1.0 INTRODUCTION

The aims of the present study were to provide a biological description of the benthos under and adjacent to a number of proposed marine farms between Pig Bay and Hunia, located on the north-west shores of Port Gore. Potential threats to any subtidal ecological values posed by the proposed activity were also discussed. All five marine farm application areas were investigated during the two sample events. Standard transects and random quadrat protocols were adopted for the investigation.

2.0 STUDY AREA

The following section dealing with the ecology of Port Gore is based on a total of 27 dives throughout much of the Bay (Figure 1). Port Gore is a large bay located in the outer Marlborough Sounds. The entrance to Port Gore between Cape Jackson and Cape Lambert is approximately 6.5 km across, while the bay is some 9.5 km in length. Depths vary considerably with a large area in the outer reaches ranging between 15 m to 25 m depth, while the inner Port is considerably deeper ranging between 31 m to 40 m depth (see Navy Chart NZ 615).

The shoreline of Port Gore is characterised by a variety of shore types reflecting their exposure to wave energy.

Very sheltered shores (Melville Cove)

Melville Cove is the most sheltered part of the Port and is some 2 km in length and between 5 00 m to 2 km wide. The Cove is dominated by cobble shores colonised by an either a sparse or absent macroalgal fringe. The cobble substratum is usually relatively narrow and grades into shelly sand and silt slopes. The flat benthos of the Cove is dominated by flat featureless mud. A relatively low range of species typical of sheltered shores is present within the Cove. This area can best be compared to the sheltered shores within the Marlborough Sounds.

Exposed shores (Black Head to Cape Jackson and Taratara to Cape Lambert)

In extreme contrast to Melville Cove, the coast between Cape Jackson and Black Head located on the south eastern side of Port Gore and the coastline between Taratara and Cape Lambert located on the north-eastern shores of Port Gore

