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Sedimentation Rates Associated with the Longline Culture of the Blacklip Pearl Oyster, *Pinctada margaritifera* at Penrhyn Atoll, Cook Islands.

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ABSTRACT

Sedimentation rates under longlines holding seeded blacklip pearl oysters were highly significantly (P<0.001) greater than control longlines without oysters, both during the wet and dry seasons. The percentage increase in the amount of dried sediment for treatments hung under longlines with pearl oysters over the controls was: Wet Season, 3,075 %; Dry Season, 433 %. A significantly (p<0.05) greater amount of dried sediment was collected under treatment site 2 during the wet season than treatment sites 1 and 2 during the dry season. Also, a significantly (p<0.05) greater amount of dried sediment was collected at control site 1 during the dry season compared with the wet season. This unexpected result may be attributed to a combination of site-specific conditions, progressive fouling on headropes and fish (gobies) which took up residence in some collectors.

During the wet season the fouling on the outside of collectors by bivalves such as Ostrea sp. and the pipi, Pinctada maculata, was highly significantly greater (p<0.001) at control sites compared with treatment sites (168% higher). This may indicate that where pearl oysters are present in the water column a component of the competent larvae in the plankton are filtered out and prevented from settling in the vicinity on suitable substrate.

Pearl oyster densities in the 8.6 ha. farm at Penrhyn were estimated at 0.26 pearl oysters / m^2 of bottom area below the farm. Given that farms are situated in deep water with moderate currents this density of culture may not result in the longterm buildup of anoxic conditions on the bottom, but more conservative advice on density would be 0.2 pearl oysters / m^2 of bottom area below the farm. The equates with longlines that are spaced 25 m apart, and chaplets on the longines spaced 2 m apart with 10 oysters/chaplet.

INTRODUCTION

The determination of sedimentation rates by collectors held under the longline culture of blacklip pearl oysters, Pinctada margaritifera, is a simple means for a direct measurement, but has not been done or ever published. The use of sediment traps set on a stake above the bottom in coral reef areas is a standard practice (English et al., 1994). Using this method, replicate pieces of PVC pipe 11.5 cm long x 5 cm I.D., with one end sealed off, are tied to the stake 20 cm above the substrate and baffles are placed in the top to deter settlement of fish inside the collectors.

The issue with regards to increased sedimentation due to the mariculture of bivalves suspended in the water column is whether the amount of sedimentation will have a deleterious effect on the bottom directly under the farm. It is well-known that high sediment loads (particularly fine sediments) may cause oxygen-depletion and promote the production of hydrogen-sulphide, the rotten-eggs smell reminiscent of sediments often surrounding mangroves. Sedimentation rates have been obtained for some temperate bivalves used in mariculture (Perez et al., 1991; Hatcher et al., 1994; Jaramillo et al., 1992; Boucher and Boucher-Rodini, 1988), and in temperate mussel culture it has been found that there is a reduction in the diversity of species present on the bottom under farms (Tenore et al., 1992; Kaspar et al., 1995; Hatcher et al., 1994).

This paper examines the results of sedimentation collection during wet and dry seasons in Penrhyn atoll lagoon (about 9°S latitude, 158 °W longitude), Cook Islands. Here, blacklip pearl oyster culture began about 5 years ago and in the near future is destined for rapid expansion. Thus, timely advice on sustainable methods of farming are required.

MATERIALS AND METHODS

Sediment collectors were made of cuts of PVC pipe which were about 12 cm in length and exactly 4.0 cm I.D. The bottoms were sealed off with circles cut from PVC plastic containers and glued with 2-part marine epoxy. A hole was drilled near the lip of the open end and monofilament nylon was used to secure the top of the collector through the strands of a 5 mm diam. line. A heavy-duty rubber band was place around the collector near its base and a monofilament nylon tied the rubber band to the line. Thus, the collector was held vertical along the line. During the first placement of collectors (wet season) the tops were completely open as the lowest collectors were at least 5 m above the bottom and the problem of fish taking up residence in the collectors was not considered to be a problem. As there were a considerable number of collectors (controls) which did have resident fish (gobies) present on final collection during the first placement, the collectors were modified before the second placement. A mesh of copper wires were woven through small holes drilled along the top lip of the pipe. The copper mesh was both a deterrent to fish as well as settlement of bivalves near the lip of the collector.

