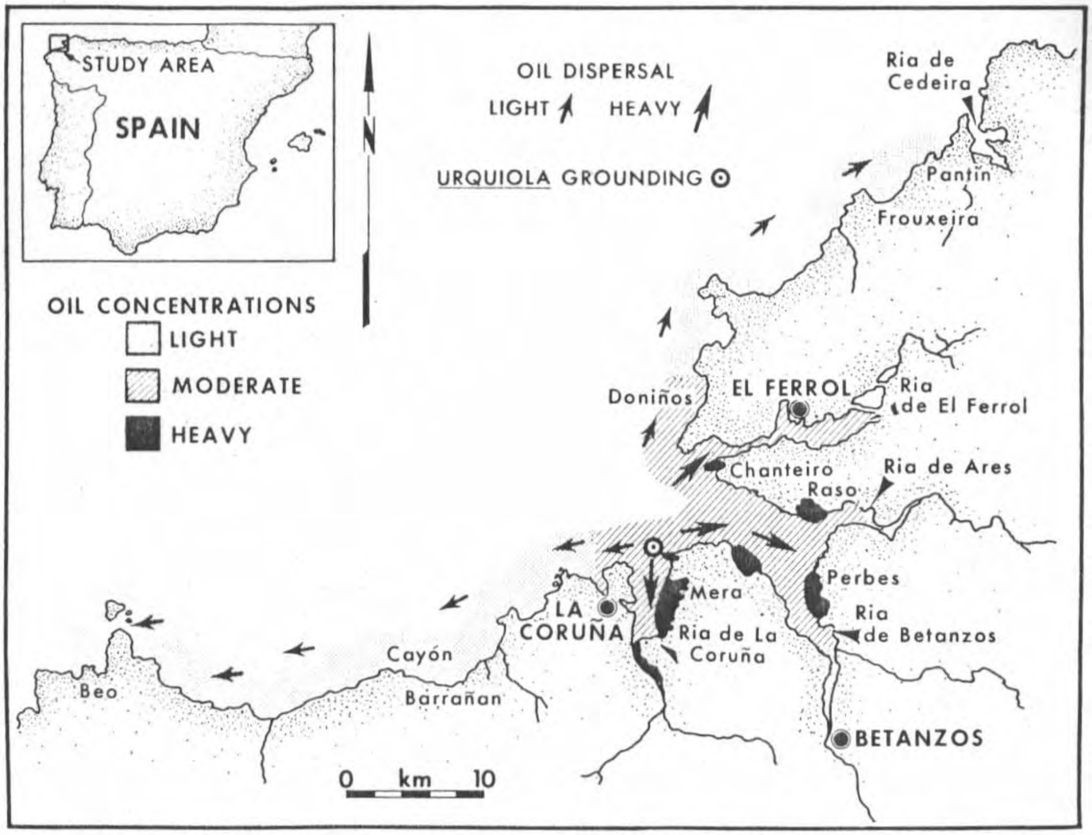


Figure 1. Location map for the URQUIOLA oil spill. In total, 215 km of shoreline was oiled; 60 km was moderately to heavily oiled (from Gundlach and Hayes, 1977).