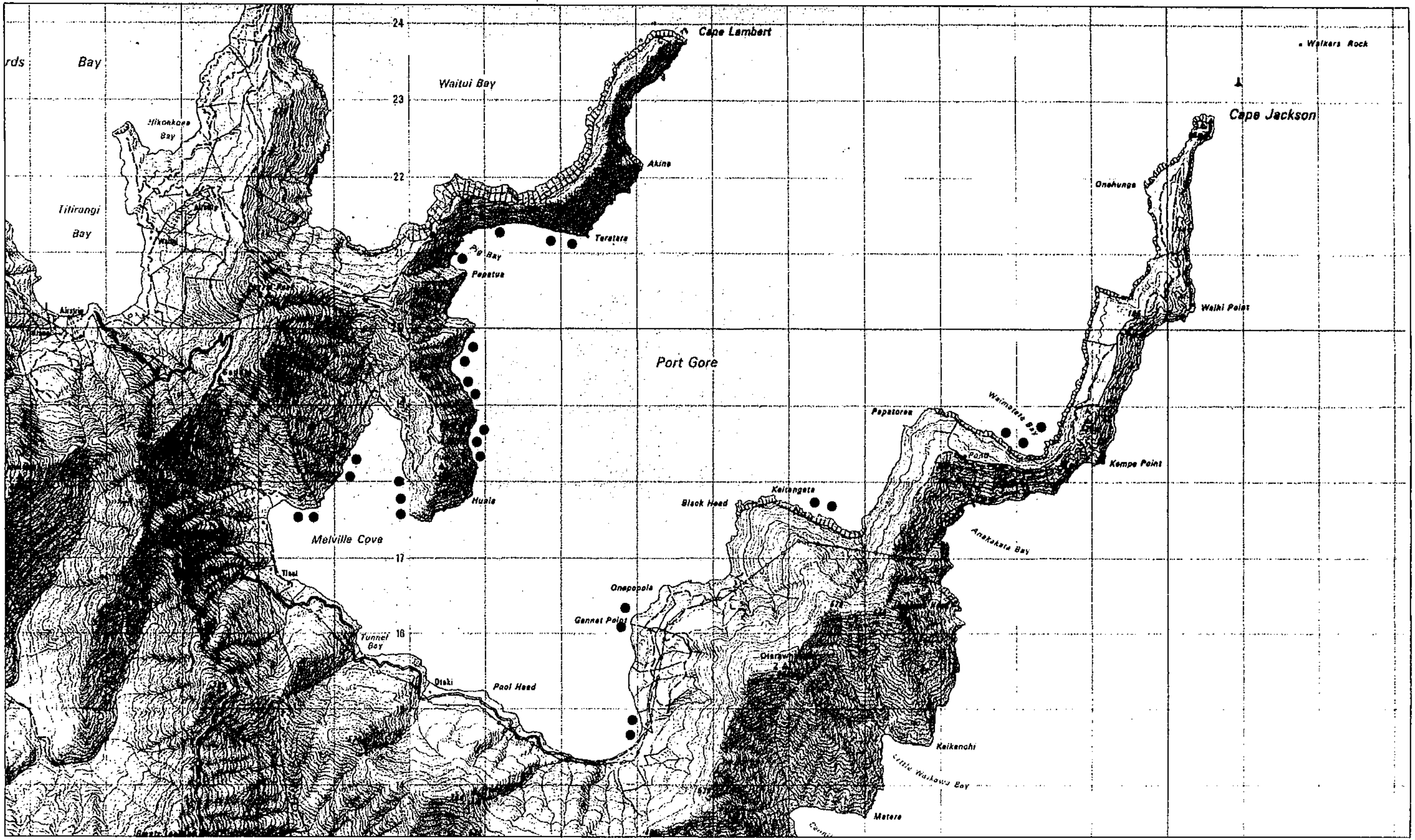


Figure 1 Dive sites located within Port Gore

represent the most exposed parts of the Port. These shorelines are dominated by bedrock and boulder substrata often rising vertically forming cliffs and overhangs. A variety of macroalgal species characteristic of exposed shores form often wide beds on rock substrata (e.g. *Durvilleae* spp. in areas closest to Cape Jackson and *Ecklonia radiata* throughout). Rocky reef areas support a wide range of invertebrate and fish species often in high abundance (e.g. paua, crayfish, tarakihi, blue moki and blue cod). Offshore of rock substrata exist coarse sand dominated shores often rippled in appearance due to wave action. On sand shores below the area of wave action exist patches of horse mussels.

Moderately sheltered (Tatara to Hunia, Black Head to Pool Head)

Coastlines between Tatara to Hunia and Black Head to Pool Head are best described as moderately exposed shores. Within these areas gradients in exposure to wave action exist especially between Back Head and Gannet Point. These areas are generally sheltered from large oceanic swells. Instead they are subject to wind generated surface chop. Choppy conditions occur during the predominant north-west winds and northerly storms (Black Head to Pool Head) and southerly to easterly winds (Tatara to Hunia). These areas often support particular species found in exposed areas (e.g. paua, blue cod and blue moki) and species found in sheltered areas (e.g. soft bottom algal beds). These areas can therefore be best considered as intermediate between exposed and sheltered shore types in Port Gore and the Marlborough Sounds.

Turbidity and water quality

Apart from Melville Cove, Port Gore is bathed by oceanic water from the immediately adjacent Cook Strait. Cook Strait water exhibits relatively low sediment loading (turbidity) compared to many inner Sounds areas such as Pelorus Sound and Port Underwood. High sediment loading in many areas is derived from river inputs during flood events. Port Gore receives sediment from a variety of small streams and from runoff, but due the small size of the catchments and the often bush clad nature of the catchments, it is expected that sediment loading is small compared to systems such as the Pelorus.

Low turbidity and sediment loading is an important variable influencing subtidal communities. For example, soft bottom red algal beds rely on sufficient light penetration for photosynthesis, while the feeding parts of many benthic organisms (e.g. tube worms) can become clogged with sediment.

Port Gore in relation to the Marlborough Sounds and New Zealand

A range of shore types from exposed through to sheltered are found in many of the outer Sounds bays such as Guards Bay, Anakoha Bay and Forsyth Bay, but Port

Gore supports a greater range of extremes than most other bays. Most comparable to Port Gore in terms of wave exposure scale is Port Hardy, northern D'Urville Island.

Low turbidity and sediment environments in the Sounds are generally restricted to the outer Sounds. Other areas in New Zealand subject to low sediment loading include Paterson Inlet, Fiordland, and offshore island around northern North Island.

Present study area (Pig Bay to Hunia)

The present study areas (Pig Bay to Hunia) is best described as a moderately sheltered shore type located in an outer Sounds environment. Bedrock promontories surrounded by boulder and cobble shores dominated the intertidal shore. In most areas, the subtidal rocky shore is relatively narrow giving way to soft sediments in relatively shallow water. Soft sediment shores are most often dominated by sand that is rippled in shallow areas. With increasing depth the sand grades into sediments dominated by shell and fine sand and finally silt and clays. Silts and clays dominate offshore flat bottom areas.

3.0 BACKGROUND

Little biological investigation has occurred or has been published within Port Gore.

Five offshore benthic samples collected from Port Gore were included in a report by McKnight and Grange (1991). The four sample stations located from Pig Bay south-west into Port Gore were classified into the community group typical of mud substrata (McKnight 1969). The sample station in Pig Bay was collected offshore in 37 m of water depth. It was therefore not surprising that the fauna was dominated by a mud dwelling community.

Hay (1990) described horse mussel beds in areas further north-east than Pig Bay towards Cape Lambert. The author stated that horse mussel beds in Port Gore and some of the other outer Sounds Bays represented the largest remaining populations of this once widespread biological community.

4.0 MATERIALS AND METHODS

The area was investigated on the 11th June and 24th November 1998. All five marine farm sites (A to E) were visited during these investigations.

Within each site, between one and two sample stations were randomly selected for study (Figure 2). At each station, a lead-lined transect line marked at 5 m intervals was installed between the low water mark and 150 m distance offshore (Figure 2). At each transect, divers recorded depth, distance, substrata and noted the presence of particular species or communities. Careful attention was paid to the boundaries of horse mussel, scallop, red algal and tube worm beds.