Five collector lines were hung at each of the two treatment sites (T1 & T2; longlines holding seeded pearl oysters) and two control sites (C1 & C2; longlines set away from the pearl oyster culture areas). Each collector line had two collectors, one set about 2-3 m below the headrope and the second set 5 m below the top collector. The collectors were set out for the following time periods:

Wet Season, 15 November 1996 - 1 April 1997; 135 days.

Dry Season, 23 May - 28 August 1997; 97 days.

Collectors were removed and contents rinsed into labelled water sample bottles on the dingy, then returned to the water quality lab at the TMRC [Tongareva Marine Research Centre], Penrhyn, for analysis. The weight of labelled plastic boats and boats + Whatman GF/A - 47 mm circle filter papers were recorded using a Sartorius electronic balance [0.0001 g]. Sediment samples and water in the water sample bottles were vacuumed pumped (Gast vacuum pump) onto the filter paper. Just prior to vacuum pumping, the sample was poured through an 800 micron sieve to remove shell grit and occasional pieces of copper sulphate (formed on some of the copper wires). The fine sediment was washed off the grit and the grit was disposed of. This shell grit originated from some small bivalves that began to grow inside the collector tube and these were partially broken up when the sediment was stirred and being washed into water sample bottles on the dingy. After vacuuming, the filter paper and any remaining water were placed back into the boat and air-dried for 2 days, including direct sunlight for 2 hrs on the last day prior to weighing. The final weighing was done (Sartorius balance) and the boat weight subtracted from the final weight to arrive at the dry sediment weight for each sediment sampler.

Analyses were made using a 1-way ANOVA for sites by season, collector position. Over the wet season only, numbers of fouling bivalves were recorded on the outside and inside of the PVC pipe collectors. Outside and inside counts were separately analysed by 1-way ANOVA for sites Numbers of organisms taking up residence in collector pipes were recorded.

RESULTS

Table 1 and Table 2 show the results of sediment collection for the wet season and the dry season, respectively. The overall pattern is clearly the same during both seasons, with highly significantly greater (1-way ANOVA, $p<0.001$) amounts of dried sediment collected at treatment sites (those where seeded oysters were present) compared with control sites. When averaging out the treatment and control sites the percentage increase in the amount of dried sediment for treatments over controls was 3,075% for the wet season and 433% for the dry season (Figure 1 a & b). There was also a significantly greater (1-way ANOVA, $p<0.05$) amount of dried sediment collected at treatment site 2 during the wet season compared with treatment sites 1 and 2 during the dry season. No significant differences ($p>0.05$) were found in the amount of dried sediment when comparing position of the collector on the collector line (top vs. bottom).

There was a significantly greater (1-way ANOVA, $p<0.05$) amount of dried sediment collected at control site 1 during the dry season compared with the wet season (an increase of 788% over the wet season).

Some fish (gobies) were found to take up residence inside of some collector pipes. Crabs and sea anemones were also found in some collectors. Table 3 shows the number of organisms found, number of collectors and the season.

Fouling outside and inside of the collector pipes by bivalves such as Ostrea sp. and the pipi, Pinctada maculata was recorded for the wet season. There was a highly significantly greater (1-way ANOVA, $p<0.001$) number of fouling bivalves on the outside of the collector pipes at control sites compared with treatment sites. The increase in fouling numbers of bivalves averaged 168% higher at the control sites over the treatment sites. Figure 2 shows this fouling data.

