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THE EFFECTS OF ORGANIC POLLUTION ON BENTHIC ORGANISMS NEAR MARSEILLE

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A quantitative survey of sublittoral marine organisms was carried out in polluted and unpolluted waters near Marseille (France). Samples from rocky substrates indicate that organic pollution effects have not decreased since earlier surveys.

Studies of beds of *Posidonia oceanica*, the dominant Mediterranean sea grass, show that its biomass is low in the polluted Gulf of Marseille compared with that in unpolluted bays near Marseille and with data from Malta. Crops were particularly low in shallow water to 15m where it is suggested that grazing by echinoids, whose numbers are probably encouraged by high levels of organic material, could be an important factor limiting growth, as well as other factors such as low underwater irradiance and detergent toxicity.

Along the most polluted coastline near the main sewer outlet at Cortiou, *Posidonia* was absent and is probably excluded by indirect and direct effects of the effluent. The decline of these sea grass beds has serious implications for sediment stability and the survival of associated biota.

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INTRODUCTION

Studies on the effects of organic pollution on the growth of marine organisms near Marseille have already been carried out by Bellan[1] and Bellan and Bellan-Santini.[2] Their work showed that on rocky substrates pure-water populations were dominated, on shelves, by the alga *Cystoseira stricta* and, on slopes, by several other algae (e.g., *Halopteris scoparia, Padina pavonia*) and the mussel, *Mytilus galloprovincialis*. In polluted waters the populations consisted of the algae *Corallina* cf. *officinalis* and *Ulva lactuca*, with large numbers of *M. galloprovincialis*. Golubic[3] quotes *Ulva lactuca* and *Codium tomentosum* as common algal "indicators" of sewage pollution.

Quantitative work by Bellan and Bellan-Santini[2] indicates that there may be an apparent increase in the standing crop on rocky substrates in polluted waters compared with that in pure waters; but this consisted of an increase in calcareous weight with an actual decrease in organic dry weight. Their results for soft substrates indicate a zone without life close to the large sewer outlet at Cortiou, a polluted zone dominated by polychaete worms, a subnormal zone of molluscs and polychaetes, and a zone of pure water with species distribution depending on substrate type and depth.

In the studies reported here, attempts were made to sample rocky substrates to see if changes had occurred since the earlier surveys, and also to investigate the growth of *Posidonia oceanica* in relation to organic pollution.

MATERIALS AND METHODS

Samples were collected using SCUBA, from rocky substrates by scraping the benthic organisms within a 1/25 m^2 quadrat into a collecting bag. Species were sorted and dried to constant weight. Two samples of *Posidonia oceanica* were obtained using $\frac{1}{4}$ m^2 quadrats at each depth which were placed subjectively on dense patches at the various sites. Larger sampling areas would have given a more representative estimate of biomass, especially in the very patchy beds at the polluted site at Mongenet, but sampling and analysis time was limited. Results therefore represent the maximum density and biomass data found. Biometric data for *P. oceanica* were obtained as described by Drew and Jupp;[4] measurements included: the number of individual shoots (separated from the rhizomes), the number of leaves on a representative ten percent of the shoots, the length and breadth of leaves in this batch to give total leaf area, the dry weight of leaves, the distance apart

of leaf scars on both the vertical and horizontal rhizomes and the number of sea urchins (echinoids) in each quadrat.

Description of Sites

Sormiou Bay (43° 12′ 30″ N; 5° 25′ 50″ E). This bay is relatively clean but it is the next bay eastwards from the Cortiou sewer outlet so it is possible that some effect of organic pollution may be felt in this bay if the wind is from the west or south-west. Underwater light penetration is good.

Morgiou Bay (43° 12′ 30″ N; 5° 27′ E). This bay is the next bay eastward of Sormiou Bay and is unpolluted with good underwater light penetration.

Mongenet Cove (43° 13′ N; 5° 21′ E). This cove is north of Les Goudes and south-west of Marseille and is within the polluted zone, as described by Bellan and Bellan-Santini,[2] in the Gulf of Marseille where *Cystoseira stricta* starts to disappear. Underwater irradiance was much lower than that at Sormiou and Morgiou bays. Subspended matter is very dense (5–20,000 coliforms l^{-1}, Bellan[1]).

Les Goudes to Cortiou coastline A rapid visual search was made for *P. oceanica* beds from the sewer outlet at Cortiou (43° 12′ 50″ N; 5° 24′ E) to Callalongue near Les Goudes.