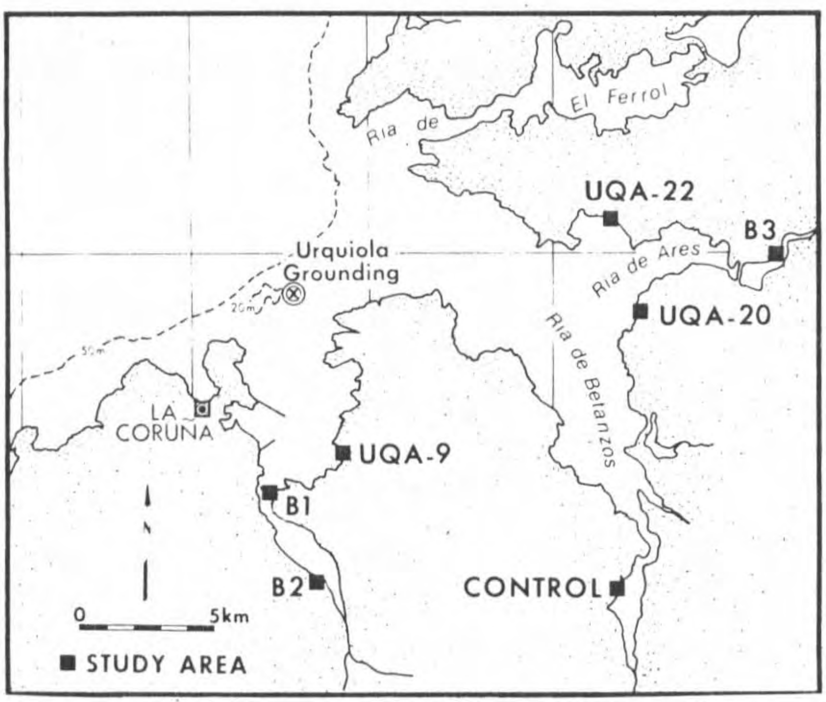


Figure 2. Location of study sites used in this report. Stations B1 to B3 and the CONTROL area were studied in detail using routine quadrat analysis methods.

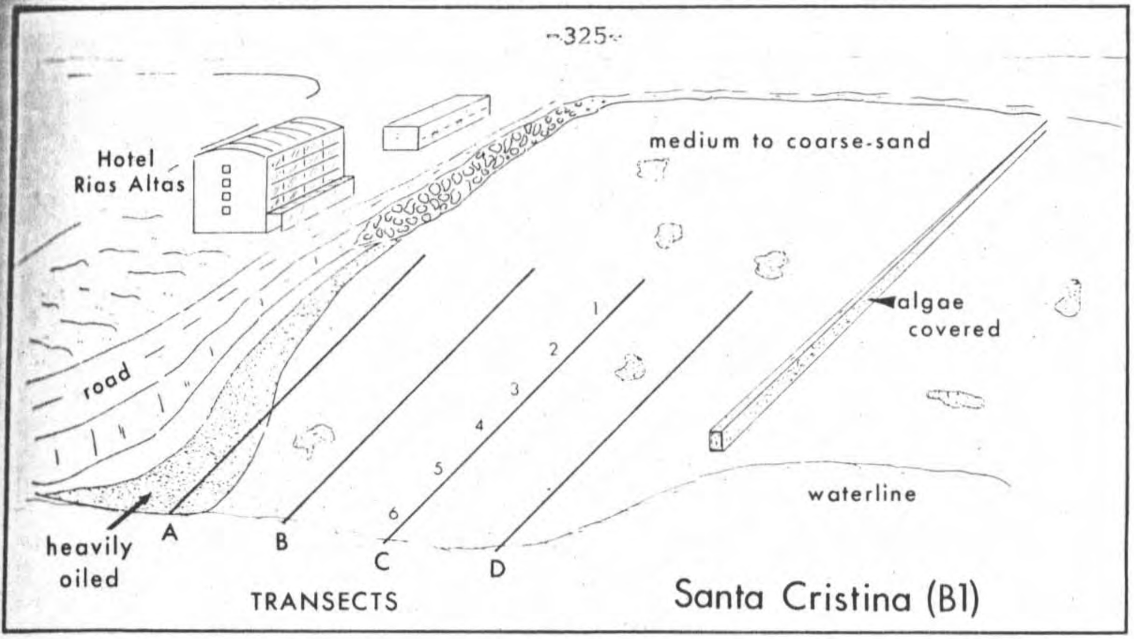


Figure 3. Sketch of the Santa Cristina sand flat (Station B1) on 2 June 1976. Transects were placed 25 m apart. Replicate samples at each of six stations along the transect were taken.