Discussion

There was a clear distinction between collectors at treatment sites (with seeded pearl oysters) and those at control sites regardless of season: levels of sedimentation were hundreds to thousands of percent higher at treatment sites compared with controls. The sedimentation found under temperate mussel farms was 200-300% greater than controls (Dahlback and Gunnarsson, 1981; Hatcher et al., 1994). The increased sedimentation rates at treatment sites would be primarily due to filtering of plankton and organic debris by the oysters and this filtration resulting in either faeces or psuedofaeces which would rain down below the oysters. A second source of the sedimentation would be other fouling organisms (particularly bivalves such as Ostrea sp. and the pipi, Pinctada maculata) which foul the blacklip pearl oyster shells and the ropes in the culture system. This second source of sedimentation would be larger at the treatment sites than control sites due to the greater surface area available for fouling on the blacklip pearl oyster shells.

Site T2 had the largest mean sedimentation rates of all sites for both wet and dry seasons. The highest densities of seeded pearl oysters in the farm of 22,200 was located in this general area where collectors were deployed.

The unexpected significant increase in sedimentation at control site 1 during the dry season compared with the wet season may be a result of fewer fish (gobies) taking up residence in the collectors over the dry season [due to copper mesh covers being added before deployment for the dry season]. However, this was also the case for control site 2 which showed a less dramatic increase in sedimentation (33.3%) during the dry season over the wet season and also had fewer fish found over the dry season. There was a concern that the fish may be decreasing the amount of sediment in the collectors in which they took up residence, thus giving the impression of lower sedimentation rates than actually were occurring. Another potential source of the increase in sedimentation at this site is due to the site-specific conditions and the fouling by other organisms. The headrope and some spat collectors on the control site headropes were becoming more fouled with Ostrea sp. and the pipi, Pinctada maculata by the dry season deployment, but control site 1 may have been more conducive to growth of filter feeders than control site 2. Control site 1 was partially enclosed by a group of broken patch reefs which somewhat protected it from the prevailing SE trade winds, whilst control site 2 was located south of control site 1 on the outside of this group of patch reefs.

Fouling bivalves on the outside of PVC pipe collectors showed an average increase of 168% on control collectors compared with treatment collectors. It is speculated that the reduction in the settlement or subsequent survival of fouling bivalves on treatment site collectors is due to the filtering efficiency of the adult blacklip pearl oysters. This may indicate that where pearl oysters are present in the water column a component of the competent larvae in the plankton are filtered out and prevented from settling in the vicinity on suitable substrate. Larvae which do settle may also be faced with reduction in food densities which are being filtered by the blacklip pearl oysters. Abundant fouling on ropes and oysters is still present in these farm areas, but control sites where new available settlement materials are placed will collect larger numbers of fouling organisms than farm areas. This warrants further investigation. Sampling of the sediment samples for quantitative counts of entrapped mollusc larvae may be the most direct means to obtain this answer.

The farm of approximately 22,200 seeded pearl oysters (count after the recent August-September 1997 harvest; 29,000 were initially seeded for the farm in 1995) in Penrhyn lagoon was measured using GPS sitings and the estimate of the bottom area below the farm to be 8.6 ha. This is a density of 0.26 oysters/m^2 using the harvest count. This averages out to 100 m longlines, holding 1000 seeded pearl oysters each with chaplets (10 oysters/chaplet) 1m apart, and longlines about 26 m apart. Although some longlines were further apart than this, there were some longlines which were 10-12 m apart, and unused space was left between sets of rows of longlines. A more conservative stocking density of 0.2 oysters/m^2 is suggested to reduce the amount of sedimentation found on this farm by over 20% If the chaplets on longlines were placed 2 m apart, the density of oysters would be reduced by 50% on the longlines alone, and also increasing filterable food available to each oyster. There would be 4 longlines over a 1 ha bottom area (25 m apart) to arrive at this more conservative stocking density.