RESULTS AND DISCUSSION

Rocky Substrates

Table I indicates the standing crop found for several species of algae and also the animals found in the relatively clean site at Sormiou and at the polluted site at Mongenet:

The species diversity found of algae at Sormiou resembles that found by Bellan and Bellan-Santini[2] on *slopes* in pure water; they also found *Corallina* cf. *mediterranea* and *Padina pavonia.* The site at Sormiou does not support as much *Corallina* (232 g organic matter m^{-2}) as that in the clean sites examined by Bellan and Bellan-Santini, and was also devoid of *Mytilus galloprovincialis.*

Bellan and Bellan-Santini[2] quote *Mytilus galloprovincialis* (in large numbers), *Corallina* cf. *officianilis* and *Ulva lactuca* as being indicative of organic pollution. The polluted site at Mongenet does not have a similar low species diversity; *Corallina* cf. *officinalis* and *U. lactuca* were not found but the site would appear to be polluted from this species list since *Codium tomentosum* (an "indicator" species of organic pollution,

TABLE I

Standing crop of species found on rocky substrates in two bays near Marseille

Site	Depth (m)	Species	Biomass (g dry weight m^{-2})
Sormiou Bay	9	*Asparagopsis armata*	30.01
		Corallina cf. *mediterranea*	21.91
		Halopteris filicina	5.36
		Ptilota plumosa	3.91
		Dictyota dichotoma	1.31
		Padina pavonia	0.16
		Total algal biomass	62.66
		Cerithium vulgatum (+ shells)	284.66
Mongenet Cove	8	*Codium tomentosum*	307.44
		Ectocarpus simplex[a]	103.43
		Corallina cf. *mediterranea*	72.24
		Rhodymenia palmata	7.37
		Ceramium rubrum	2.90
		Dictyota dichotoma	0.80
		Colpomenia sinuosa	0.77
		Total algal biomass	494.95
		Mytilus galloprovincialis	48.01

[a]Epiphytic on *Codium tomentosum.*

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Golubic[3]) and *M. galloprovincialis* were found at Mongenet. The biomass data agree with that of Bellan and Bellan-Santini in that overall biomass increases in the polluted site compared with the clean water site and there is an increase in calcification with more *C.* cf. *mediterranea* in the polluted site than at Sormiou.

It would appear that the Mongenet site is an intermediately polluted site, with a high crop of *M. galloprovincialis* and is within the zone where *Cystoseira stricta* starts to disappear. Conditions have therefore not improved in this southern section of the Gulf of Marseille since the earlier surveys of Bellan and Bellan-Santini (which were originally reported in 1969) for rocky substrates.

Posidonia Oceanica Meadows

Data on biomass and other growth measurements of *Posidonia oceanica* collected from various sites are shown in Table II:

It can be seen that biomass is not very different at 15m at all the sites, but that the smallest biomass in the two shallow collections is present at 10m in Mongenet Cove, the most polluted of the sites sampled. *P. oceanica* was not found in water shallower than 10m at Mongenet, whereas it grew much nearer the surface at Sormiou, a cleaner site, and the 8m sample here gave the highest biomass found in the survey.

The biomass data also indicate that the growth of *P. oceanica* around Marseille is poor compared with biomass data collected from the clean waters off Malta (Drew,[5] Drew and Jupp[4]). The biomass of leaves of *P. oceanica* in Malta reaches an average of 954 g dry weight m^{-2} at 6m, about 800 gm^{-2} at 15m and about 750 gm^{-2} at 27m, with 400–500 shoots m^{-2}, 4.5 leaves per shoot and about 7.3 m^2 total leaf area per m^2 of sea-bed over the 3 to 38m depth range.

There is surprisingly little variation in the development of *P. oceanica* at Malta over the complete depth range. Thus, total leaf biomass near the limit of growth at 30m is 60 percent of that at 6m, despite there being a reduction in ambient light intensity of about 90 percent between the surface and 40m. Drew[5] suggested that the growth of *Posidonia* in shallow water above 15m is largely controlled in Malta by sea urchin grazing. This is thought to affect growth measurements such as leaf area per unit area of sea-bed and biomass, such that grazing reduces biomass in shallow water to much the same level as that found in much deeper (27m) beds. There are few sea urchins found below 15m (Drew and Jupp[4]), so that deeper beds do not suffer grazing but are limited by the reduced light intensity.

Up to 15 *Paracentrotus lividus* per m^2 may be present in the top 5m in Maltese waters with an average of 5 per m^2 in the upper 15m of the sublittoral.

TABLE II

Standing crop data for *Posidonia oceanica* near Marseille

Site	Depth (m)	Shoot density (number m^{-2})	Leaves per shoot	Leaf area ($m^2 . m^{-2}$ sea-bed)	Biomass (g drywt $. m^{-2}$)
Sormiou	8	432	5.45	7.11	599.80
	15	556	5.45	8.28	436.12
Morgiou	14	440	6.05	6.45	460.44
Mongenet	10	414	5.30	4.08	298.00
	15	353	6.75	6.41	436.52

TABLE III

Densities of echinoids near Marseille. Data are numbers per m^2

Site:	Sormiou		Morgiou	Mongenet	
Species Depth (m):	8	15	14	10	15
Paracentrotus lividus	13	11	1	2	14
Sphaerechinus granularis	4	6	2	—	—
Psammechinus miliaris	4	10	1	2	10
Spatangus purpureus	—	2	—	—	—

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The data in Table III indicate that there are considerably more sea urchins down to 15m at the Marseille sites compared with data from Malta. Drew[5] suggests that features such as leaf area per m^2 sea-bed and biomass of *P. oceanica* are likely to be affected by echinoid grazers; whereas other growth features such as shoot density and number of leaves per shoot are more likely to be modified as a result of changes in the growth rate of the plant. Such changes are dependent on factors such as light intensity, nutrients, etc., rather than grazing effects. Shoot density and number of leaves per shoot of the Marseille samples, apart from the shallow Mongenet sample, are not very different from the Maltese samples (see Table II and data for Malta, p. 3).