At transects Tr3, Tr4 and Tr6, densities of horse mussel (*Atrina zelandica*) and scallop (*Pecten novaezelandiae)* were collected using two methodologies. Firstly, divers collected densities from contiguous 10 x 1 m^2 quadrats installed along the length of these transects. Secondly, divers collected densities from random $1m^2$ quadrats installed within and inshore of the proposed marine farm areas. Where present along transects, divers also recorded the percentage cover of red algal beds within each 10 metre distance interval located along transects. Divers recorded the depth and location of any species of particular ecological, scientific or conservation value as defined in:

1. the Department of Conservation guideline document for the investigation of marine farms (Department of Conservation 1995); and
2. the Department's report on areas of ecological and scientific importance in the Marlborough Sounds (Davidson *et al.* 1995).

All depths presented in this report are adjusted to datum.

5.0 RESULTS AND DISCUSSION

5.1 Shore Profiles

The intertidal zone adjacent to the proposed marine farm area was characterised by combinations of bedrock, large, medium and small boulders, cobbles and pebbles. In isolated areas, small pebble beaches usually located between small bedrock promontories were observed.

At most transects a similar range of habitats colonised by a comparable range of associated communities and species were recorded during the study. Transects and the associated shore profiles have therefore been described based on the typical range of biological features recorded during the study.

The subtidal shore was initially dominated by hard substrata composed of combinations of bedrock, cobbles and small, medium and large boulders (Figures 3, 4, 5, 6, 7, 8, 9 and 10). At most stations, this hard shore habitat was relatively narrow, extending less than 20 m distance at transects 3, 5, 6 and 7 and less than 55 m distance at transects 1, 2, and 8. In contrast, hard shores were recorded offshore to 90 m distance from the low tide level at transect 4 (Figure 5). In shallow areas < 4 m depth, hard shores were often colonised by brown macroalgae dominated by *Carpophyllum maschalocarpum, C. flexuosum* and *Ecklonia radiata*. The first of these two species are widespread throughout the Marlborough Sounds, while the latter is restricted to the outer parts of the Sounds (e.g. Queen Charlotte Sound east of Long Island). Hard shores below approximately 4 m depth were colonised by a cover of coralline paint and a typical range of Marlborough Sounds invertebrates.

Below the reef zone, rippled sand was widespread in shallow areas (<6 m depth)(Transects 3, 6 and 7). With increasing distance from shore, the proportion of shell, fine sand and silt substrata increased. In general, coarser substrata extended well offshore, finally grading into a silt (mud) dominated benthos at 120 m to 160 m distance from low tide. Between the inshore sand and hard shores and the offshore silt substrata, the benthos was dominated by combinations of dead shell, broken shell, fine sand, sand and silt.

5.2 Fish

Six species of fish were observed within the boundaries of the proposed farm sites (blue cod, spotty, opal fish, leatherjacket, sea perch, stargazer and an unidentified species of triplefin). A further eight species were observed inshore of the proposed marine farm areas (variable, common, yellow black, blue-eye and oblique triplefins, blue moki, banded wrasse). The number and composition of fish species were representative of sheltered rubble dominated areas in the Marlborough Sounds. The exceptions were sea perch and oblique and blue-eye triplefins that are generally restricted to outer parts of the main Sounds and the outer Marlborough Sounds.

Of particular note was the occurrence of adult blue cod up to 110 m offshore. These fish were observed within horse mussel beds. Juvenile cod less than 10cm length were also regularly observed in these offshore areas, but were less common from inshore areas (i.e. in depths of approximately <8 m).

5.3 Horse mussels (*Atrina zelandica*)

Horse mussels were observed from all transects during the present investigation. Horse mussels were observed between 6 m to 35 m depth, but were most abundant between 10 m to 35 m depth. At two stations (Tr3, Tr4 and Tr6), densities of horse mussels were collected from random $1m^2$ quadrats and from 10x $1m^2$ quadrats located along the length of each transect. Summary densities are presented in Table 1, while densities versus distance from shore are plotted in Figure 11, while density versus depths are plotted in Figure 12.

Comparison of results collected from the two transects suggest that horse mussel abundance varied with depth and distance from shore. Overall, horse mussels were most abundant between 20 m and 160 m distance from shore reaching highest densities between 10 m to 24 m depth (40 m to 120 m distance from shore) on transect 3, between 16 to 34 m (100 and 160 m distance from shore) on transect 4 and 23 m to 32 m (120 m to 150 m distance from shore) on transect 6. Mean horse mussel density pooled from each transect varied little (Figure 12) and were considerably higher than the Department of Conservation trigger level of 0.2 individuals per m^{-2} (Department of Conservation 1995). Mean densities inside the proposed marine farm were highest at transect 4 due to the horse mussel bed being located further from shore. At transect 3, over half of the horse mussed was located inshore of the proposed marine farm (Figure 11). Pooled density data collected from all quadrats showed that horse mussels were well above Department of Conservation trigger levels both inside and outside the proposed marine farms (Table 1).

Table 1 Density of horse mussels collected from transects from (a) random 1 m^2 quadrats between 30 m and 160 m distance from shore and (b) 10x1 m^2 contiguous quadrats along the length of the transect.

