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Intertidal Culture of the Manila Clam, *Tapes japonica*, Using Hatchery-Reared Seed Clams and Protective Net Enclosures

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Abstract

Commercial feasibility of intertidally culturing the Manila clam, *Tapes japonica*, was investigated at Filucy and Wescott Bays in Puget Sound, Washington. Hatchery-produced seed clams were marked and planted at densities of 1000 clams/m^2 in areas protected by two layers of 12.5mm mesh lightweight plastic netting. Unprotected areas were seeded at densities of 900 clams/m^2. Recovery and growth of the marked clams were studied after 3, 6 and 12 months.

Recovery in protected areas (30-60%) was higher than in unprotected (2-12%); this was attributed to greater predation and washout in unprotected areas. Because of this, growth could be evaluated only for the protected areas, in which mean shell lengths were similar in both bays after 12 months. Clams were larger at lower tidal heights; the growth rate appeared to decrease with increasing tidal height.

At Filucy Bay, the average population density of large ($\geq$ 8 mm) wild Manila clams in the protected area increased tenfold to 191 clams/m^2 while the density of these wild clams in the unprotected area decreased twofold to 16 clams/m^2. This suggests that the netting may act to concentrate juvenile clams from the wild population as they are moved about by wave activity. It is further speculated that the density of larval settlement may be higher in the protected area.

The net value of the potential harvestable biomass/m^2 suggests that this type of commercial culture operation is both practical and economically feasible.

Culture sur littoral de la Palourde de Manille, Tapes japonica, utilisant des établissements de pisciculture pour produire les naissains et des filets pour protection

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Résumé

La practicabilité commerciale de la culture de la palourde de Manille Tapes japonica sur le littoral a été examiné aux baies de Filucy et de Wescott dans le détroit de Puget au Washington. Des naissains de palourdes produits par des établissements de pisciculture furent marqués et ensemencés a des densitées de 1000 palourdes par mètre carré, en des endroits protégés par deux couches de filets plastic très léger d'une maille de 12.5 millimètres. Les endroits non protégés furent ensemencés a des densitées de 900 palourdes par mètre carre. Le rétablissement et la croissance des palourdes marquées furent etudié après trois, six et douze mois.

Le rétablissement dans les endroits protégés (de 30 a 60 %) fut tres élévé comparé avec endroits non protégés (de 2 a 12 %); ceci fut attribué a l'intensité des rapaces et à la mer emportant les palourdes des endroits non protégés. Ces facteurs étant ce qu'ils sont, la croissance des palourdes ne put être evaluée que dans les endroits protégés dans lesquels les moyennes de longeur de coquilles sont semblables dans les deux baies après douze mois. Les palourdes de bas littoral sont larges; le rythme de croissance semble diminuer avec la hauteur du littoral.

Dans la Baie de Filucy, la densité de population moyenne des larges (28 mm) palourdes de Manille sauvages augmenta de dix fois jusqu'à cent quatrevingt-onze palourdes par mètre carré dans les endroits protégés, tandis que la densité des palourdes sauvages dans les endroits non protégés diminua de deux fois jusqu'à seize palourdes par mètre carré. Ceci suggère que le filet pourrait aider à concentrer les palourdes juveniles de la population sauvage lorsqu'elles sont déplacées par les vagues. Il est par ailleurs speculé que la densité de l'établissement du naissain pourrait être plus haute dans les endroits protégés.

La valeur net du potentiel récoltable des palourdes dans un mètre carré suggère que ce type d'opération pour culture commerciale est non seulement pratique mais aussi économiquement possible.

INTRODUCTION

The Manila clam, Tapes japonica, is a commercially important species ranging from California to British Columbia on the west coast of North America. In Washington, commercially exploited populations exist principally in bays and inlets of southern Puget Sound on private or leased tidelands. Demand for the clam has recently increased considerably while commercial supplies have risen only slightly. On public beaches, increasing recreational harvest pressure combined with typically inconsistent recruitment has often reduced the productivity of some populations (Miller, Chew, Jones, Goodwin and Magoon, 1978; Williams, 1978).

To maintain present stocks of T. japonica and restore depleted stocks, workers have investigated the feasibility of seeding clam beds with hatchery-produced juvenile clams. Jones (1974) and Lukas and Gaumer (1974) observed rapid declines in recovery of Manila clam juveniles seeded intertidally without protection. Similar findings were reported for the quahog, Mercenaria mercenaria, when planted on beaches in Florida (Menzel and Sims, 1962). The poor recoveries were attributed to predation, dispersal due to hydrologic forces, and possibly active migration from the study area.

Recent experiments in Puget Sound have demonstrated that recoveries of planted Manila clams improve significantly when protection from predation and washout is provided (Miller et al., 1978; Glock and Chew, 1979). These workers concluded that the most successful and practical method of protection is to cover seeded areas with 6.25 mm - 12.50 mm mesh Vexar plastic netting. High recovery rates for M. mercenaria were achieved using a similar technique in Virginia, U.S.A. (Michael Castagna, pers. comm.) and at Conwy England (Walne, 1974).

Commercial applicability of this technique for Manila clam culture has been uncertain because of the high cost of plastic netting (approximately \$3.56 (US) per m^2). However, Miller et al., (1978) performed limited-scale but promising seeding experiments with an inexpensive (\$0.46 (US) per m^2), lightweight Vexar netting called "Car Cover". Further testing in 1978 confirmed Miller's earlier results (Anderson and Chew, unpubl. data). This suggested that clam culture using hatchery-produced Manila clams and a plastic netting of adequate mesh size might be economical.

