Journée spéciale "AMOCO CADIZ", Brest, France, 7 Juin 1978.
Publications du C.N.E.X.O. Série "Actes de Colloques" n° 6 - 1978 : page 175 à 192

ONSHORE SURVEY OF MACROBENTHOS ALONG THE BRITTANY COAST FOLLOWING THE AMOCO CADIZ OIL SPILL

by

Jeffrey L. Hyland
U.S. Environmental Protection Agency
Environmental Research Laboratory
Narragansett, Rhode Island

RESUME

Une étude écologique preliminaire a été faite le long de la côte nord de Bretagne afin d'évaluer le choc initial de la fuite de petrole venant du vaisseau Amoco Cadiz sur les communautés macrofauniques intertidales. Le but spécifique était d'observer sur les plages souillées, les organismes manifestement couverts de pétrole, les organismes morts et les organismes moribonds; et de faire une étude limitée de la structure et de la composition des communautés benthiques en péril de souillure par le pétrole. On discute les résultats de ces études pour plusieurs habitats différents.

ABSTRACT

A preliminary ecological survey was conducted along the northern Brittany coast for the purpose of evaluating the initial impact of the Amoco Cadiz oil spill on intertidal macrofaunal communities. Specific objectives were to observe obviously oiled, dead, or moribund organisms on contaminated beaches, and to conduct a limited examination of the structure and composition of benthic communities considered at risk to impact. Results reflecting these objectives are discussed for a variety of habitats.

MOTS-CLES: Amoco Cadiz, pétrole brut, étude écologique, intertidal, communautés macrofauniques, impact de pétrole.

KEY WORDS: Amoco Cadiz, crude oil, ecological survey, intertidal, macrofaunal communities, oil impact.

INTRODUCTION

On March 16, 1978, the supertanker Amoco Cadiz lost her steering and ran aground on rocky shoals approximately 1.5 km offshore of Portsall, France. The vessel was carrying two cargos of light mideastern crude oil, amounting to 223,000 tons, in addition to 4000 tons of bunker fuel. On the morning of March 17, the vessel broke apart forward of the wheelhouse, and during the following 15 days released all of the oil into neighboring waters. Prevailing northwest winds together with strong waves and tidal currents drove much of the oil onshore, heavily impacting nearly 140 km of the Brittany coast from Portsall east to Ile de Brehat.

Immediately after the spill, a team of American scientists from the U.S Environmental Protection Agency and the National Oceanic and Atmospheric Administration visited the area to assist French scientists in assessing the impact of the spill. Overall results of this joint research effort are discussed in Hess (1978). As a part of that effort, a preliminary intertidal survey was conducted on 3/27-3/31/78 from Argenton to Ile Grande for the purpose of developing a general understanding of the extent of the oiling and the magnitude of initial onshore ecological impact. Two specific objectives of this preliminary survey were (1) to observe and photograph obviously oiled, dead, or moribund organisms found on contaminated beaches, and (2) to conduct a limited examination of the structure and composition of benthic macrofaunal communities considered at risk to impact. Results reflecting these two objectives are discussed herein for each of several habitats investigated.

SAMPLING TECHNIQUES AND TREATMENT OF DATA

Research stations varied in habitat type and included an intertidal sand cove with algal-coated rocky zones (Roscoff-EPA station 1); a salt marsh (Ile Grande-EPA station 2); and a high energy, ocean-exposed sandy beach backed by steep dunes (Corn ar Gazel-EPA station 3). Station locations are illustrated in Figure 1. Each station was photographed and samples of dead, moribund, and oil-coated organisms were returned to the laboratory for gross observation and species identification.

At each station, samples were also collected for examination of the structure and composition of macrofaunal communities. Sampling was conducted during low tide, three to five days after the arrival of spring tides. In the rocky intertidal zone at Roscoff, density estimates of epifauna were made at five substations using 0.25 m^2 quadrats. Infaunal samples were collected at Roscoff from three additional sandy substations (high water mark on beach at Mariner's Home--substation 1-1; middle of cove between Roscoff and tip of Perharidic peninsula---substation 1-2; and low water mark at mouth of cove, near edge of channel between Roscoff and Ile de Batz--substation 1-3). Infauna alone were sampled from one substation at Ile Grande (on a mud flat along southern edge of main channel intersecting highway D21) and from three sandy substations at Corn ar Gazel (10 m above low water mark--substation 3-1; low water mark--substation 3-2; and 5 m below low water mark--substation 3-3). At each infaunal substation, 10 replicate samples were collected with a 0.01 m^2 PVC corer to a depth of 20 cm. Replicate samples were then pooled together and rough sieved through a 2.0 mm screen. Contents on the screen were preserved in 10% formalin in the field and returned to the laboratory for identification and enumeration of all macroinvertebrates. Most organisms were identified to the species level with the aid of the following literature:

Polychaeta: Fauvel (1923, 1927), Clark (1960), Day (1967)

Mollusca: Cornet and Marche-Marchad (1951), Allen (1962), Tebble (1966).

