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Effects of the "Amoco Cadiz" oil spill on an eelgrass community at Roscoff (France) with special reference to the mobile benthic fauna

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ABSTRACT: In October 1977 an investigation was initiated of the qualitative and quantitative composition of the fauna of the eelgrass *(Zostera marina)* beds at Roscoff. Samples were taken in 2 seagrass beds at different tidal levels in order to follow numerical changes in the course of the year. In March 1978 the area of study was struck by the oil slick of the tanker "Amoco Cadiz". For this reason sampling has been continued at the same frequency. The tabulated results show clearly that the oil slick had a profound but selective influence on the various animal groups; some of them disappeared while others were apparently unaffected. Rapid recovery of some species has taken place, but re-establishment of other species, particularly the filter feeders has not been observed. The very diverse amphipod fauna has disappeared, and has been replaced by a population of *Pherusa fucicola* and *Gammarus locusta*; the latter was absent in the year before the oil disaster took place.

INTRODUCTION

Since the beginning of 1976 an ecological study of structural and functional aspects of the eelgrass communities in the surroundings of Roscoff (France) has been in progress. From February 1976 to February 1977 the productivity, the biomass fluctuations, and the growth pattern of the dominant species, *Zostera marina* L., have been studied (Jacobs, 1979). Furthermore the epiphytic algae, including the diatoms, on *Zostera* were examined with special emphasis on their colonization patterns, and their dependence on the rhythm of leaf production and leaf shedding of the host plant. A quantitative study of the macrofauna was started in May 1977.

Unfortunately, in March 1978, this ecological programme was drastically disturbed by the stranding of the tanker "Amoco Cadiz" which released its cargo of 216 000 tons of crude oil and 4000 tons of bunker fuel and thereby polluted a considerable stretch of the coastline of northern Brittany.

On 20 March the oil slick reached the surroundings of Roscoff and covered our study area. As we were in the position to make a comparison with the original situation, we decided to continue the sampling programme, although with a changed objective, viz. the effect of the oil spill on the *Zostera* community.

This paper deals with the preliminary results of this study, with respect to the mobile invertebrates. The benthic infauna results are discussed by Jacobs (1980).

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STUDY AREA

Eelgrass beds are a prominent feature in the coastal area of Roscoff. They cover 12.7 km^2 of which almost 80 % is situated above the mean low water mark at spring tide (MLWS). The upper limit of the eelgrass beds coincides more or less with the mean low water mark at neap tide (MLWN). In the sublittoral *Zostera marina* descends to ca. 4 m below MLWS (Jacobs, 1979).

The history of the eelgrass beds of the Roscoff area is reasonably well known; they were mapped by Pruvot (1897), Joubin (1909), and later by Blois et al. (1961) and Jacobs (1979); a detailed report was presented by De Beauchamp (1914). More detailed observations on the *Zostera* beds can be found scattered in the extensive literature on the Roscoff area.

The study of the fauna of the eelgrass community was concentrated in two homogeneous beds, one situated just below the level of MLWN, and the other approximately 0.5 m lower. The former was characterized by relatively many *Zostera* shoots (700–800 per m^2) which were not longer than 30 cm. The rhizome mat was ca. 9 cm thick, and there was no mat of loose-lying algae. This bed became exposed during almost every low water period.

The lower eelgrass bed was characterized by fewer but longer shoots (500–600 per m^2; up to 50 cm long) The rhizome mat was ca. 6 cm thick. This bed was situated in an enormous tidal pool that retained a few centimetres of water during each low water period. Between the shoots a mat of entangled, loose-lying algae was present; it consisted mainly of *Corallina officinalis* L., *Cladostephus spongiosus* (Huds.) C. Ag. and *Sphacelaria* species.

In this paper only the results obtained from the low littoral eelgrass bed will be discussed. In the other bed the natural process of sanding-up, causing a decrease in species and individuals, interfered with the effect of the oil pollution, and the data could be easily misinterpreted.

METHODS

Although the study of the fauna of the eelgrass bed was begun in May 1977, the first months were devoted to identification of species, improving the sampling technique, and selecting the most representative sites. The data obtained in the period May–September 1977 have not been used in the present analysis.

From October 1977 until April 1979 a bottom sample of 20 × 20 cm^2 was taken monthly in the high and in the low littoral eelgrass beds. These samples were sieved (1-mm mesh size) and all individuals were collected, preserved and identified. The sample size chosen was in fact a compromise. For the smaller species it was more than sufficient, for some larger species probably too small. A larger sample size, however, would have increased the work to such a degree that its execution would have been impossible within a reasonable time.

Comparison of 4 samples of 20 × 20 cm^2 taken simultaneously showed a random or an aggregated distribution of the individuals over the samples for 99 % of all species. The number of species per sample was approximately 65 % of the total number of species present.