The purpose of this study was to determine the feasibility of commercial-scale clam culture using hatchery-produced Manila clam seed and an enclosure of "Car Cover" netting. In this paper we present preliminary results of experiments carried out between April 1979 and May 1980.

MATERIALS AND METHODS

Two locations in the Puget Sound region were selected for this study (Figure 1). Filucy Bay is a shallow, protected inlet in central Puget Sound, approximately 72 km southwest of Seattle. Wescott Bay is a shallow, semi-enclosed bay on San Juan Island in northern Puget Sound. Seasonal water temperature regimes are similar in both bays with summer maximums exceeding 16°C at the surface. The substrate at Filucy Bay is a homogeneous mixture of sand, gravel, and some cobble; at Wescott Bay, the substrate is more variable, ranging from silty-mud to sand-gravel-shell aggregate.

Preliminary sampling in the study areas indicated that both locations had wild populations of Manila clams. Populations were greatest at Filucy Bay, ranging 20-38/m^2 (protected and unprotected areas, respectively) while at Wescott Bay, the density was estimated to be 8/m^2.

In April 1979, a 10 x 30 m area between 0.6 and 2.0 m above mean lower low water (MLLW)[1] at Filucy Bay was covered with two layers of Vexar Car Cover 12.5 mm (bar length) mesh plastic netting. Edges of the netting were staked and buried to prevent the entry of predators, particularly moon snails (<u>Polinices lewisii</u>), crabs (<u>Cancer productus</u>), and several species of flatfish. At Wescott Bay, a 10 x 25 m area between 1.0 and 2.3 m above MLLW was similarly covered with netting.

The protected areas were left to equilibrate for 3 weeks (until 16 May 1979) before seed clams averaging 4.2 mm shell length (antero-posterior) were planted through the netting at densities of 1000 clams/m^2. Unprotected (control) areas (3 x 10 m) planted with 4.2 mm seed clams, but at densities of 900 clams/m^2, were established in each bay. Unprotected areas were adjacent to, but not abutting the protected areas. Seed clams used in all plantings were marked on at least one valve with flourescent spray paint.

A stratified random scheme (four equal strata, I-IV, by increasing tidal height) was used to sample clams after 3, 6 and 12 months. The

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[1] Puget Sound experiences a semi-diurnal unequal tide, see Sverdrup, Johnson and Fleming (1942).

protected area at Wescott Bay was further stratified into two halves by substrate type (mud vs sand-gravel-shell aggregate). Each sample unit consisted of substrate from 8 to 15 cm deep delimited by a 25 x 25 cm frame. Holes left after sampling were refilled with sediment to prevent abnormal shifting of the unsampled substrate and clams and thus to preclude possible biases in later recovery estimates.

Samples were sieved in the field and all clams were returned alive to the laboratory. Marked clams were identified by UV light which caused the original painted mark to flouresce. Planted clams lacking paint could be identified by a distinct disturbance check in the shell at the planting size. All clams (wild and planted) were measured (shell length to 0.1 mm) and weighed (whole animal live weight to 0.01 grams). Data concerning cost of materials, hours of labor, harvesting costs, lease fees, and current wholesale prices of the clams were gathered throughout the study for economic analysis. Interest paid on bank loans and the cost of obtaining environmental permits were not included since they vary greatly and have only a small impact when considered in the long run.

RESULTS

It was found at 3 months that the mud stratum of the protected area at Wescott Bay could not be sampled without greatly disturbing the substrate. Results presented for the protected area at Wescott Bay are therefore based on samples of only the sand-gravel-shell aggregate stratum.

Recovery and Growth of Marked Clams:

Recovery of marked clams in the protected areas remained relatively constant throughout the study averaging (mean of pooled samples from all strata) 60% at Filucy Bay and 30% at Wescott Bay after 12 months (Figure 2). Recovery in the unprotected areas was generally low, with pooled recoveries of 2% and 12% at Filucy Bay and Wescott Bay, respectively (Figure 3). Only in Stratum I (low intertidal) at Wescott Bay was recovery (40%) comparable to that in the protected areas. In both protected and unprotected areas, recovery appeared to decrease with increasing tidal height (see Figures 2 and 3).

Individual growth, measured as change in mean shell length (Figure 4) and mean live weight (Figure 5), was similar in the protected treatments at both sites. Growth rates varied between strata in both bays and appeared to decrease with increasing tidal height (see Figures 4 and 5).

Recruitment of Wild Clams:

The average population density of large (≥ 8 mm shell length) wild Manila clams in the protected area at Filucy Bay increased from $20/m^2$ to $191/m^2$ during the 12 months of study while densities in the unprotected area decreased from an average of $38/m^2$ to $16/m^2$ (Figure 7). Smaller individuals (< 8 mm) were not retained in samples after 3 months due to the minimum sieve size used (6.25 mm).

The population density of wild Manila clams in both protected and unprotected areas did not change significantly at Wescott Bay during the period of study.