Crustacea: Sars (1890), Truchot and Toulmond (1964), Bourdon (1965), Allen (1967), Barnard (1969), Bouvier (1940), Chevereux and Fage (1925).

Other general works which were useful included Barrett and Yonge (1958), Eales (1967), Day (1969), and Gosner (1971).

Data analysis included the generation of preliminary species lists with numerical abundances and the calculation of several community structural indices. These included species diversity (H', in bits per individual; from Shannon and Weaver, 1963), species richness (Gleason diversity, D_G; from Gleason, 1922), and evenness (J'; from Pielou, 1966). Together these indices reflect the variety of species within a sample and the evenness of distribution of individuals among the species present.

Additional samples of sediment and organisms were collected from each station for routine hydrocarbon analysis, the results of which are discussed in Hess (1978).

Field work was facilitated through the services of James Lake (U.S. Environmental Protection Agency, Narragansett, RI) and Ford Cross (U.S. National Marine Fisheries Service, Beaufort, NC). Taxonomic assistance was provided by Sheldon Pratt (Oceanography Dept., University of Rhode Island, U.S.A.), Robert Bullock (Zoology Dept., University of Rhode Island, U.S.A.), and John Scott (U.S. Environmental Protection Agency, Narragansett, RI).

ROCKY INTERTIDAL ZONE AT ROSCOFF

The five rocky intertidal substations (quadrats) were randomly positioned on boulders located approximately 30 m below the high water mark on the beach at the Mariner's Home. The substations may be regarded as replicates since they were apparently exposed to similar environmental conditions and were located at similar depths (0.5 to 1.5 m from the bottom). Table 1 lists epifaunal species identified and enumerated within the five substations. These commonly occurring species are considered members of the mesolittoral zone and were found attached or crawling on the bare rock or on dense patches of algae (mostly *Ascophyllum nodosum* and *Fucus spp.*) Table I includes only the obvious species which were large enough to recognize and enumerate in the field, and is therefore exclusive of the smaller organisms, particularly amphipods and small gastropods, associated with microhabitats. Limpets (*Patella vulgata*) and periwinkles (*Littorina obtusata* and *L. littorea*)were the most numerous.

Other species included the gastropod, Gibbula umbilicalis; the chiton, Lepidochitona cinereus; the tube dwelling polychaete, Spirorbis borealis; and the barnacle, Elminius modestus.

All species within these quadrats were exposed to the oil, as thick layers of oil still heavily coated the rocks and algae. Consequently, most organisms were considered at risk to impact and some were in fact dying at the time the survey was conducted on March 29. Limpets and periwinkles for example were particulary impacted, and dead and moribund individuals were observed at the base of the rocks. Some limpets were beginning to lose purchase on the rocks and were easily removed with the flick of a finger. Limpets are unable to hold their shells firmly against the substrate for prolonged periods of time, since the adductor muscles must relax occasionally allowing the shells to lift slightly. In heavily oiled areas, the oil can then penetrate beneath the shell margin, thus contaminating the gills and other delicate tissues. Macroscopic examination of the limpets revealed contamination of the soft body parts and deterioration of the flesh. Shore birds were observed feeding on the upturned shell contents.

Other epifaunal species not necessarily occurring within the five quadrats were found dead or moribund in the immediate vicinity. These included the topshells (Gibbula cineraria, G. umbilicalis, and Calliostoma zizyphinum) and the green crab (Carcinus maenus) (Figure 2). Microscopic examination of dissected crabs revealed that the oil had formed a thick coating around the gills.

These same rocky intertidal species were similarly affected along Cornish coasts in 1967 after exposure to a mixture of detergents and crude oil spilled from the Torrey Canyon (Smith, 1968; Nelson-Smith, 1968a). However, in contrast to Smith's account that oil alone had resulted in little harm to shore life, and that ecological effects were induced mostly by the application of detergents, the current impact to rocky intertidal organisms was observed in an area where detergents were allegedly not used prior to sampling.

Mussels, Mytilus edulis, were not observed on the rocks at Roscoff. However, dense populations were found subsequently at Locquirec. The mussels were oiled, yet they appeared unharmed at that time.

INTERTIDAL SAND COVE AT ROSCOFF

The sandy cove between Roscoff and the Perharidic peninsula is almost entirely exposed at low tide. Consequently, oil was initially concentrated in thick layers high up on the beaches, and then with receding tides was also dispersed throughout the cove. This spreading was observed as visible droplets of mousse at depth in the sediment and as occasional surface stains even in the middle of the cove. That the underlying sediment and pore water contamination had reached toxic levels was evident since some dead and moribund infaunal specimens were collected throughout the cove, particularly toward the beachface where the oil was most concentrated. These species included the edible cockle, Cardium edule, the carpet shell, Venerupis decussata, and the polychaete, Nereis diversicolor (Figure 2). The epifaunal green crab, Carcinus maenus, was also found dead in large numbers.