Table 1. General data of the fauna in the low littoral *Zostera marina* bed at Roscoff (numbers per 400 cm^2)

Parameters		1977									1978							1979		
		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Number of individuals	*N*	540	899	577	566	1162	802	393	101	222	115	133	194	214	444	395	255	439	529	686
Number of species	*S*	48	46	47	49	73	70	39	26	37	22	30	30	28	26	33	31	51	56	44
Diversity index	*H'*	2.49	2.58	2.47	2.66	2.71	2.62	2.28	2.64	2.55	2.46	2.85	2.45	2.37	1.86	1.98	2.36	2.79	2.67	2.01
Evenness	*J*	0.64	0.67	0.64	0.68	0.63	0.62	0.62	0.81	0.71	0.80	0.84	0.72	0.71	0.57	0.56	0.69	0.71	0.66	0.53

Table 2. Gastropoda in the low littoral *Zostera* bed at Roscoff, before and after the oil spill of the "Amoco Cadiz" (numbers per 400 cm^2)

Species	1977			1978												1979			
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Gibbula cineraria (L.)	7	1					1	2							1				
Gibbula pennanti (Philippi)	2	2	5	6	2		1					2	5	5	3	11	2	7	4
Gibbula umbilicalis (Da Costa)	3			1	2				1	2	2						2	6	6
Cingula semicostata (Montagu)		48	3	146	118	61	30	12	28	14	6	5	4				74	44	84
Bittium reticulatum (Da Costa)	3	1			4	1	1		5	2	1	1	2		1		2		5
Cerithiopsis tubercularis (Montagu)		1			1				2		1						1	1	
Rissoa parva (Da Costa)				2	3							2	3				12	9	11
Rissoa membranacea (Adams)					1			2					1	1			10	5	1
Ocinebrina aciculata (Lamarck)	1		4		2	3	4	1							2		1	1	3
Chauvetia minima (Donovan)			1		1		4		5			1	1				2		2
Hinia reticulata (L.)			1			1				1	1							1	7
Hinia incrassata (Ström)	1			1	1						1							1	2
Alvania crassa (Kanmacher)					1				1		1								
Odostomia unidentata (Montagu)					2	1					1								
Retusa truncatula (Maton et Rockett)					1		5			1									
Barleeia rubra Adams						1	1												
Lamellaria perspicua (L.)	2		1															1	
Elysia viridis (Montagu)					1													1	
Helcion pellucidum (L.)	1																		
Cantharidus striatus (L.)						1													
Tricolia pullus (L.)					1														
Acmaea virginea (Müller)											1								
Calliostoma zizyphinum (L.)													1	1				1	
Lacuna vincta (Montagu)									1										
Littorina obtusata (L.)									1	1		1							
Littorina saxatilis (Olivi)																1			
Mangelia attenuata (Montagu)							2												
Mangelia costulata Risso											1								
Cingula cingillus (Montagu)												1						1	
Number of individuals	20	53	15	156	141	69	49	17	44	21	16	13	17	7	7	12	196	79	125
Number of species	8	5	6	5	15	7	9	4	8	6	10	7	7	3	4	2	9	13	10

Table 3. Amphipoda in the low littoral *Zostera* bed at Roscoff, before and after the oil spill of the "Amoco Cadiz" (numbers per 400 cm^2)

Species	1977			1978												1979			
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Pherusa fucicola Leach	9	4		1	64	58	3		1				5	2	9	25	19	30	10
Stenothoe monoculoides (Montagu)			1	1	9	11			1								6	2	
Harpinia pectinata O. Sars	3		1	1	13	7	2											1	
Melita obtusata Montagu	3					3										1	1		
Dexamine thea Boeck		6	1	1	13	2											2	1	
Ampelisca spinipes Boeck				1	2	1													
Harpinia crenulata Boeck	1	5			11	2													
Apherusa bispinosa (Bate)						2													
Nototropis guttatus (A. Costa)				1	1	4													
Elasmopus rapax A. Costa				1		1													
Dexamine spinosa (Montagu)						1													
Aora typica Kröyer	1		1		1	1													
Lembos websteri Bate	3	5	6	3	26	9													
Microprotopus longimanus Chevreux					2	3													
Eurystheus maculatus (Johnston)	1	1			4														
Amphithoe vaillanti Lucas	1		1		1														
Amphithoe rubricata (Montagu)				4	1														
Pleonexes gammaroides Bate		1																	
Sunamphithoe pelagica (Milne-Edwards)			1		1	1													
Jassa falcata (Montagu)	1	1		1	1	2													
Erichthonius brasiliensis (Dana)					2														
Podocerus variegatus Leach					1	5													
Coremapus versiculatus Norman		5	1		1														
Phtisica marina Slabber					1	1													
Caprella sp.					2	5													
Lysianassidae sp.	2		3	1	3	1													
Gammarus locusta (L.)												8				13	1	3	
Leucothoe spinicarpa (Abildgaard)									1										
Leucothoe incisa D. Robertson															1		2		
Apherusa jurinei (Milne-Edwards)																			2
Number of individuals	25	28	16	16	160	120	5		3			8	5	2	10	39	31	37	12
Number of species	10	8	9	11	21	20	2		3			1	1	1	2	3	6	5	2