Estimation of Potential Production:

Because the clams in the protected areas at both bays were too small to harvest after 12 months, it was necessary to estimate the potential production of clams (kg live weight/m^2) for a later harvest date. In Washington the minimum size of Manila clams harvested commercially is approximately 35 mm (shell length). Using growth rates determined in a previous study (Anderson and Chew, unpubl. data) for clams grown at Filucy Bay and length-frequency data (after 12 months) from the present study, we estimated that 90% of the marked clams would be of harvestable size (≥ 35 mm) by autumn of 1981, approximately 2.5 years after planting. To allow for natural mortalities, we adjusted the estimates to allow for an additional 20% loss of clams prior to harvesting. Using length: live weight relations derived for planted and wild Manila clams grown at Filucy Bay (Anderson and Chew, unpubl. data), potential production of clams in the protected areas of both locations was estimated. The wild manila clams at Filucy Bay were included in the estimates since they would contribute significantly to the total production.

Production and harvesting costs ($\$(US)/m^2$) that clam growers in Washington would incur using our technique are listed in Table 1. The potential production and its monetary value for protected areas in both bays are shown in Table 2. A comparison of the average production cost with the wholesale value of the potential production shows that a net monetary profit would be realized from the protected area at Filucy Bay, but not at Wescott Bay if harvested after 2.5 years.

DISCUSSION

Recovery rates attained in this study for protected and unprotected areas are similar to those reported for both small scale (< 50 m^2) and large scale (50-200 m^2) plantings of Manila clams (Menzel and Sims, 1962; Jones, 1974; Lukas and Gaumer, 1974; Miller et al., 1978; Glock and Chew, 1978; Latrouite and Perodou, 1979). Movement of clams to lower tide levels, dispersal of small seed clams by waves and/or currents, and mortalities caused by emersion at low tide probably account for the reduced densities in protected areas during the first three months of the study. No significant decrease in recovery was observed in either bay suggesting that greater initial recovery rates might be possible if a smaller mesh netting were used for the first few months of growth.

The rapid and near complete loss of clams from unprotected areas was likely due to both washout and predation. Washout of clams from unprotected planting areas has been commonly reported for Manila clams (Lukas, 1973; Jones, 1974; Miller et al., 1978; Glock and Chew, 1979) and similarly for the quahog, M. mercenaria (Menzel and Sims, 1962).

Predators on Manila clams in Puget Sound have been well documented (Glude, 1964; Mark Miller pers. comm.). Several of these species including C. productus, P. lewisi, and scoter ducks have been observed at both locations and may have preyed on the planted clams.

The apparent decrease in the growth rate of Manila clams with increasing tidal height has elsewhere been attributed to extended periods of emersion and, consequently, short feeding periods for clams living in the upper intertidal (Glock and Chew, 1979). In this study, the lowest growth rate was found for clams in Stratum IV (high intertidal) of the protected area at Wescott Bay. The tide level of this stratum (approximately 2.0 to 2.3 M above MLLW) is usually considered the upper limit of Manila clams (Quayle and Bourne, 1972).

The rapid increase in density of wild Manila clams in the protected area at Filucy Bay indicates that the netting acts to concentrate juvenile clams moving over the beach and perhaps to increase the intensity of larval settlement. Glock and Chew (1979) found high densities (350-600/m^2) of small (no size reported) wild Manila clams under plastic netting and suggested that the netting disrupted current flow and caused clams to fall from suspension. Surface irregularities, such as tubes of benthic organisms and rocks, on soft bottoms have been shown to affect small-scale dispersion patterns of settling larvae by disrupting water flow and causing the settling larvae to concentrate around them (Eckman, 1979). Zahradnik and Walker (1979) demonstrated that plastic netting laid on the bottom in the intertidal zone significantly increased the settlement density of the soft-shell clam, *Mya arenaria*. These results imply that enhanced production of wild Manila clams could possibly reduce costs and increase profits to clam growers using plastic netting in areas which receive regular spatfall but have poor survival of the clams to maturity.

CONCLUSIONS

The preliminary results of this study strongly suggest that commercial culture of Manila clams involving protective net coverings and hatchery-produced seed clams is both practical and economically feasible. Profitability of the technique, however, will depend largely on the location and efficiency of the culture operation and upon labor costs.