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TABLE 1: Sediment Collector Data - Wet Season Placement [135 days, 15 November 1996 - 1 April 1997]. Penrhyn lagoon, northern Cook Islands. Collectors were PVC pipes closed at the base, 40 mm I.D. (12.56 cm^2 area of collection). There were 2 collectors per line hanging below the longline headropes, with the top one being about 2-3 m below the headline and the bottom collector being 5 m below the top one. Sites are designated as T1 and T2 for the collectors hung under headropes holding seeded blacklip pearl oysters, and those designated as C1 and C2 are for collectors hung under headropes which did not hold any adult oysters [control longlines away from pearl culture areas]. N = No. of collectors sampled; bottom seal broken on missing collectors.

SITE	N	MEAN DRY SED. (g)	g/cm^2	g/m^2	g/m^2/day	g/m^2/mo.	g/m^2/yr.
T1	9	0.6515	0.05187	518.7	3.84	115.3	1,402.4
T2	10	1.0740	0.08550	855.0	6.33	190.0	2,311.6
Mean T1T2	19	0.8626	0.06868	686.8	5.08	152.6	1,856.7
C1	9	0.0307	0.00244	24.4	0.18	5.4	65.9
C2	7	0.0252	0.00201	20.1	0.15	4.5	54.3
Mean C1C2	16	0.02795	0.00222	22.2	0.16	4.9	60.0

TABLE 2: Sediment Collector Data - Dry Season Placement [97 days, 23 May - 28 August 1997]. Penrhyn lagoon, northern Cook Islands. Collectors were PVC pipes closed at the base, 40 mm I.D. (12.56 cm^2 area of collection). There were 2 collectors per line hanging below the longline headropes, with the top one being about 2-3 m below the headline and the bottom collector being 5 m below the top one. Sites are designated as T1 and T2 for the collectors hung under headropes holding seeded blacklip pearl oysters, and those designated as C1 and C2 are for collectors hung under headropes which did not hold any adult oysters [control longlines away from pearl culture areas]. Copper wires were woven across top opening to deter fish (gobies) entering some collectors as was found during the Wet Season Placement; this also reduced any shellfish settlement near top lip of collectors. N = No. of collectors sampled.

SITE	N	MEAN DRY SED. (g)	g/cm^2	g/m^2	g/m^2/day	g/m^2/mo.	g/m^2/yr.
T1	10	0.5265	0.04192	419.2	4.3	129.63	1,577.1
T2	10	0.6410	0.05103	510.3	5.3	157.80	1,919.9
Mean T1T2	20	0.5837	0.04647	464.7	4.8	143.74	1,748.5

C1	10	0.2020	0.01608	160.8	1.6	49.73	605.1
C2	10	0.0302	0.00240	24.0	0.2	7.42	90.3
Mean C1C2	20	0.1161	0.00924	92.4	0.9	28.5	347.0

TABLE 3: Organisms taking up residence inside of PVC collector pipes (CP). G - goby (fish); T - Thais sp. (gastropod); A - sea anemone; C - crab. Fish were the largest organisms (up to ~7 cm length) while invertebrates were ≤ 4 cm. Note that during the dry season the collector opening was modified by adding a mesh of copper wires to deter fish and invertebrates taking up residence.

Site	Wet Season	Dry Season
T1	1 G / 1 CP 2 T / 1 CP 1 A / 1 CP	1 G / 1 CP
T2	1T / 1 CP 35 A / 9 CP	2 C / 2 CP
C1	3 G / 3 CP 1 A / 1 CP 1 C / 1 CP	1 G / 1 CP
C2	6 G / 6 CP	2 G / 2 CP