Quantitative sampling of the sand substations revealed a generally diverse infaunal assemblage, consisting of a rather large number of species in comparison to the other stations (Table 2). Twenty-one species were found, representing 78% of the total number of species found at all stations combined. The dominant organisms were the two polychaetes, Nereis diversicolor, which was found at substation 1 at a density of 52 per 0.1 m^2, and Scoloplos armiger, which was found at moderate densities (12 to 17 per 0.1 m^2) at all three substations. Abundant on the sediment surface were the shingled tubes (90/m^2) of the polychaete, Lanice conchilega, and casts (36/m^2) of the lugworm, Arenicola marina. However, these species were not well represented in the infaunal samples.

Community structure and composition varied between substations, with the number of species and other structural indices increasing from substation 1 to substation 3. At substation 3, 15 species per 0.1m^2 were recovered, and relatively high values for H' (3.34), D_G (7.51), and J'(0.85) were recorded. In contrast, at substation 1 only 6 species per 0.1 m^2 were sampled and values for H' (1.30), D_G (2.66), and J' (0.50) were relatively low. Intermediate values were observed for substation 2. Each substation was intertidal, yet environmental conditions generally varied between them. For example, substation 1 was located at the high tide mark on the beach at the Mariner's Home; substation 2 was located in the middle of the cove, approximately 0.5 km from the mouth; and substation 3 was located at the low water mark at the mouth of the cove. Furthermore, sediment grain size increased toward substation 3, while visible levels of petroleum contamination increased toward substation 1. Possible explanations for the observed variation in community structure and composition between substations then are: (1) the greater availability of microhabitats toward substation 3 as a result of the increase in sediment grain size, (2) an increase in environmental stability toward substation 3 as a result of a decrease in shoreward influences (breaking surf, atmospheric exposure, etc.), and the elimination of some species from substation 1 as a result of the greater concentration of oil on the beachface. Without additional data, however, it is difficult to determine which of these factors (if any) are most significant.

Since such a large number of organisms were found still living within the sediments at the time of sampling on March 29, it appeared that up to this time many of these infaunal species (particularly toward the channel edge) had escaped initial impact. Perhaps the sediment itself provided a blanket of protection against immediate impact, whereas a greater number of rocky intertidal organisms succumbed to the effects of direct physical contact with heavy oil slicks. These infaunal assemblages are nonetheless considered threatened in view of several observations including the visible levels of sediment and pore water contamination throughout the study area, and the observed death of infauna (e.g., cockles, clams, and polychaetes) in the immediate vicinity. Subsequent surveys of neighboring localities (e.g., at St. Michel-en-Greve four days later) revealed massive kills of infauna, particularly heart urchins (Echinocardium cordatum) and razor clams (Pharus legumen and Ensis siliqua). Dead urchins and razor clams were similarly reported along the Cornish coast after the Torrey Canyon spill (Smith, 1968). Also, impact of oil spills on soft-bottom intertidal communities has been reported elsewhere in the literature by Hampson and Sanders (1969), Thomas (1973), and Bender, Hyland, and Duncan (1974).

One striking observation was the presence of reproductively active polychaetes throughout the infaunal samples. Perinereis cultrifera was found in its heteronereid stage, while other polychaetes including Phyllodoce sp., Glycera convoluta, and Nephtys hombergii were carrying numerous ripe ova. It is possible that adult mortality at such a sexually productive period could have a local impact through reduced recruitment of young, thus significantly altering the numerical distribution of species for some time to come. Larval forms are also known to be extremely sensitive to petroleum pollutants.

SALT MARSH AT ILE GRANDE

Oil coverage of the marsh at Ile Grande was extensive, contaminating vegetation (Juncus sp., Spartina patens, and Salicornia sp.) and leaving most mud surfaces coated with several centimeters of mousse. Dead and moribund invertebrates were commonly found in large numbers on the oil-soaked mud flats, and included polychaetes (Nereis diversicolor and Arenicola marina), cockles (Cardium edule), and green crabs (Carcinus maenus) (Figure 3).

Quantitative sampling of the infauna was conducted on March 30 along a mud flat immediately adjacent to the main channel. Sampling was nearly impossible due to the nature of the soft sediments coupled with the extent of oiling. Therefore only one substation was sampled, and this became feasible only after scraping away large areas of surface oil. Table II reveals the extremely low diversity at this site, reflecting the presence of only two species, namely Nereis diversicolor and Arenicola marina. Although Nereis was the most abundant, neither were found alive in large numbers.