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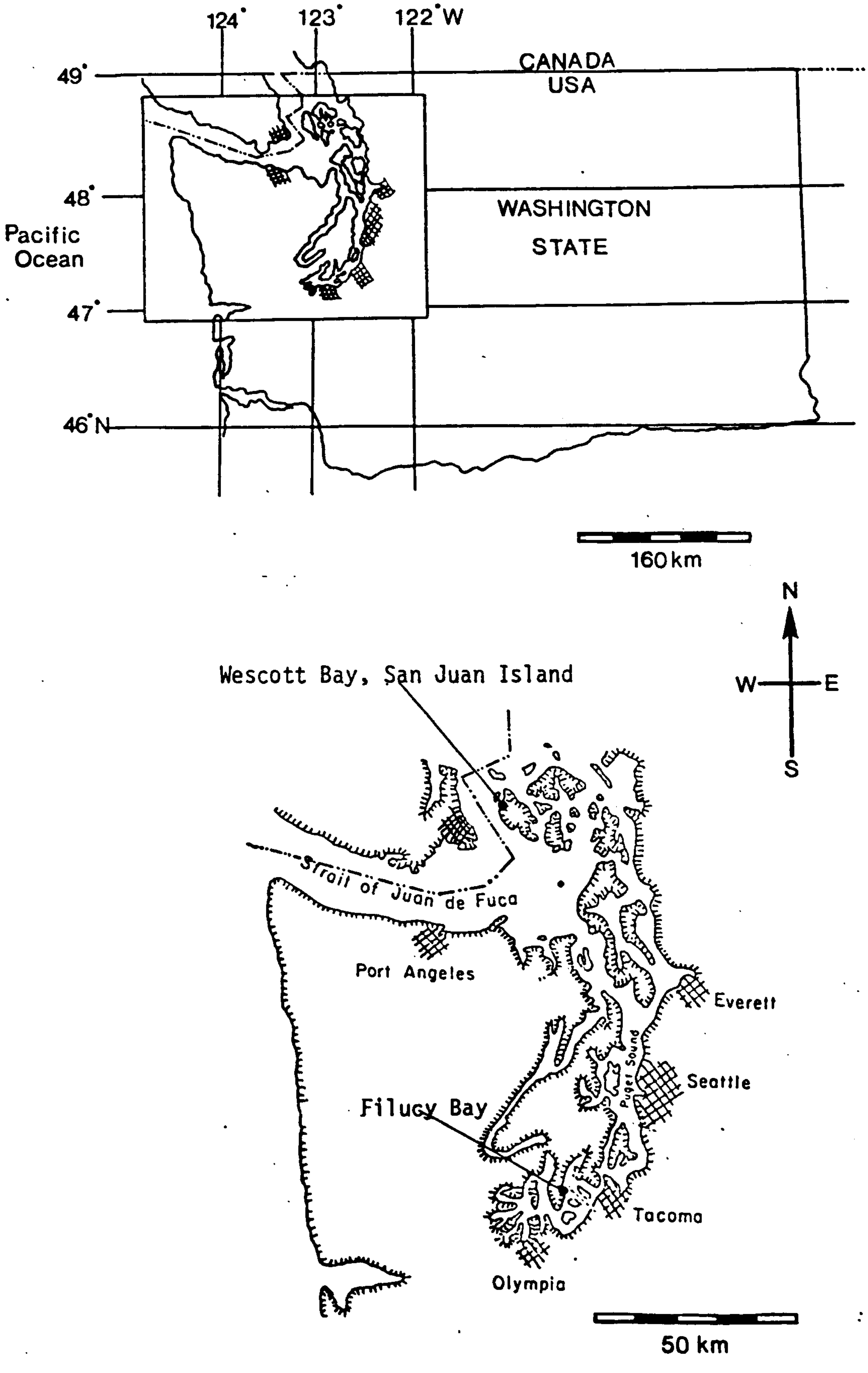
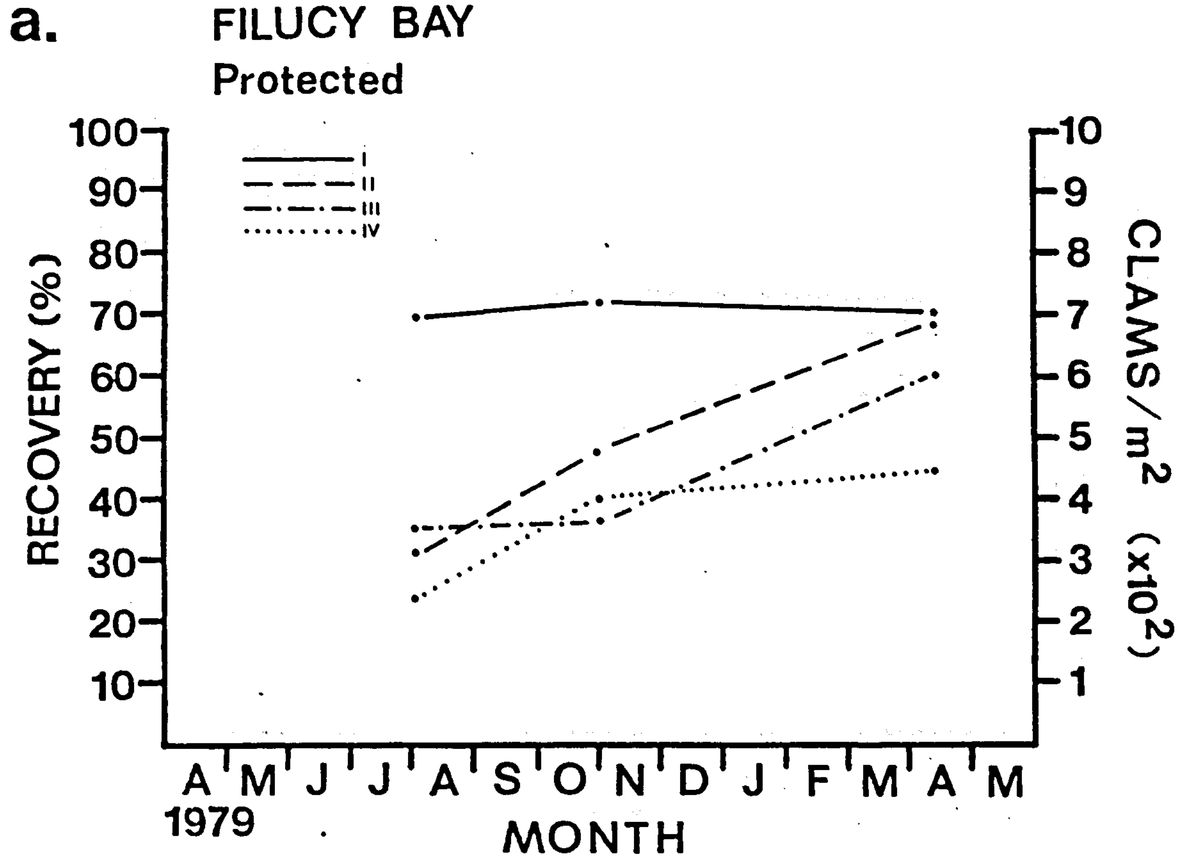


Figure 1: Map of Puget Sound Region showing study locations.

a.