The polluted site at Mongenet has a much reduced leaf area per m^2 of sea-bed and biomass of *P. oceanica* in shallow water than any of the other sites and even at the best site for growth—8m at Sormiou—the leaf area and biomass was lower than that found at a similar depth in Malta, where sea urchins are less abundant. This would suggest that grazing pressures may be an important limiting factor on growth. It is known that sewage encourages sea urchins. Leighton *et al.*[6] have found that near sewage outfalls in California the combined effects of turbidity, reducing light penetration, and grazing can result in the complete destruction of giant kelp beds. Similar effects seem to be occurring in the Gulf of Marseille on sea grass beds.

Reduced light penetration and direct toxic effects from effluent can also act to inhibit growth rates of submerged plants. Vertical and horizontal growth rates of *P. oceanica* at polluted and unpollutted sites near Marseille are presented in Table IV.

The data can be compared with that of Drew and Jupp[4] for all depths collected from *Posidonia* meadows at Malta; the average data there showed a vertical rhizome leaf scar separation of 1.5 mm and growth rate of 6.0 mm $year^{-1}$ and a horizontal rhizome leaf scar separation of 4.33 mm and growth rate of 17.3 mm $year^{-1}$. It can be seen that the vertical and horizontal rhizome growth data at Mongenet are lower than all the other sites. This would indicate that factors such as poor underwater irradiance, toxic effects, etc., are affecting the growth rates of *P. oceanica* in the Gulf of Marseille.

Overall it would appear that the growth of *P. oceanica* within the Gulf of Marseille is considerably poorer than that in cleaner sites both within the region and at Malta. This appears to be attributable to grazing pressures from echinoids and also to reduced light penetration and possibly to direct toxic effects as a result of organic effluent.

J. G. Harmelin (personal communication, 1976) indicated that the lower limit of *P. oceanica* in the Gulf of Marseille has been raised from 36 m to about 25 m and the data presented here suggest that the upper limit has been depressed to 10 m. The overall extent of *Posidonia* beds within the Gulf of Marseille has contracted since earlier records (see Harmelin and True[7]). Pérès and Picard[8] have also pointed out this decline and have attributed it to an increase in the turbidity of the water and to large amounts of clay with absorbed detergents which are transported into the Gulf of Marseille by the now harnessed River Rhône. The results presented here for growth rates of *P. oceanica* rhizomes at Mongenet support the conclusion of Pérès and Picard that factors such as poor underwater irradiance and toxic effects may be important in explaining the decline of *Posidonia* because of the low growth rates found for the species in the Gulf of Marseille. Comparative data for growth measurements also suggest that grazing

TABLE IV

Growth rates of rhizomes of *Posidonia oceanica* at several sites near Marseille

	Vertical rhizome		Horizontal rhizome	
	Leaf scar separation[a]	Growth rate[b]	Leaf scar separation[a]	Growth rate[b]
Site	(mm)	(mm $year^{-1}$)	(mm)	(mm $year^{-1}$)
Sormiou	2.08	8.32	2.84	11.36
Mongenet	1.46	5.84	0.97	3.88

[a]Means of collections at all depths.
[b]Assuming 4 leaves shed per year (Drew and Jupp[4]).

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pressure from echinoids, encouraged by high levels of organic pollution, is important in reducing leaf area and biomass.

The rapid survey of the coastline from the Cortiou sewer outlet to Callalongue and Les Goudes showed that most sites surveyed, which otherwise appear to be suitable subtrates for *Posidonia*, were free of sea grass and were covered with a fine sediment and large numbers of echinoids. It is possible that in this highly polluted area poor underwater irradiance and heavy grazing pressure has obliterated *Posidonia* beds. Sea urchins could presumably continue to survive on organic detritus alone.

CONCLUSIONS

A survey of rocky sublittoral substrates near Marseille indicated that species commonly found in organically polluted water are present in the same area described as polluted by Bellan and Bellan-Santini.[2] It would appear then that conditions have not ameliorated since these earlier surveys.

Studies on *P. oceanica* beds in this area indicated that the species has a low biomass and growth rate in the polluted site compared with clean sites near Marseille and in Malta. The poor performance of *P. oceanica* in the polluted Gulf of Marseille would appear to be a result of indirect effects of high levels of organic pollutants such as low underwater irradiance and grazing pressure from sea urchins, which can be encouraged by organic matter in the effluent, and to direct effects such as detergent toxicity.

The serious decline in beds of *P. oceanica* in the Gulf of Marseille may have repercussions on both the stability of sediments in the area and on associated biota; Drew[5] has pointed out that *Posidonia*, by its rhizome growth, can trap and build up sediments and its meadows house a considerable flora and fauna.

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