It is not uncommon to find low species diversity in salt marshes. However, many characteristic marsh species still large enough to be sampled in a 2.0 mm sieve (e.g., larger gammarid amphipods, capitellid and spionid polychaetes, and lamellibranch molluscs) were absent from the collection. It is felt then that the observed absence of species is not only a result of the natural tendency for marshes to exhibit low numbers of species, but also a result of the demise of organisms due to the impact of the spill. As mentioned above, numerous dead infaunal organisms were found in the sampling area. Also, a day earlier at this same site, Eric Gundlach (Research Planning Institute, Columbia, SC, U.S.A.) reported that thousands of moribund polychaetes were attempting to escape their oily environment by emerging from the sediment, only to wind up on the surface of oil pools. Ecological damage to salt marsh communities has been reported previously as a result of the Chryssi P. Goulandris spill in Milford Haven, England (Nelson-Smith, 1968b); the Arrow spill in Chedabucto Bay, Canada (Thomas 1973); and the West Falmouth spill in Massachusetts, USA (Michael, et al., 1975).

INTERTIDAL SAND BEACH AT CORN AR GAZEL

Station 3 was situated on a high energy, ocean-exposed sandy beach, located approximately 500 m NW of the small town of Corn ar Gazel and 6 km SE of the wreck site. The beach was apparently once well coated with oil, since at the time of sampling on March 31 occasional stains and droplets were still visible both on the surface and at depth in the sediment. Also, grass growing on the sides of the steep dunes still revealed visible traces of oil. For the most part, though, the waves and tides effectively removed the bulk of surface oil from the beachface. On the other hand, seaward the oil was still heavily concentrated and appeared as an oil-in-water emulsion throughout the water column. Nearby boulders located just offshore were still heavily oiled.

Toxicity was apparent as the jetsam line was littered with a large number of dead and moribund organisms, many of which revealed visible quantities of oil. These species included the edible crab, Cancer pagurus; an unidentified fish; the lugworm, Arenicola marina; an unidentified Holothuroidean (sea cucumber); the gastropods, Patella sp., Calliostoma zizyphinum, Gibbula cineraria and G. umbilicalis; and the bivalves Dosinia exoleta, Venerupis pullastra, and Venus verrucosa (Figure 4). Some of these were washed up from the neighboring rocks (e.g., Patella and Gibbula), while others arrived from the soft-bottom intertidal and subtidal areas. Oil was also lethal to organisms living higher up on the shore. For example, Eric Gundlach observed on a similar beach 5 km west thousands of dead sand hoppers, Talitrus saltator, which normally live among the deposited jetsam. Many of these species were similarly affected after the Torrey Canyon spill (Smith, 1968).

Table II reveals the results of the quantitative sampling of infauna. There were no clear patterns in the distribution of species between substations and any variation is most likely attributable to normal spatial patchiness. Values for the number of species, species diversity, and richness were generally between those observed at stations 1 and 2, while values for J' for all three substations were particularly high, revealing an even distribution of the relatively few individuals among the species present. Because so few organisms were present in the samples, a more detailed discussion of community structure is unwarrantable. Fewer organisms (particulary at substation 2) in comparison to the situation at Roscoff was most likely a result of natural factors, since the physical environment here was less stable (e.g., shifting sands and exposure to wave action). However, one should not rule out the possibility that fewer organisms were found as a result of the oil, since visible oil levels were observed both in the water column and in the sediments, and since many dead and moribund organisms were observed on the sediment surface in the immediate vicinity.

Here, as elsewhere, several species of polychaetes that were still alive were found in sexually productive states. Glycera convoluta, Nephtys hombergii, Audouinia tentaculata, and Arenicola marina were all carrying ova. One dead Arenicola was examined and also contained a large number of ova.

CONCLUSIONS

To assess the impact of the spill on onshore macrobenthos, a preliminary survey was conducted with two objectives in mind: to observe and photograph obviously oiled, dead, or moribund organisms found on contaminated beaches; and to conduct a limited examination of the structure and composition of macrofaunal communities considered at risk to impact. Sampling was necessarily very limited in scope due to the urgency to complete an immediate, broad-scale spill damage assessment. Accordingly, the overall purpose of this work was to aid in developing a general understanding of the extent of oiling and magnitude of initial onshore ecological impact. In addition, it is anticipated that the preliminary species lists and observations presented herein will provide useful "quasibaseline" information for comparison with more definitive, long-term studies which may be conducted in the future.