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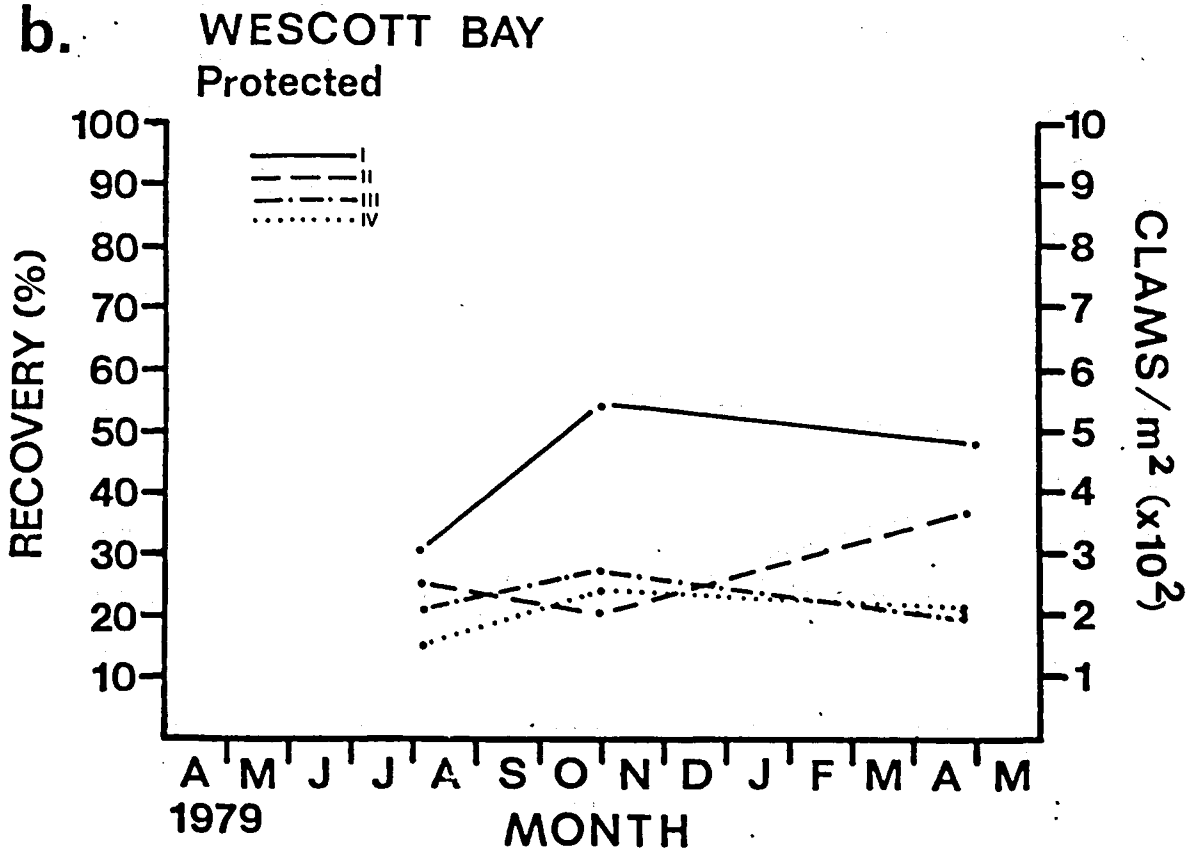

Figure 2: Average recovery rate and density of marked Manila clams in protected areas after 3, 6 and 12 months: (a) Recovery of clams in Strata I-IV at Filucy Bay. N = 16 for all strata except at 3 months for which N = 2, 5, 11, 10 for Strata I-IV respectively; (b) Recovery of clams in Strata I-IV at Wescott Bay. N = 8 for all strata at 3 months, N = 10 for all strata thereafter.