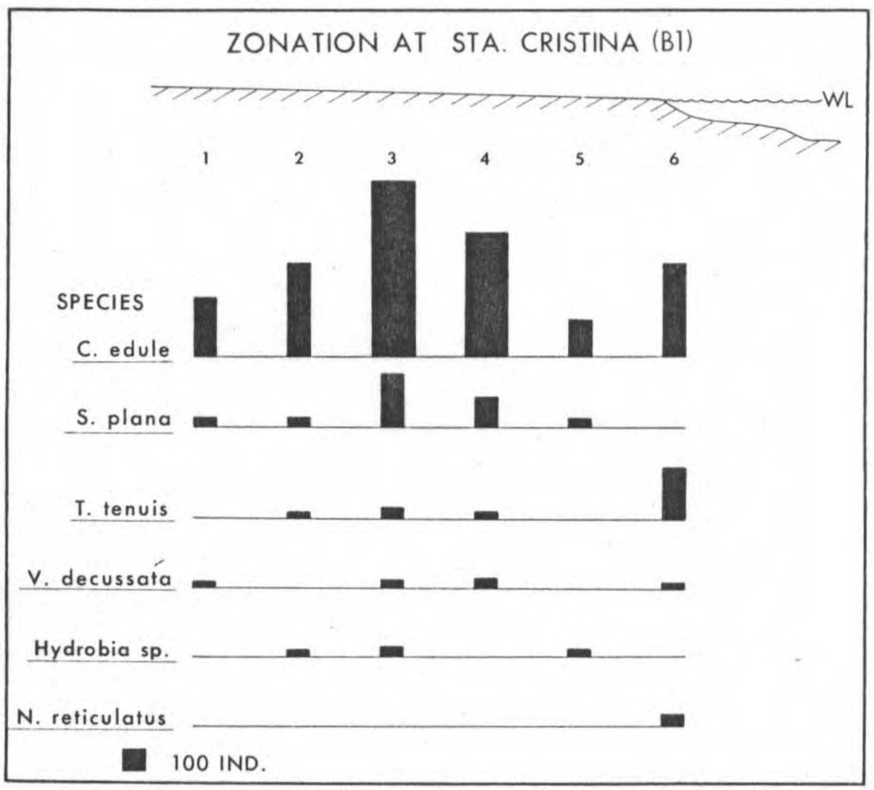


Figure 4. Zonation at Santa Cristina (B1) indicating the abundance and distribution of species along a transect.

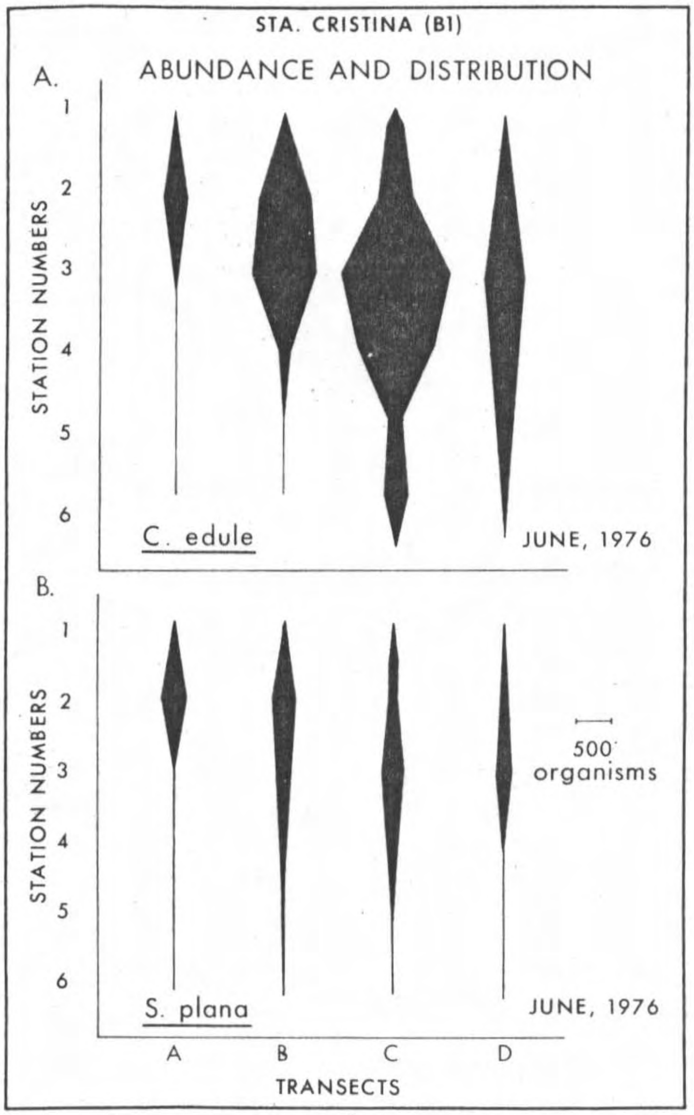


Figure 5. Zonation at Santa Cristina (B1) indicating the abundance and distribution of C. edule and S. plana along each of the four transects.