Research stations were established two weeks after the spill in a variety of habitats and included an intertidal sand cove with algal coated rocky zones (Roscoff); a salt marsh (Ile Grande); and a high energy, ocean-exposed sand beach (Corn ar Gazel). All stations were heavily oiled, however the marsh at Ile Grande was the most polluted with surface oil accumulating to several centimeters. Removal of visible surface oil from the substrate as a result of the waves and currents was most effective at the higher energy stations, particularly at Corn ar Gazel. However, even at Corn ar Gazel, traces of sediment and pore water contamination were still observed at depth in the sediment two weeks after the spill. Removal of visible oil form algal-coated rocks and salt marshes was less effective.

Lethal effects of the oil were apparent from the number of dead and moribund organisms collected at the various stations. Affected species included limpets (Patella vulgata), periwinkles (Littorina obtusata and

L. littorea), topshells (Gibbula cineraria, G. umbilicalis, and Calliostoma zizyphinum), cockles (Cardium edule), clams (Venerupis decussata), polychaetes (Nereis diversicolor), and green crabs (Carcinus maenus) at Roscoff; polychaetes (Nereis diversicolor and Arenicola marina), cockles (Cardium edule), and green crabs (Carcinus maenus) at Ile Grande; and edible crabs (Cancer pagurus), fish (unidentified), sea cucumbers (unidentified), limpets (Patella sp.), and top shells (Gibbula cineraria, G. umbilicalis, and Calliostoma zizyphinum) at Corn ar Gazel. Numerous dead amphipods (Talitrus saltator), sea urchins (Echinocardium cordatum), and razor clams (Ensis siliqua and Pharus legumen) were collected from neighboring sites.

Samples of the living organisms remaining at each of the stations were collected to provide a limited description of community structure and composition. Sampling of infauna revealed a relatively high diversity of species for the intertidal sand cove at Roscoff, an intermediate level for the sand beach at Corn ar Gazel, and an extremely low level for the marsh at Ile Grande. For the most part, the observed variation in community structure reflects the natural variation in environmental conditions between contrasting habitats (e.g., protected sand cove vs. ocean-exposed beach vs. marsh). However, for some areas (particularly in the heavily oiled marsh) abnormally low numbers of species and individuals could have resulted partly from the impact of the oil. All of these infaunal communities are nonetheless considered threatened by the spilled oil because of the visible sediment and pore water contamination and the observed kill of organisms in the immediate vicinity of sampling. If possible, subsequent observations in these areas are recommended to delineate future changes in the numerical and spatial distribution of species.

All of the epifaunal species observed at Roscoff rocky intertidal substations were directly exposed to heavy oil slicks, and some (particularly limpets) were dead or moribund at the time of sampling. Similarly, these communities are considered threatened, and again subsequent observations to delineate population changes are recommended.

Several species of oil-impacted polychaetes were examined microscopically and were observed in sexually active states. The heteronereid stage of Perinereis cultrifera was found in one sample, and other polychaetes (Phyllodoce sp., Glycera convoluta, Nephtys hombergii, Audouinia tentaculata and Arenicola marina) were carrying numerous ripe ova. Widespread adult mortality during such a sexually productive period could affect the future recruitment of species, accentuating the ecological significance of the initial impact.

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TABLE I. Species List with Numerical Abundances (No.'s per 0.25 m^2) for Rocky Intertidal Quadrats at Roscoff

Quadrat No.:	1	2	3	4	5
Gastropoda					
Patella vulgata	2	-	4	16	16
Littorina obtusata	1	-	1	6	-
Littorina littorea	-	-	1	-	-
Gibbula umbilicalis	-	-	-	1	-
Polychaeta					
Spirorbis borealis	occasional calcareous tubes	2	-	occasional calcareous tubes	-
Amphineura					
Lepidochitona cinereus	-	-	1	-	-
Cirripedia					
Elminius modestus	-	-	dense population	-	-
Algae					
Mostly Ascophyllum nodosum and fucus spp.	←	80 to 100% cover			→

TABLE II. Species List With Numerical Abundances and Associated Structural Indices for the Three Infaunal Stations.