Station	Treatment	n	Mean density (per m^2)	Standard error
Transect 3				
1 m^2 quadrats	Inside farm boundaries	47	2.0	0.424
	Outside farm boundaries	39	3.26	0.488
10x1 m^2 contiguous quadrats	Inside farm boundaries	6	0.65	0.293
	Outside farm boundaries	9	1.29	0.497
Transect 4				
1 m^2 quadrats	Inside farm boundaries	56	2.89	0.233
	Outside farm boundaries	4	0.25	0.25
10x1 m^2 contiguous quadrats	Inside farm boundaries	7	1.85	0.70
	Outside farm boundaries	10	0	0
Transect 6				
1 m^2 quadrats	Inside farm boundaries	18	0.66	0.25
	Outside farm boundaries	21	0	0
10x1 m^2 contiguous quadrats	Inside farm boundaries	5	0.36	0.16
	Outside farm boundaries	6	0	0
Pooled totals	**Inside farm boundaries**	**139**	**1.4**	**0.41**
	Outside boundaries	**89**	**0.8**	**0.53**

5.4 Scallops (*Pecten novaezelandiae*)

Scallops were observed from all transects. Densities were collected from transects Tr3, Tr4 and Tr6 located from within the proposed farm (i.e. between 90-110m and 150 m distance from low water) and from areas inshore of the proposed marine farms (Table 2).

No obvious pattern in scallop distribution was apparent. Scallops were found in association with the horse mussel beds and from inshore areas dominated by relatively bare shell and sand substrata. Densities from the three transects and from areas within and inshore of the proposed marine farms were all above the Department of Conservation guideline density as representing a scallop bed (i.e. >0.1 scallops per m^{-2}).

All scallops encountered within quadrats were measured. A total of 43 scallops were measured, averaging 107.7 mm in diameter with a standard error of 2.25 mm. The population was dominated by large adults with no juvenile scallops (<60mm) observed.

Table 2 Density of scallops collected from transects from a site in Waitata Bay.

Station	Treatment	Number	Mean density (per m^2)	Standard error
Transect 3				
1 m^2 quadrats	Inside farm boundaries	43	0.814	0.465
	Outside farm boundaries	37	0.595	0.137
Transect 4				
1 m^2 quadrats	Inside farm boundaries	56	0.143	0.047
	Outside farm boundaries	4	0.25	0.25
Transect 6				
1 m^2 quadrats	Inside farm boundaries	18	0.38	0.16
	Outside farm boundaries	21	0.38	0.13
Pooled total	**Inside farm boundaries**	**117**	**0.446**	**0.196**
	Outside boundaries	**62**	**0.408**	**0.487**

5.5 Lampshells (Brachiopods)

Lampshells (*Magasella sanguinea*) were observed, but not in high numbers or forming a distinct bed. One giant lampshell (*Neothyrus lenticularis*) was observed on transect 1 at 21 m depth, some 120 m distance from shore. No other giant lampshells were observed during the present study