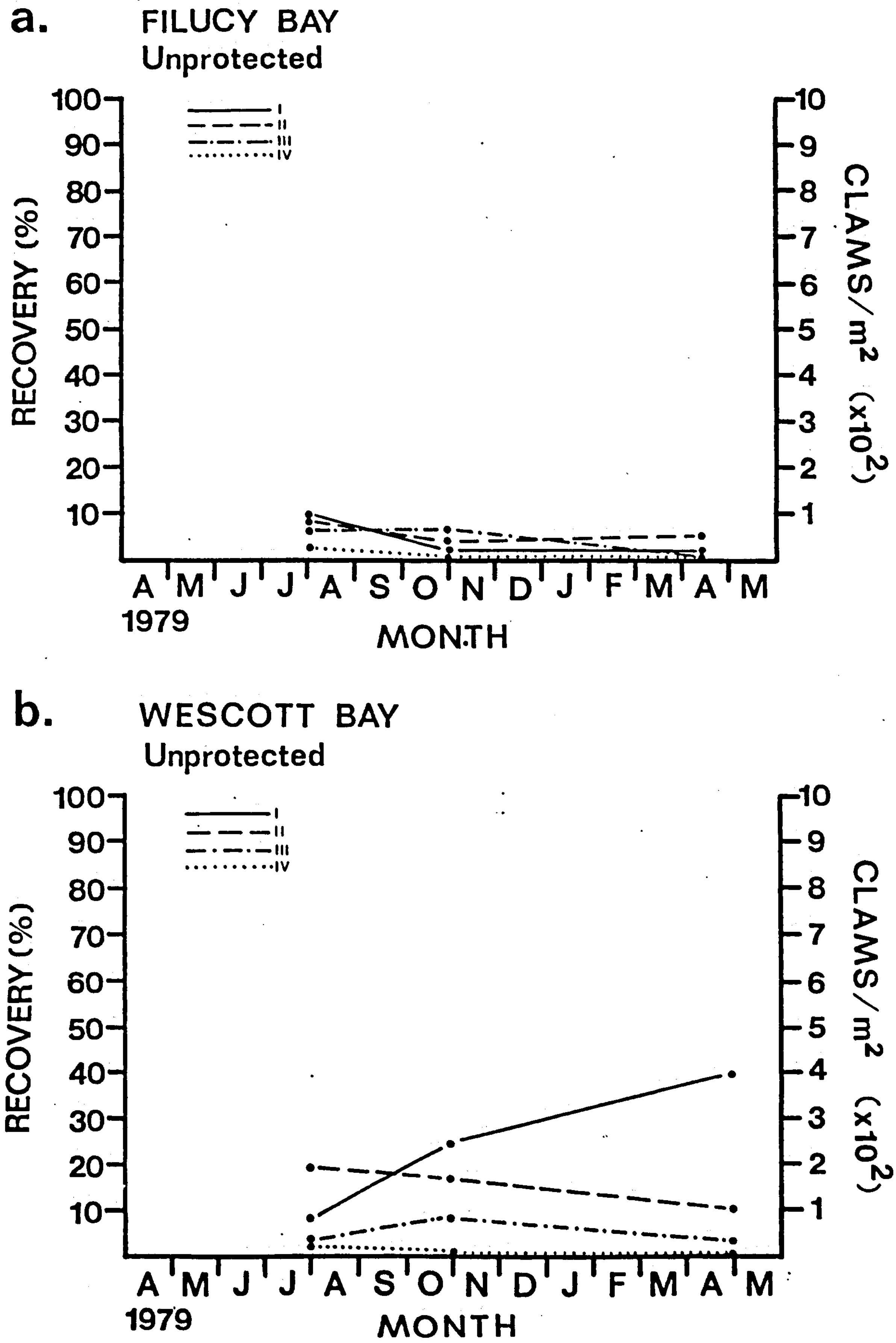

Figure 3: Average recovery rate and density of marked clams in unprotected areas in each bay after 3, 6 and 12 months: (a) Filucy Bay, N = 4 for all strata; (b) Wescott Bay, N = 4 for all strata.