Station:	Roscoff[1]			Ile Grande[2]	Corn ar Gazel[3]		
Substation:	1-1	1-2	1-3	2	3-1	3-2	3-3
Polychaeta							
Nereis diversicolor	52	1	-	14	-	-	-
Scoloplos armiger	17	12	15	-	-	-	2
Polycirrus aurantiacus	1	1	1	-	-	-	-
Notomastus latericeus	2	5	20	-	-	-	-
Arenicola marina	-	1	-	1	-	-	1
Nephtys hombergii	-	1	1	-	3	-	-
Spio filicornis	-	1	5	-	1	-	1
Nicomache sp.	-	5	-	-	-	-	-
Aonides oxycephala	-	-	1	-	-	-	-
Nephtys sp.	-	-	1	-	-	-	-
Perinereis cultrifera	-	-	3	-	-	-	-
Lanice conchilega	-	-	3	-	-	-	-
Syllis sp.	-	-	1	-	-	-	-
Phyllodoce sp. A.	-	-	1	-	-	-	-
Phyllodoce sp. B.	-	-	-	-	-	-	1
Clymene sp.	-	-	13	-	-	-	-
Harmothoe lunulata	-	-	-	-	1	-	-
Glycera convoluta	-	-	-	-	-	-	2
Audouinia tentaculata	-	-	-	-	-	-	4
Amphipoda							
Haustorius arenarius	2	-	-	-	-	-	-
Phoxocephalopsis deceptionis	1	1	-	-	-	-	-
Decapoda							
Carcinus maenus	-	1	1	-	-	-	-
Cancer pagurus	-	-	-	-	-	1	1
Bivalvia							
Tellina tenuis	-	1	-	-	-	-	-
Loripes lucinalis	-	4	1	-	-	-	-
Loripes sp.	-	-	6	-	1	-	-
Gastropoda							
Littorina obtusata	-	-	-	-	1	1	-
S (No. species/0.1 m^2)	6	12	15	2	5	2	7
N (No. indiv./o.1 m2)	75	34	73	15	7	2	12
H'	1.30	2.90	3.34	0.35	2.13	1.00	2.58
D_G	2.66	7.18	7.51	0.85	4.71	3.33	5.56
J'	0.50	0.81	0.85	0.35	9.91	1.00	0.91

Figure 1. Location of Environmental Protection Agency (EPA) research stations. Note: Only stations 1 through 3 are relevant to the study discussed herein.