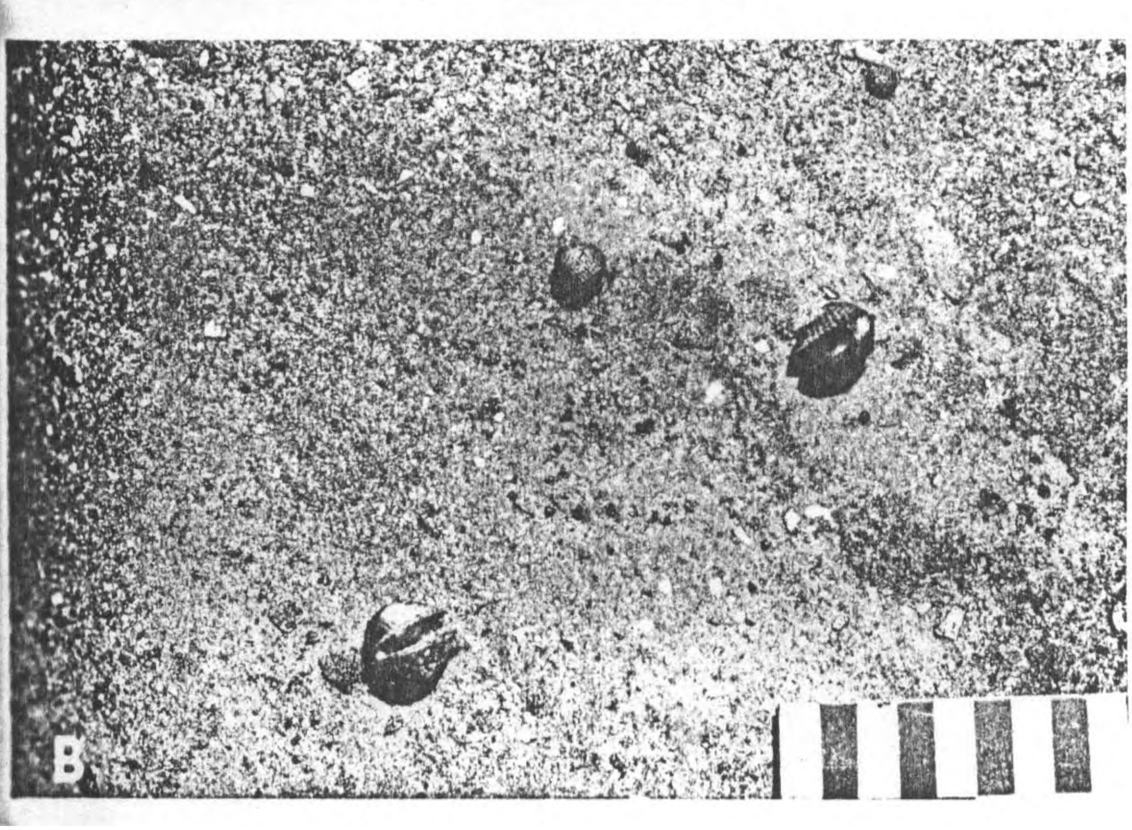


Figure 6. (A) The sand flat at Santa Cristina was dramatically affected by the spill. Millions of dead cockle shells littered the beach as shown here. (B) Close-up photograph of dying cockles (Cerastoderma edule).

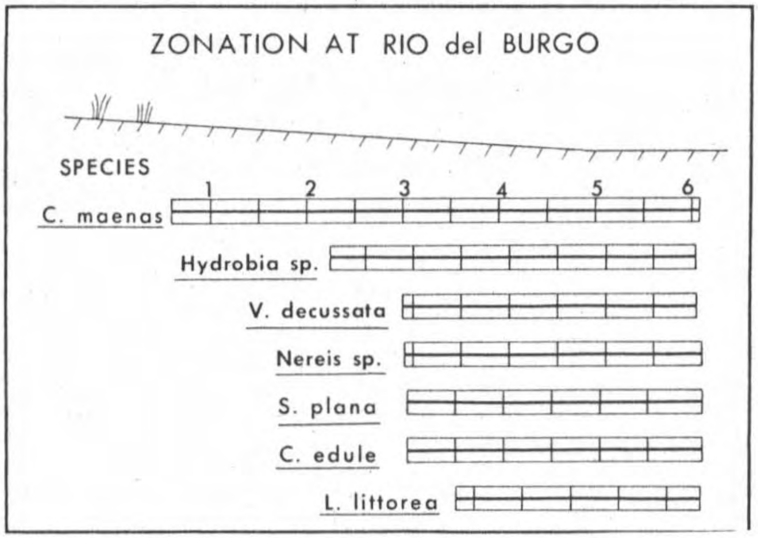


Figure 7. Zonation at Rio del Burgo (B2) indicating the distribution of species along a transect 300 m long.