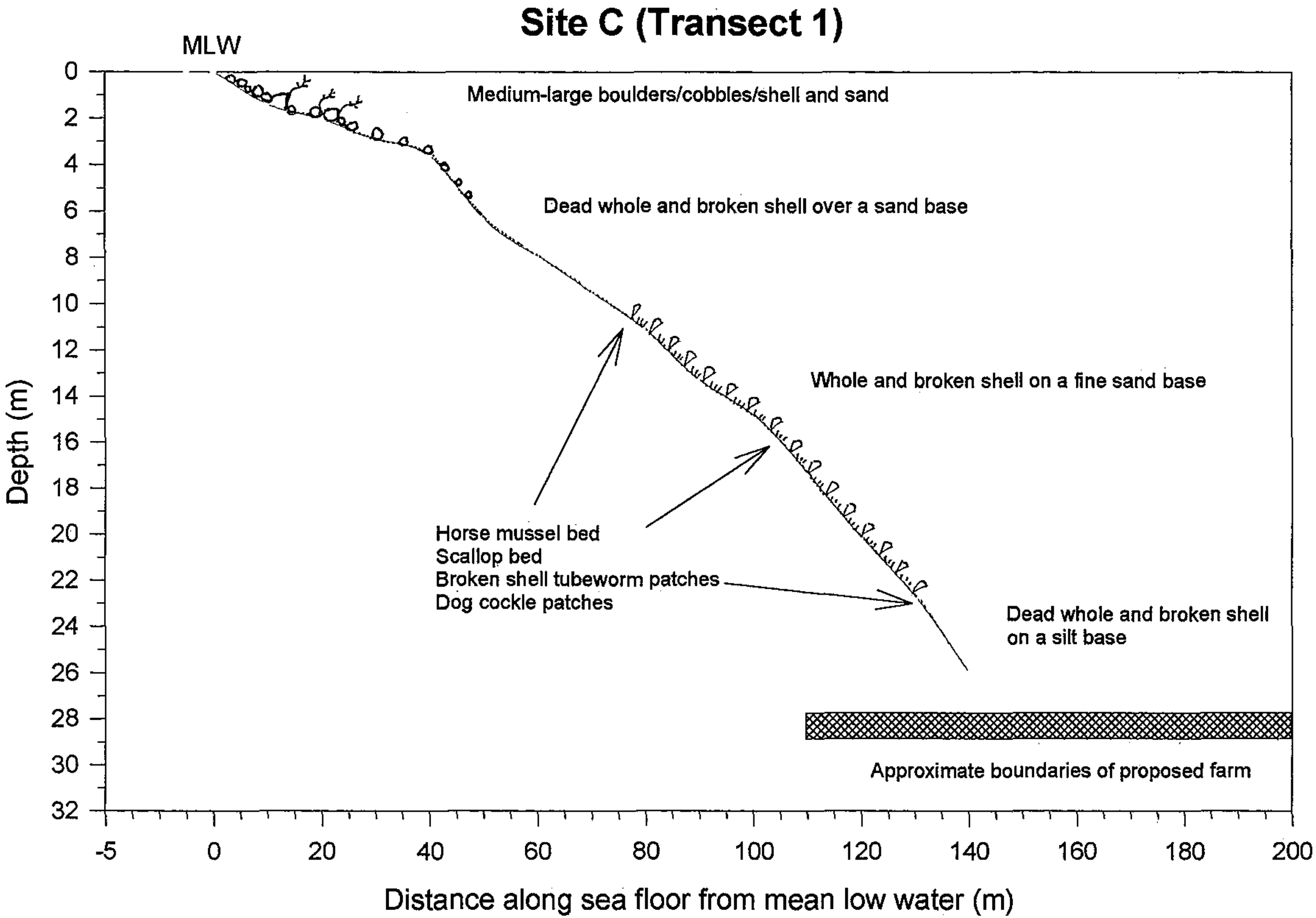


Figure 3 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

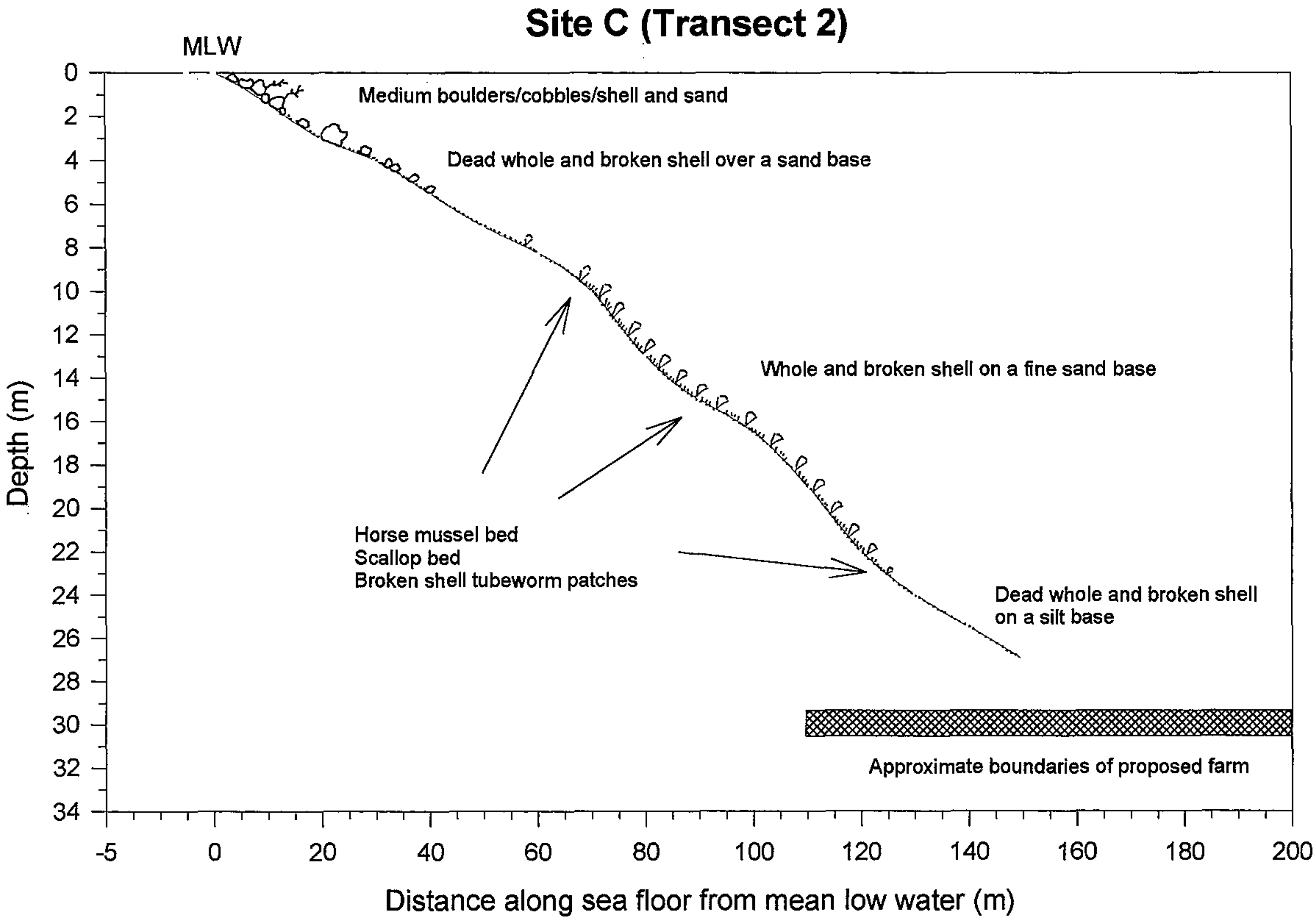