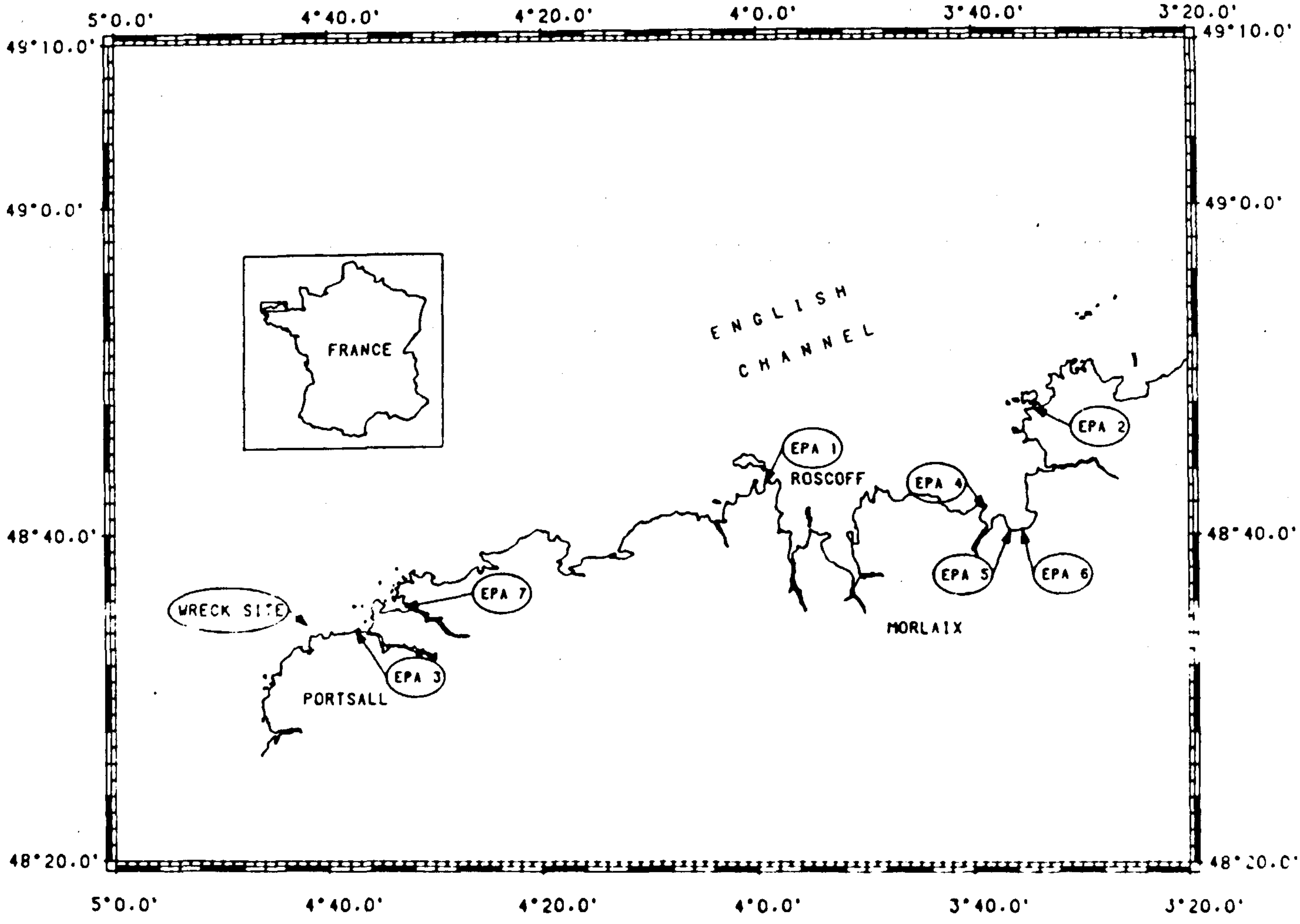

Figure 2. Dead and moribund organisms at EPA Station 1, Roscoff. Left to right: Top row = *Venerupis decussata*, *Cardium edule*, *Patella vulgata*, and *Littorina littorea* (with attached *Elminus modestus*). Middle row = *Littorina obtusata* (one black and one yellow specimen), *Gibbula umbilicalis*, *Gibbula cineraria*, and *Calliostoma zizyphinum*. Bottom row = *Nereis diversicolor* and *Carcinus maenus*.

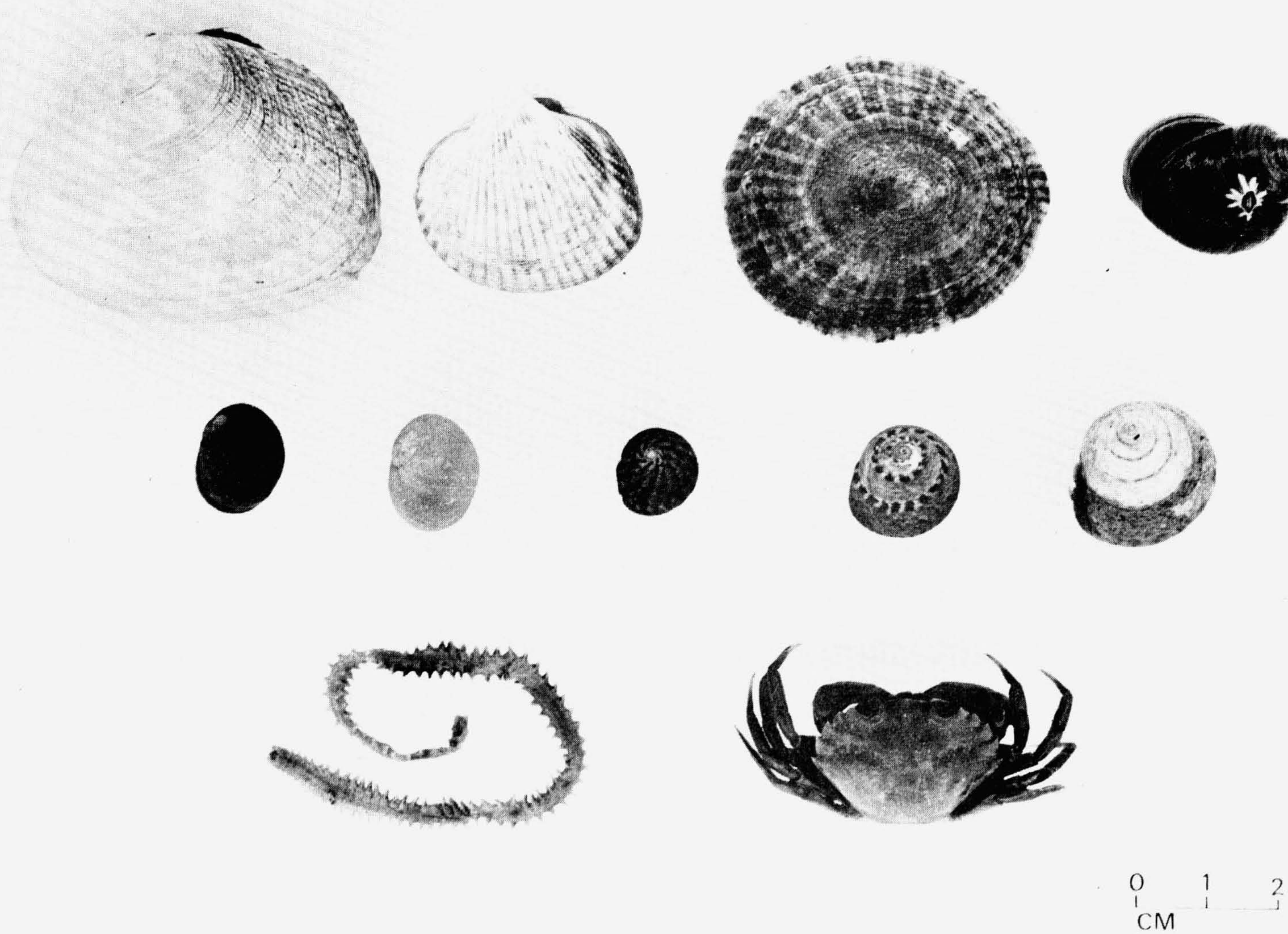

Figure 3. Dead and moribund organisms at EPA Station 2, Ile Grande. Left to right: Top row = *Carcinus maenus* and *Cardium edule*. Bottom row = *Arenicola marina* and *Nereis diversicolor*.