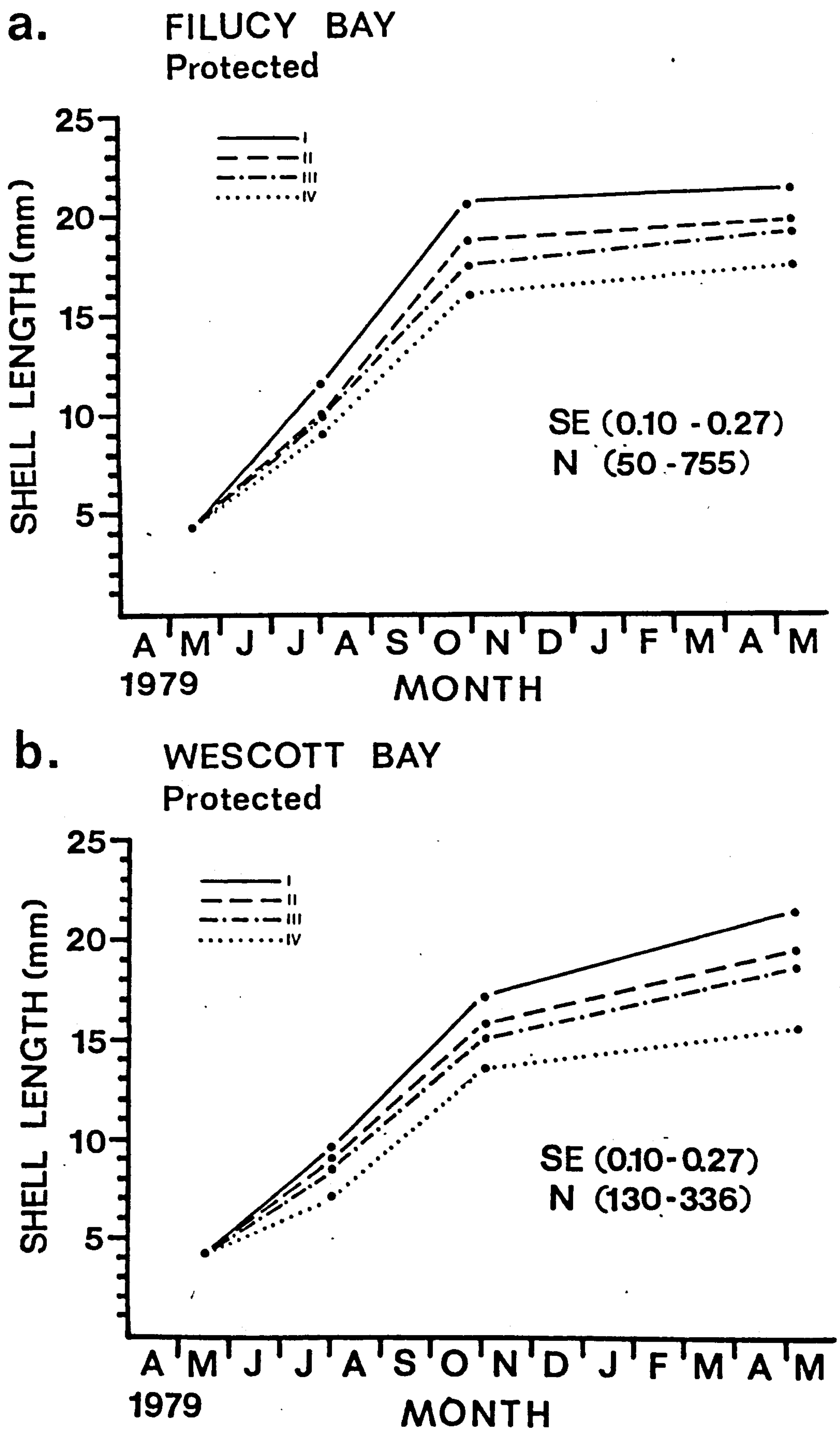

Figure 4: Mean shell length (mm) of clams by stratum on all sample dates in the protected areas at each bay after 3, 6 and 12 months. Range of SE (standard error) and N given for data: (a) Filucy Bay; (b) Wescott Bay.

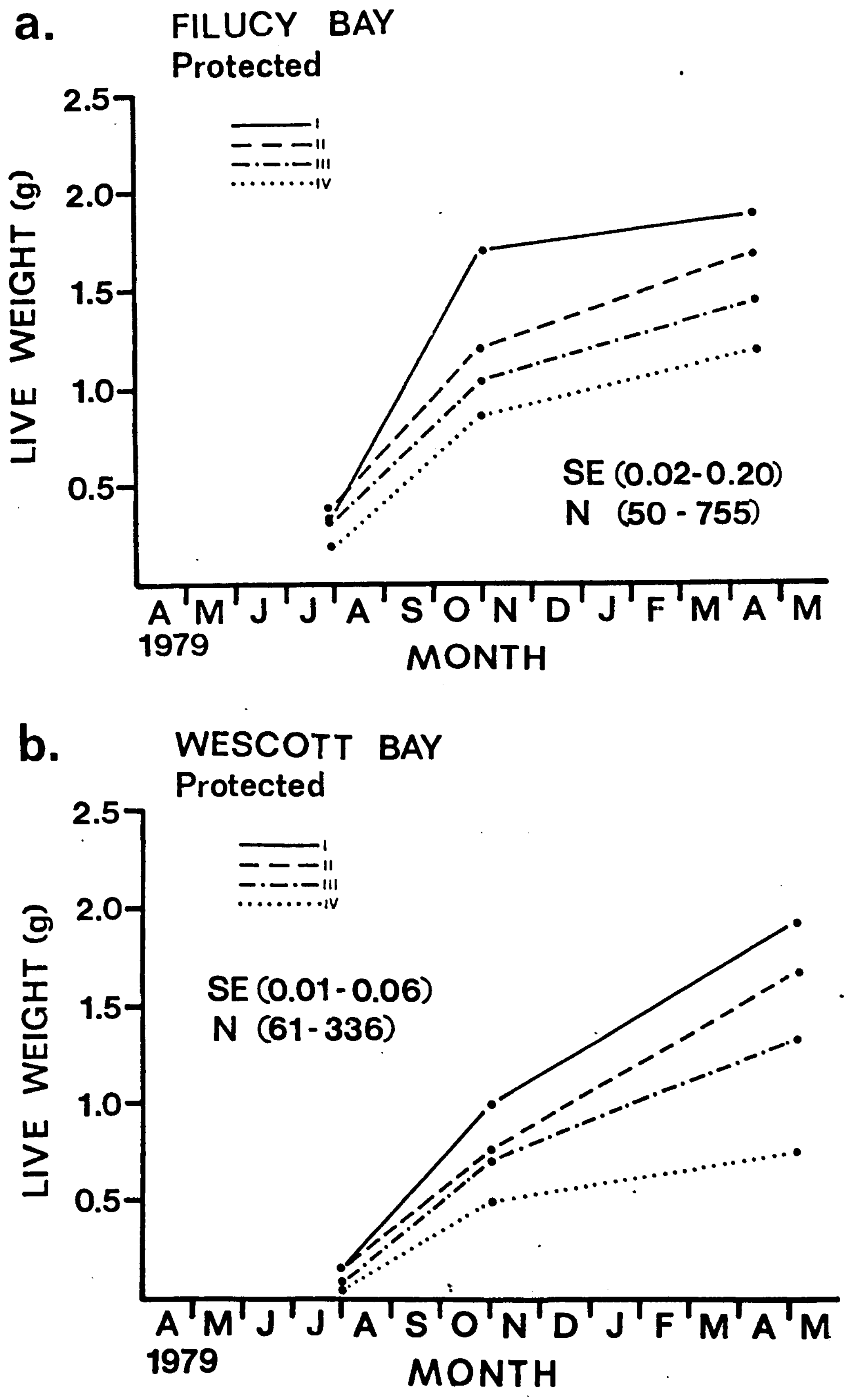

Figure 5: Mean individual live weight of clams in each stratum in the protected areas in each bay after 3, 5 and 12 months. Range of SE and N given for all data: (a) Filucy Bay; (b) Wescott Bay.