Figure 4 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

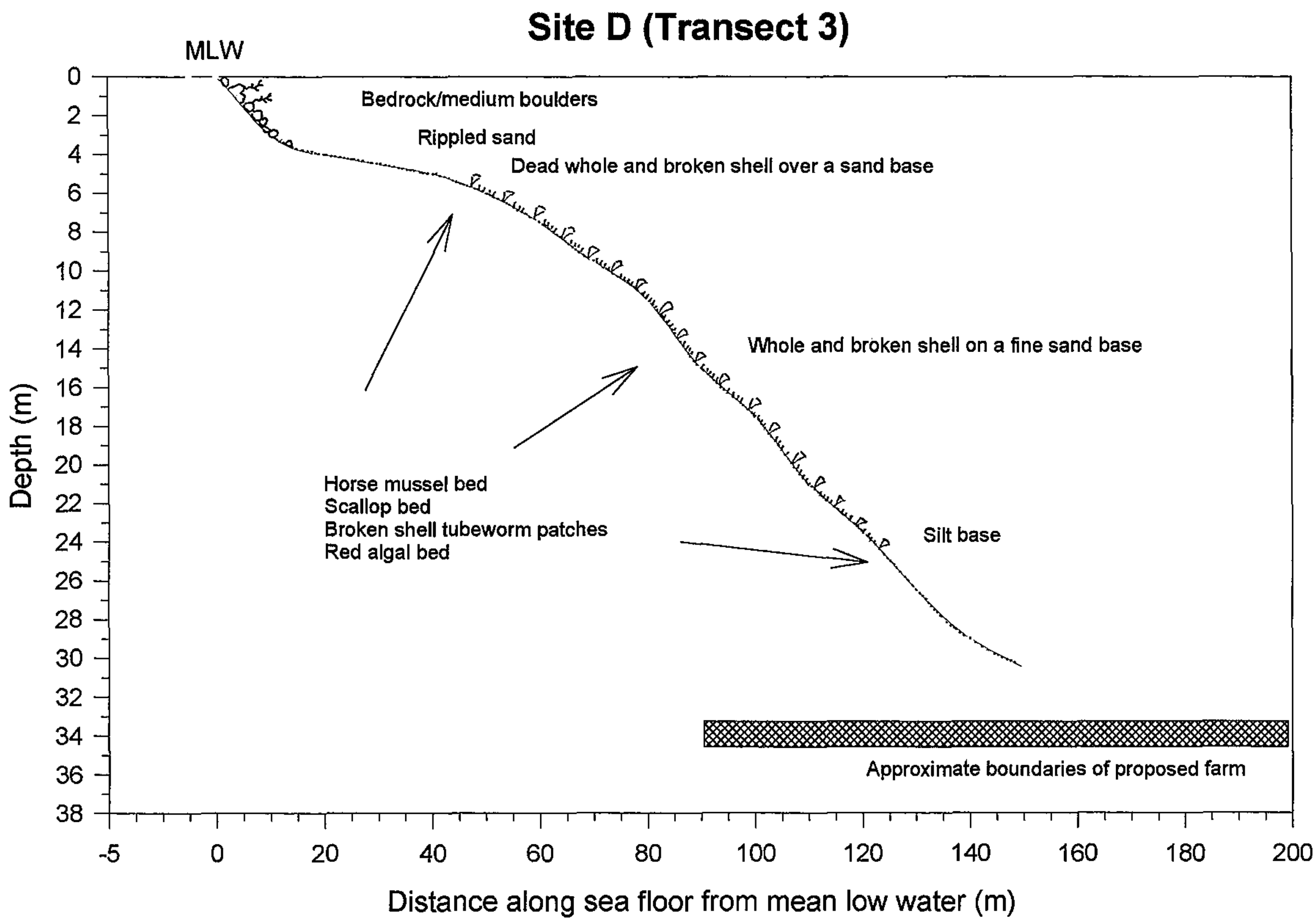


Figure 5 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