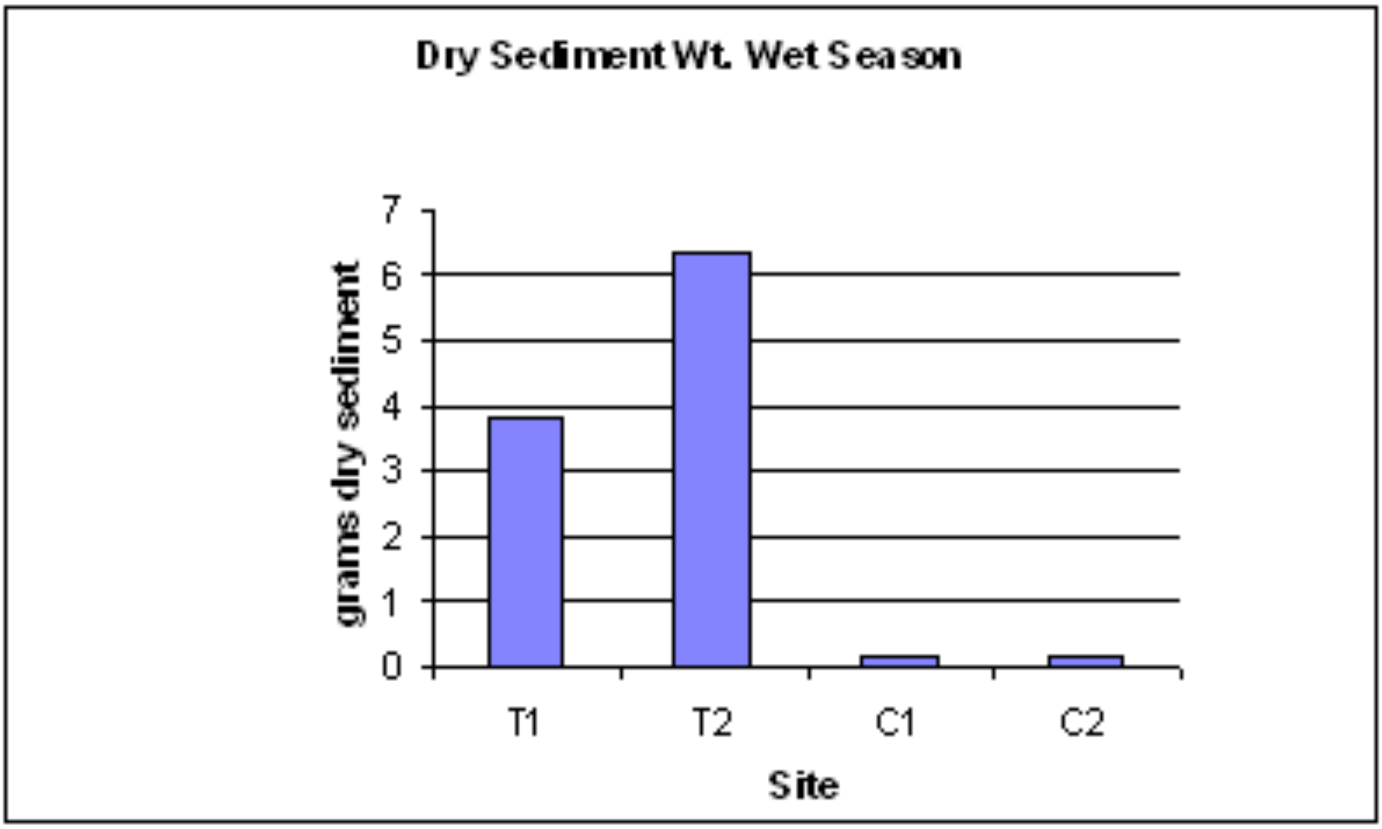

FIGURE 1a: Wet season sedimentation rates at treatment and control sites shown as g / m^2 / day.