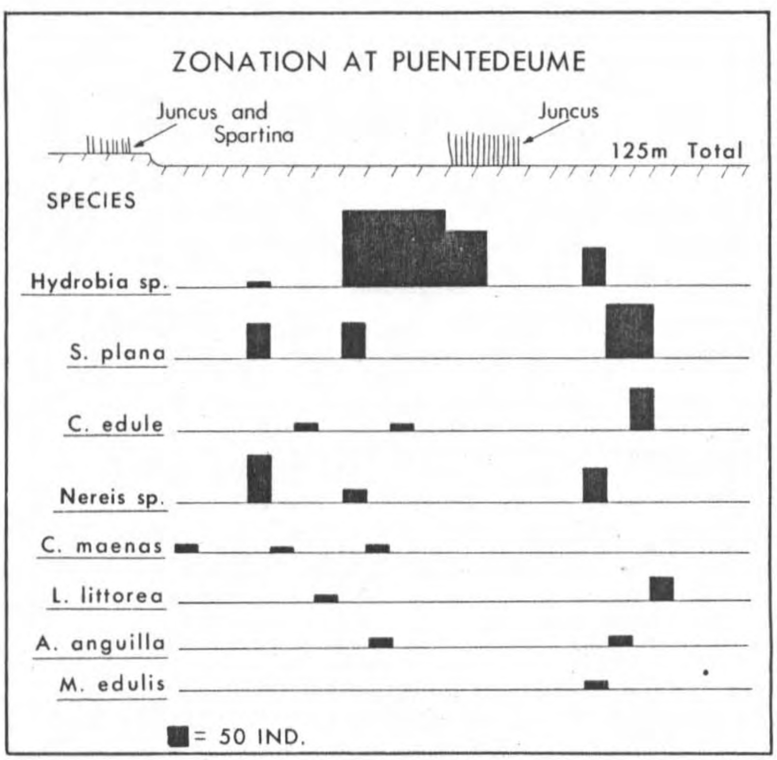
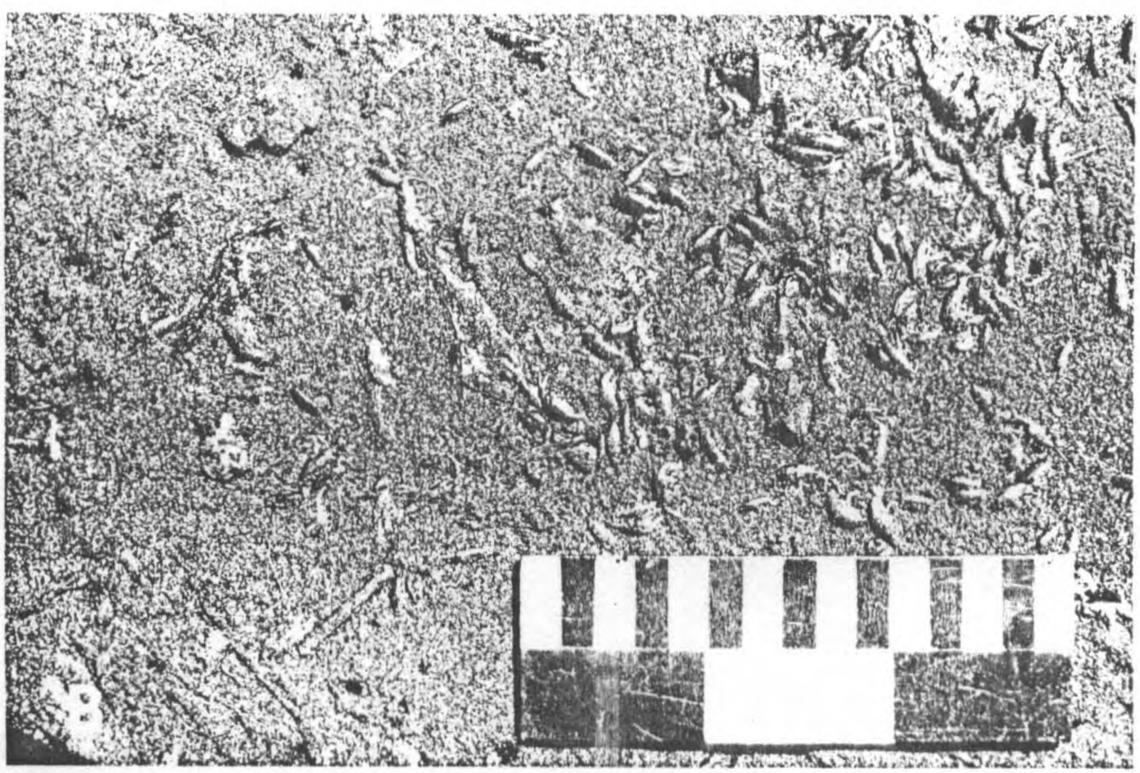


Figure 8. Zonation at Puentedeume (B3) indicating the abundance and distribution of species along a transect 125 m long.