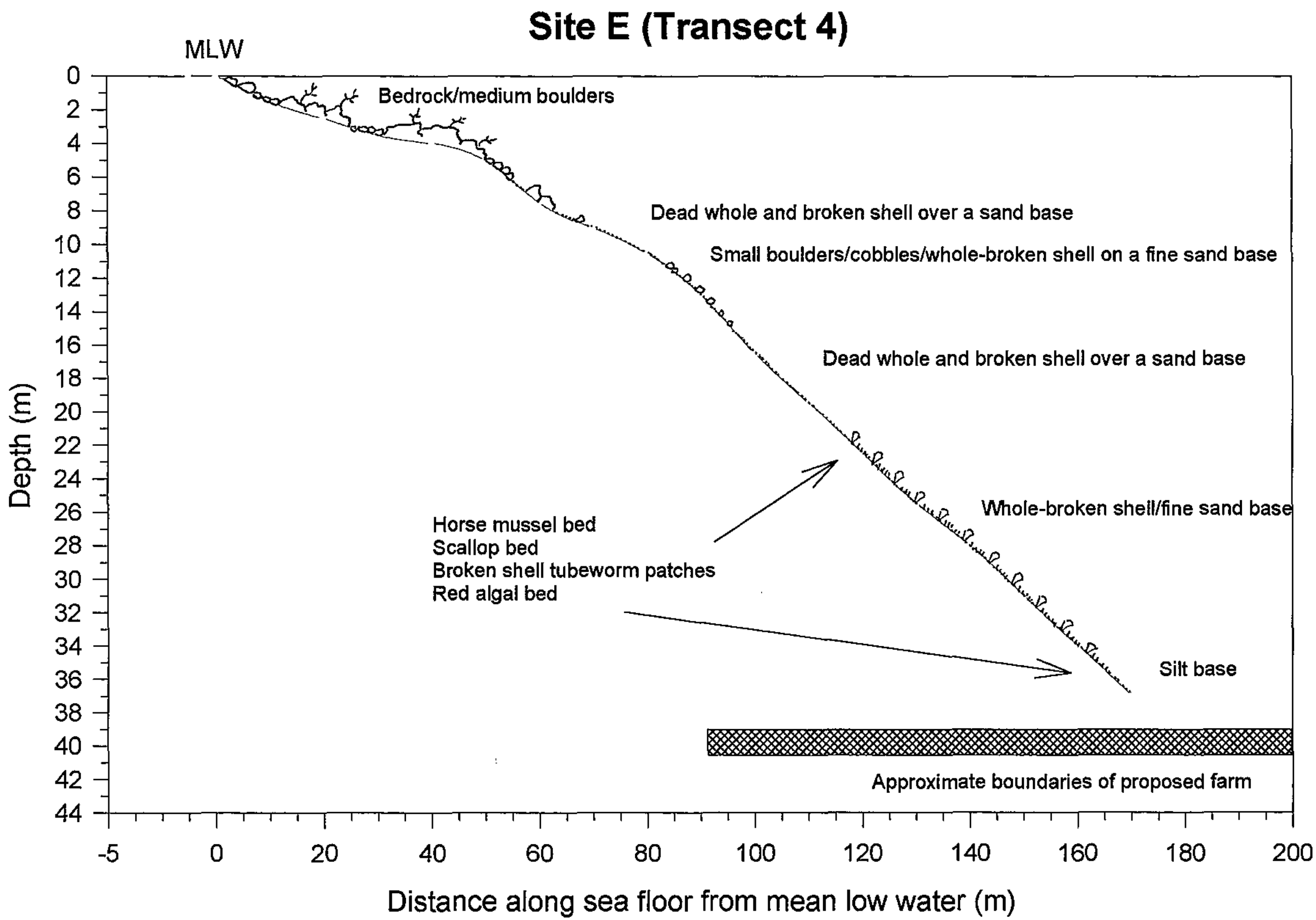


Figure 6 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

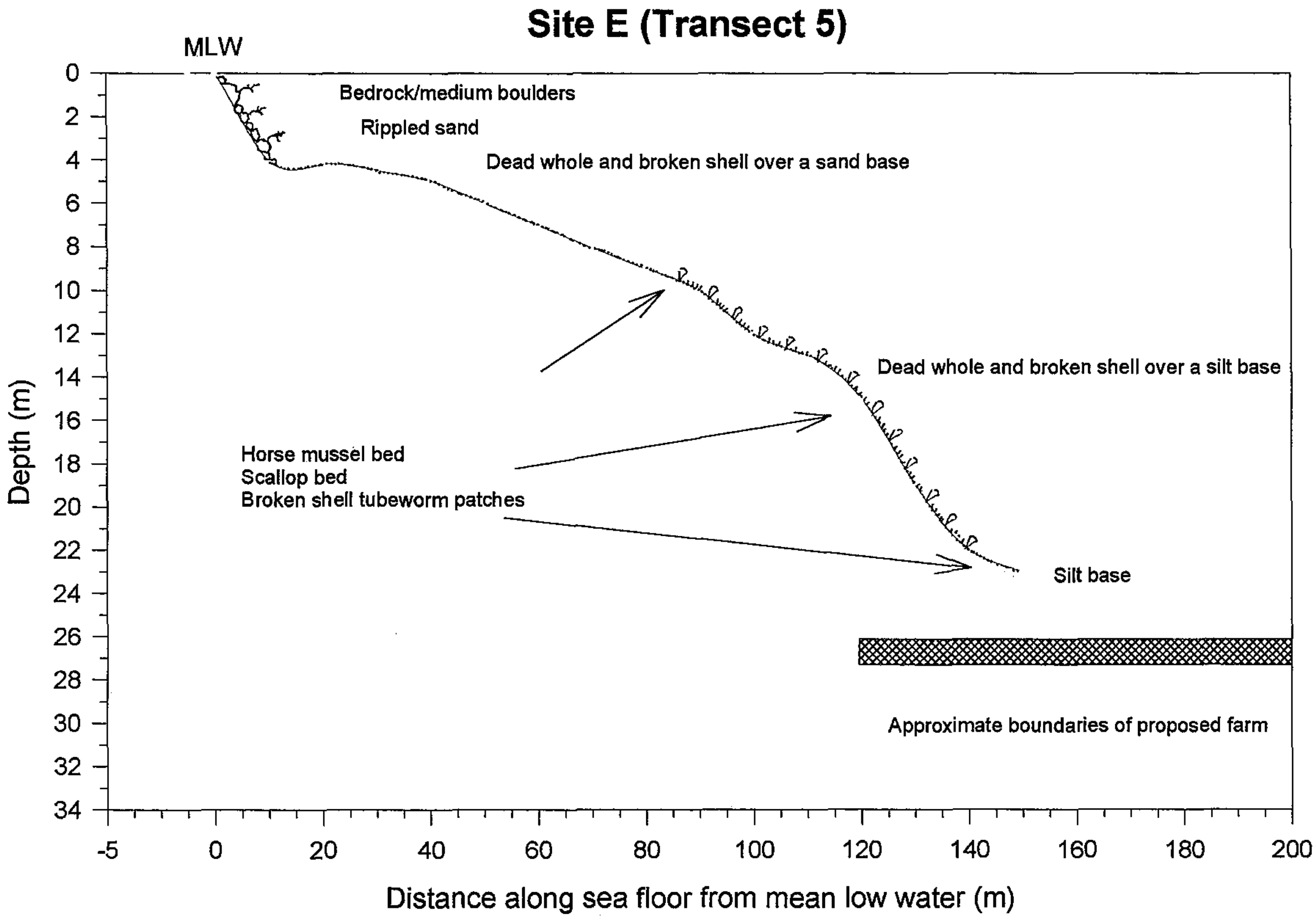