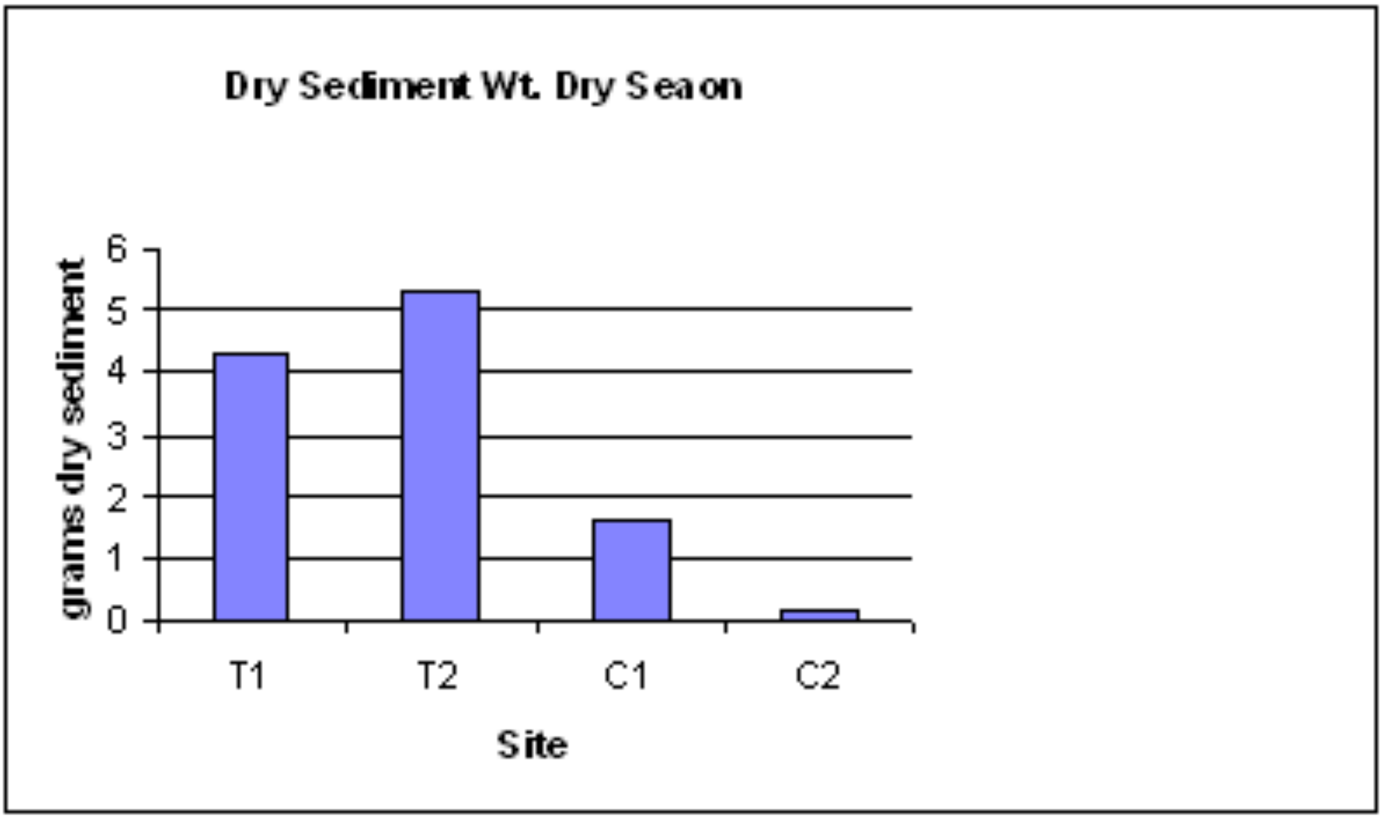

FIGURE 1b: Dry season sedimentation rates at treatment and control sites shown as g / m^2 / day.