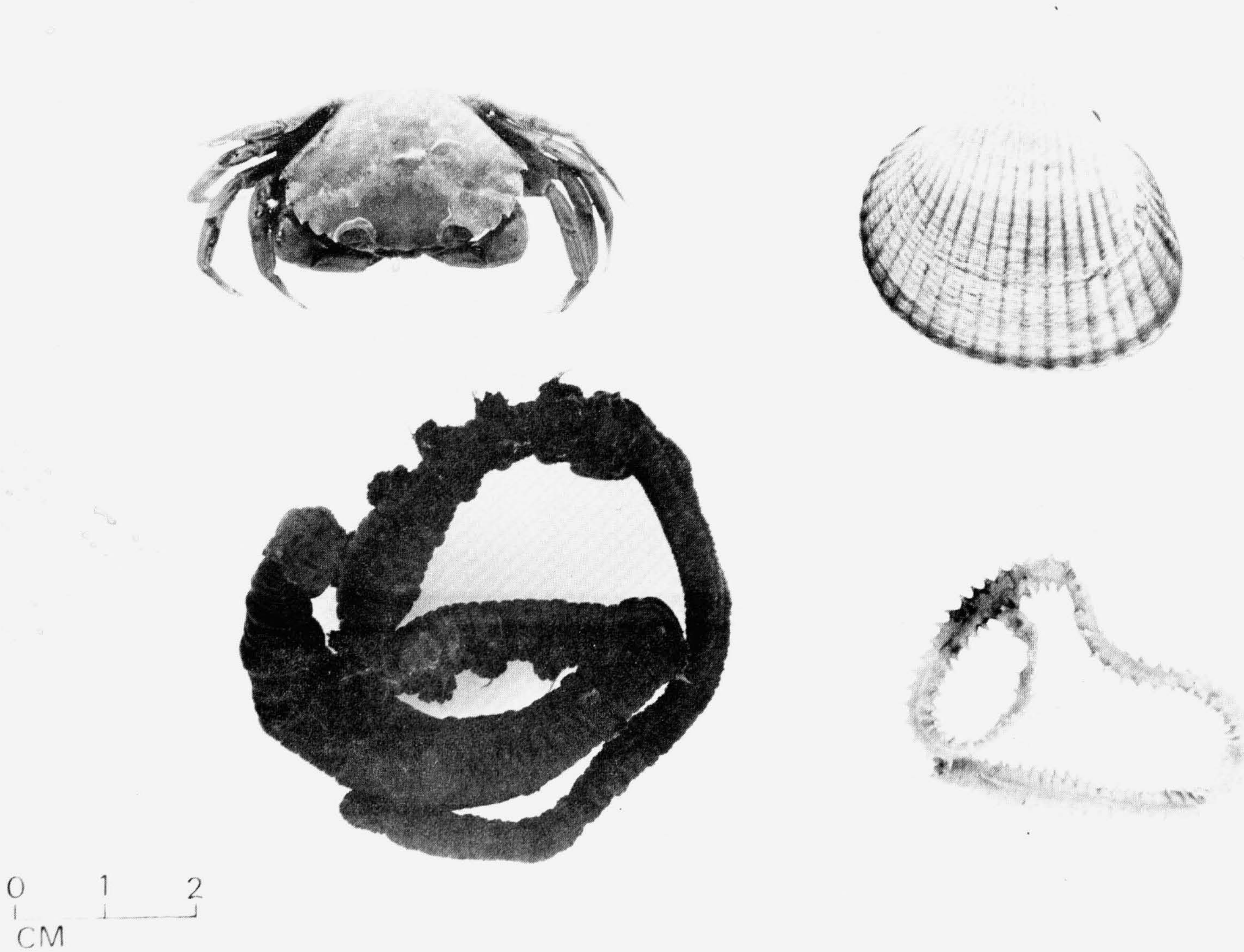

Figure 4. Dead and moribund organisms at or near EPA Station 3, Corn ar Gazel. Left to right: Top row = *Cancer pagurus*, unidentified Holothuroidean, and unidentified fish. Middle row = *Arenicola marina*, *Venus verrucosa*, *Dosinia exoleta*, and *Venerupis pullastra*. Bottom row = *Patella sp.*, *Calliostoma zizyphinum*, *Gibbula cineraria*, *Gibbula umbilicalis*, and *Talitrus saltator*.