Table 4. Cumacea, Tanaidacea, Isopoda and Echinodermata in the low littoral *Zostera* bed at Roscoff, before and after the oil spill of the "Amoco Cadiz" (numbers per 400 cm^2)

Species	1977			1978												1979			
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Cumacea																			
Iphinoe tenella G. O. Sars		10	11	7	30	21	1									13	8	11	7
Cumella pygmaea G. O. Sars						1													
Bodotria scorpioides (Montagu)																		1	2
Tanaidacea																			
Apseudes latreillei (Milne-Edwards)	203	190	100	51	353	278	56	6	10	6	5	42	68	238	214	91	113	117	337
Apseudes talpa (Montagu)	28	69	20	27	57	3	5		2							1	9		
Leptochelia dubia Kröyer			1	2	6	1	1												
Isopoda																			
Paranthura costana Bate et Westwood		2	1		1	2		1											
Dynamene bidentata (Adams)				1			1								1				
Janira maculosa Leach			1		1	6	1											1	
Idotea pelagica Leach					1													1	
Astacilla longicornis (Sowerby)						1													
Munna minuta Hansen						2													
Idotea chelipes (Pallas)																	1		
Echinodermata																			
Amphipholis squamata (Delle Chiaje)	72	210	190	120	178	134	164	20	12	7	19	37	27	20	43	41	47	82	85
Asterina gibbosa (Pennant)					1														
Ophiura albida Forbes							1												

RESULTS

The eelgrass itself remained almost unaffected by the oil spill. Although during the first weeks after the spill many plants had black "burnt" leaves, these were shed according to the pattern normal for the species. Apart from this short-term effect no other damage was observed. The general structure of the eelgrass beds was not harmed at all. Changes observed in the fauna, therefore, cannot be ascribed to damage to the frame plant of the community.

In Table 1 the total numbers of species and individuals collected monthly are presented. It is obvious that both decreased after the oil spill, a decrease which became even more apparent in May 1978. However, in the course of 1978 the numbers of individuals increased again, although in spring 1979 the high maxima of the preceding spring were not reached. The number of species remained considerably lower than before the oil spill.

The Shannon-Wiener index values for diversity *(H)* and evenness *(J)* were calculated monthly. In the period before the oil spill these were reasonably constant, H ranging from 2.5 to 2.7 and J varying between 0.62 and 0.68, indicating a stable well-balanced community. After the oil spill the fluctuations of H were between 2.0 and 2.8 and those of J between 0.53 and 0.84, indicating a disturbed balance.

In Tables 2–4 the data of some groups of mobile animals are presented. Data on fish and decapod crustaceans have not been considered because the sampling technique was not adequate for these groups.

Gastropoda

The Gastropoda were little affected by the oil spill (Table 2). Most of them are bound to the bottom; some of them crawl on the eelgrass leaves, but when the tidal currents become too strong they usually drop to the bottom, where they remain until the next low water period.

From Table 2 it is obvious that almost all species found before the oil spill were found also later. The greatest richness in species was found in February 1978 and in March 1979. The most numerous species was *Cingula semicostata*, with the highest number of individuals in winter.

In general the number of individuals and of species in the winter of 1978 and 1979 appeared to be of the same magnitude. In 1978 the number of specimens had already dropped considerably before the oil spill took place. Some species were not found after the oil pollution took place, and others were not seen after the summer of 1978. These species, however, were not common in eelgrass beds, and their absence is probably merely accidental.

Amphipoda

The Amphipoda of the eelgrass bed formed a very diverse animal group, rather poor in individuals but rich in species (Table 3). The greatest richness in species and individuals occurred in the late winter and early spring. The oil spill brought this to an abrupt end; of the 26 species found before the oil spill 21 have not been found since. In the summer of 1978 amphipods were practically absent, but in the autumn *Pherusa fucicola*, the species most abundant before the oil spill, reappeared, followed by *Gammarus locusta*, a ubiquist formerly not observed in this amphipod community; a few individuals of a few other species were found, but a recovery had not taken place by April 1979.

Cumacea

This group was in fact represented by one frequent species *Iphinoe tenella* (Table 4). In the period November 1977–March 1978 it was fairly abundant; after the oil spill only 1 specimen was found in April and since then it was absent for 8 months. In the winter of 1979 it reappeared in numbers comparable to those before the oil spill.