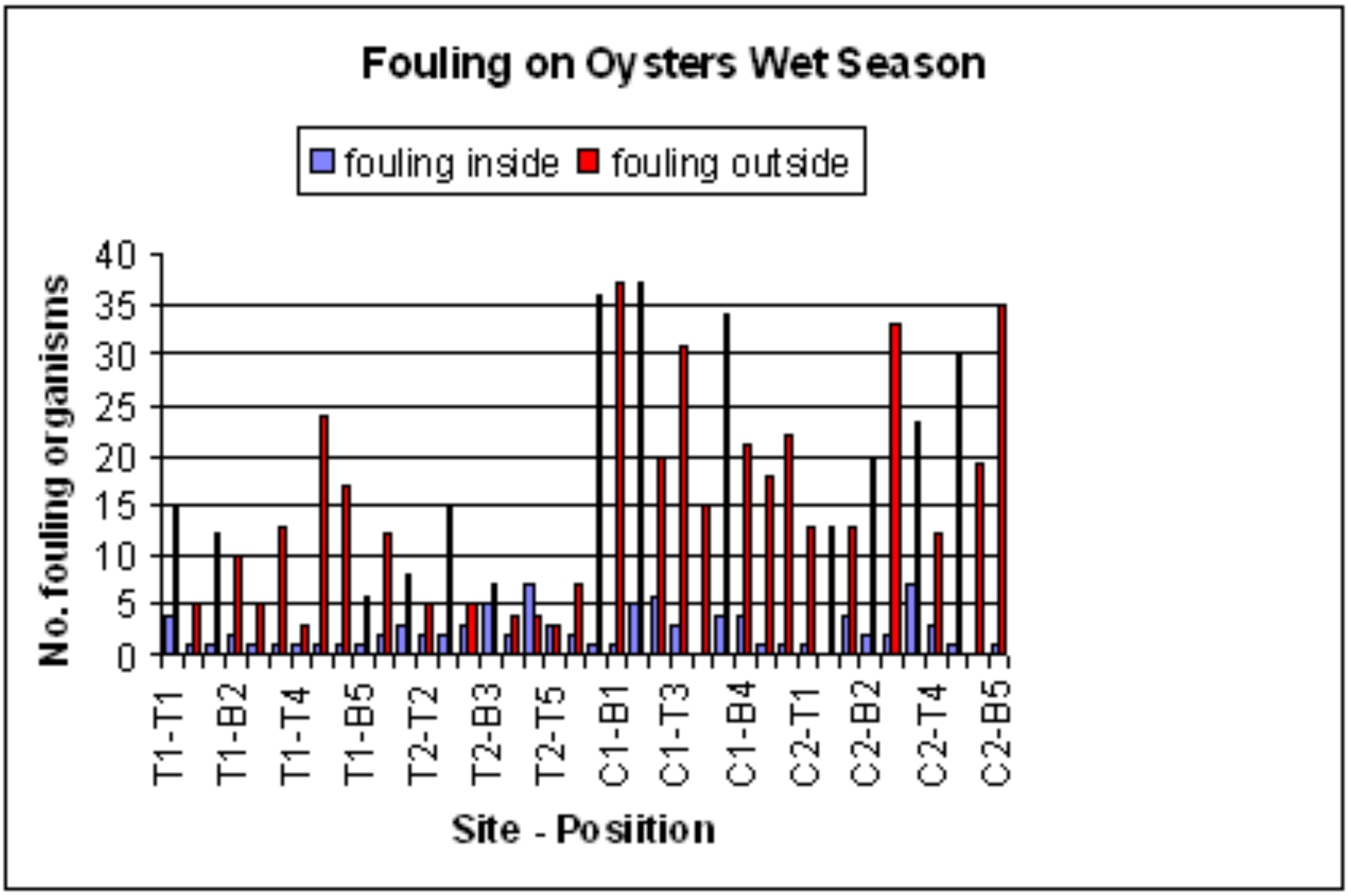

FIGURE 2: Fouling of sediment collectors (inside and outside) by bivalve molluscs (Ostrea sp. and Pinctada maculata) during the wet season.