Figure 9. (A) Heavily oiled beach at Playa de Raso (UQA-22) on 19 May 1976. The dead amphipods pictured in (B) were located along the high tide swash line.



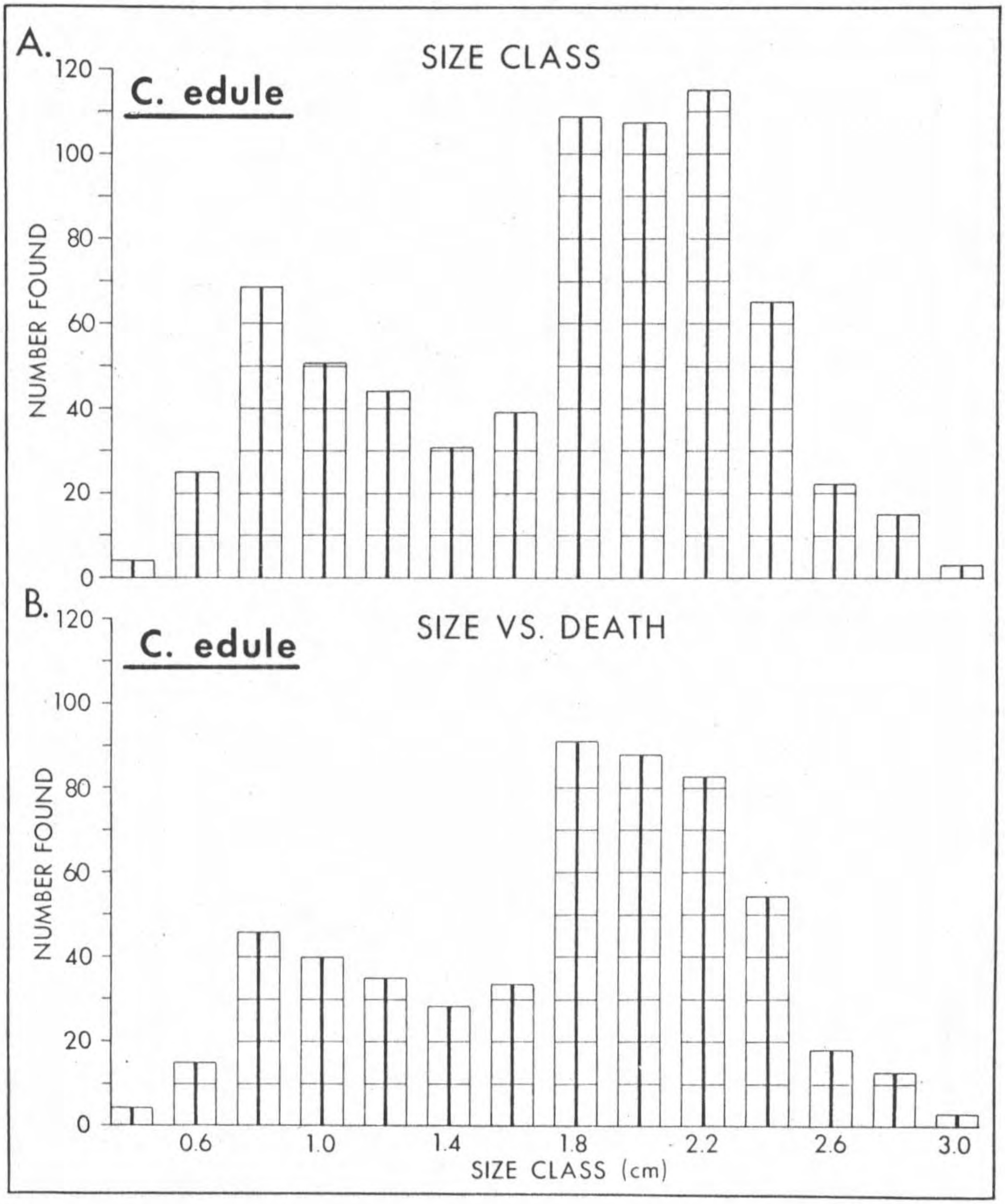


Figure 10. These histograms, based on an analysis of samples taken at Santa Cristina, indicate that the number of dead cockles, Cerastoderma edule, within each size-class interval, is proportional to the number of individuals comprising that size class throughout the entire population size-range.