Tanaidacea

Before the oil spill 3 species of Tanaidacea were present. *Apseudes latreillei*, which was by far the commonest, showed a great decrease in numbers after the oil spill but recovered completely in the following autumn. The second species, *A. talpa*, had decreased in numbers before the oil spill; in winter of 1979 a few individuals were present. The decrease in numbers of these two species in spring is a natural phenomenon, although the decrease in 1978 was more pronounced due to the oil pollution. The rarest species, *Leptochelia dubia*, was found only once after the oil spill.

Isopoda

The number of Isopoda in the *Zostera* bed was usually very low with a slight increase in winter. This group was also affected by the oil slick. *Paranthura costana*, which was found also on several occasions in spring and summer 1977, was seen only once after the oil disaster. For 6 months not a single isopod was seen; in the following winter only 4 specimens, representing 4 species, were collected. Although this group was not common, the oil pollution caused an observable reduction in the numbers of species and individuals.

Echinodermata

Amphipholis squamata appeared to be common in the eelgrass bed. Remarkably, it did not decrease directly after the oil spill, but a month later. The numbers remained low but increased gradually towards the end of the observation period; the maxima observed in the winter 1977–1978 were not reached.

DISCUSSION

The tabulated results show clearly that the oil slick had a profound, but selective influence on the various animal groups inhabiting the eelgrass beds. The Gastropoda hardly suffered; the representatives of the Cumacea, Tanaidacea and Echinodermata recovered within a year, although the latter reached a lower maximum than in the year before the oil spill. Some influence of the oil spill on the Isopoda could be detected, but as this group was never numerous in the eelgrass bed under investigation, the result is not convincing. The effect of the oil spill on the Amphipoda, however, was spectacular.

The situation of the eelgrass beds below the level of mean low water neap tide implied that the contact between the oil slick and the eelgrass lasted only for at most 6 hours a day. During this time the flat-lying eelgrass leaves formed a buffer between the oil slick and the bottom. Due to the firm rhizome mat, mixing of oil and sediment was not possible in the eelgrass bed. In fact only the dissolved fraction of the oil could penetrate under the eelgrass and in the interstitial water. This may explain the fact that just the filter feeders such as most Amphipoda and some families of Polychaeta (Jacobs, 1980) were struck, while other groups of organisms remained relatively unaffected.

The buffer effect of the eelgrass also becomes evident when the numbers of oil victims are compared with those from open beaches and sheltered areas where there was no cover of eelgrass, and where the bottom and the oil came into direct contact (Hyland, 1978).

A similar function may have been fulfilled by the Fucaceae in the intertidal belt; however, due to their higher position on the shore, their contact with the oil would have been of longer duration, and the degree of protection of the organisms under the Fucaceae cover may have depended on the thicknes of that cover.

From the results obtained it is apparent that the effect of the oil spill on various animal groups was only a temporary disturbance which could be overcome by the high reproductive potential of the survivors. In the case of the Amphipoda it cannot be predicted whether the effect of the oil spill will be temporary or permanent because they nurse their breed and, therefore, have a low reproductive potential. The "Amoco Cadiz" disaster has attracted much attention because of the enormous scale of the oil pollution it caused. Less spectacular oil spills may cause locally similar damage. The data obtained give an impression of the influence of an oil spill on a *Zostera* community in the early spring, just after the winter peak of a number of littoral organisms, and before the start of the rapid development of the eelgrass. It is not certain whether the effect on the fauna would have been similar had a spill occurred in the summer.

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LITERATURE CITED

Blois, J. C., Francaz, J. M., Gaudichon, M., Gaudichon, S. & Le Bris, L., 1961. Observations sur les herbiers à Zostères de la région de Roscoff. – Cah. Biol. mar. *2*, 223–262.

De Beauchamp, P., 1914. Les grèves de Roscoff. Paris, 270 pp.

Hyland, J. L., 1978. Onshore survey of macrobenthos. In: The Amoco Cadiz oil spill. Ed. by W. N. Hess. Washington, 216–228. (NOAA/EPA Spec. Rep.)

Jacobs, R. P. W. M., 1979. Distribution and aspects of the production and biomass of eelgrass, *Zostera marina* L., at Roscoff (France). – Aquat. Bot. *7*, 151–172.
Jacobs, R. P. W. M., 1980. Effects of the "Amoco Cadiz" oil spill on the seagrass community at Roscoff with special reference to the benthic infauna. – Mar. Ecol. Prog. Ser. *2*, 207–212.
Joubin, L., 1909. Recherches sur la distribution océanographique des végétaux marins dans la région de Roscoff. – Annls Inst. océanogr., Monaco *1* (1), 1–17.
Pruvot, G., 1897. Essai sur les fonds et la fauna de la Manche occidentale (côtes de Bretagne), comparés à ceux du Golfe de Lion. – Archs Zool. exp. (Ser. 3) *5*, 511–617.