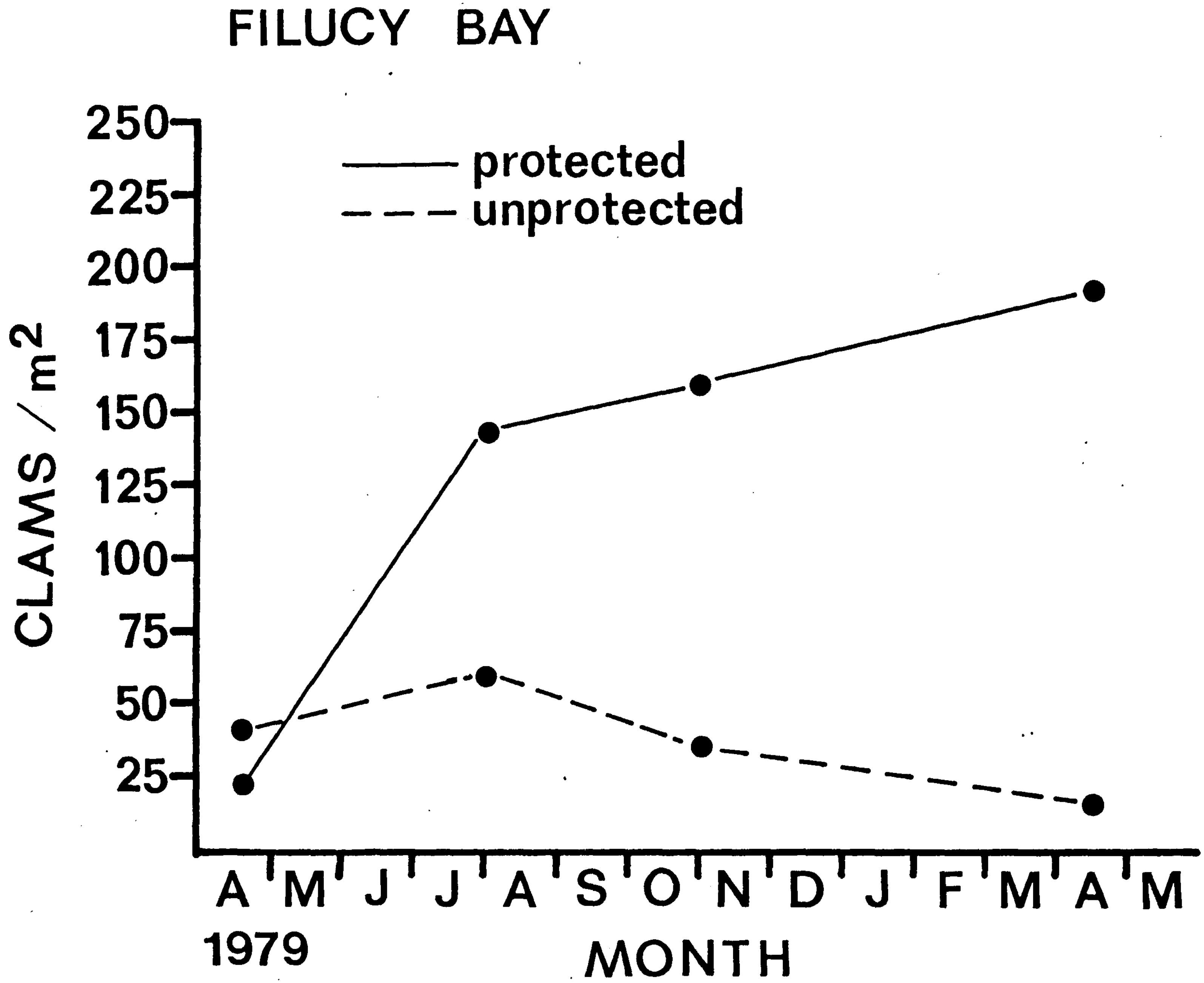

Figure 6: Average population density (clams/m^2) of wild manila clams $\geq$ 3 mm shell length in the protected and unprotected areas at Filucy Bay prior to treatment and after 3, 6 and 12 months.

Table 1: Estimated production and harvesting costs for a clam grower in Washington using plastic net enclosures and hatchery-produced seed clams.

Production Costs (1979)	Cost per m^2
Manila Clam seed (Pacific Mariculture, Inc.)	$4.00
Vexar(C) Car Cover netting, 2 layers	0.46
Wooden Stakes, nails, twine, etc. for construction of enclosures	0.05
Labor to construct nets, plant and maintain clam bed ($4.50 (US)/hour)	1.02
TOTAL	$5.53/$m^2$

Harvesting Costs (1980)	Cost per kg
Hand harvest and washing	$0.55
State lease fee	0.07
TOTAL	$0.62/kg

Table 2: Potential harvestable weight of Manila clams and the wholesale and net values of the production from the protected areas at Filucy and Wescott Bays (based on 1980 prices).

	Potential Harvestable Weight kg/m^2	Wholesale Value per m^2	Production and Harvesting Cost per m^2	Net Profit per m^2
<u>Filucy Bay</u>				
Planted clams	6.1 kg	$11.59	$ 9.31	+$ 2.28
Wild clams	2.1	3.99	1.30	+ 2.69
TOTAL	8.2	$15.58	$10.61	+ 4.97
<u>Wescott Bay</u>				
Planted clams	3.1	5.89	7.45	- 1.56