Figure 7 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

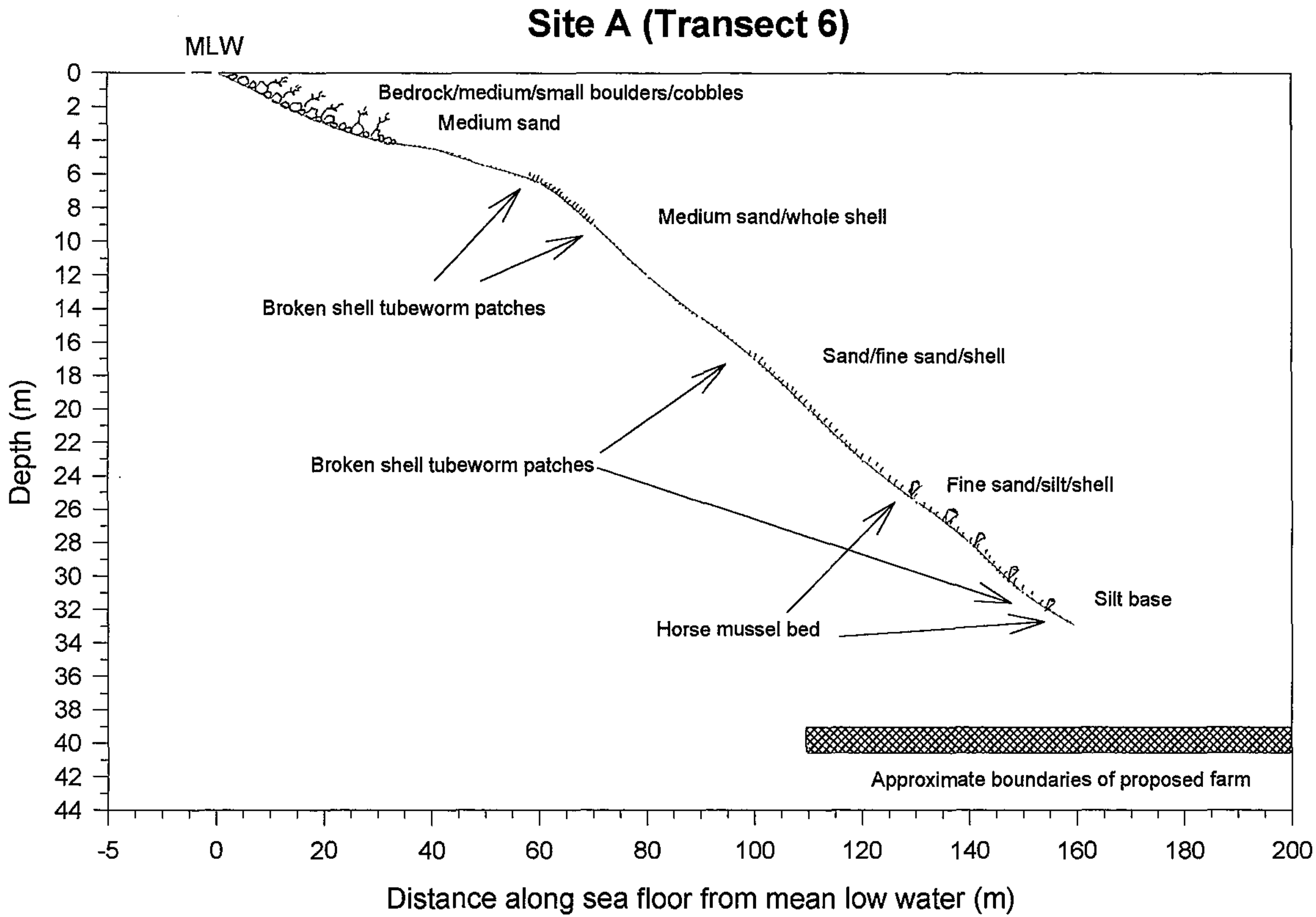


Figure 8 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

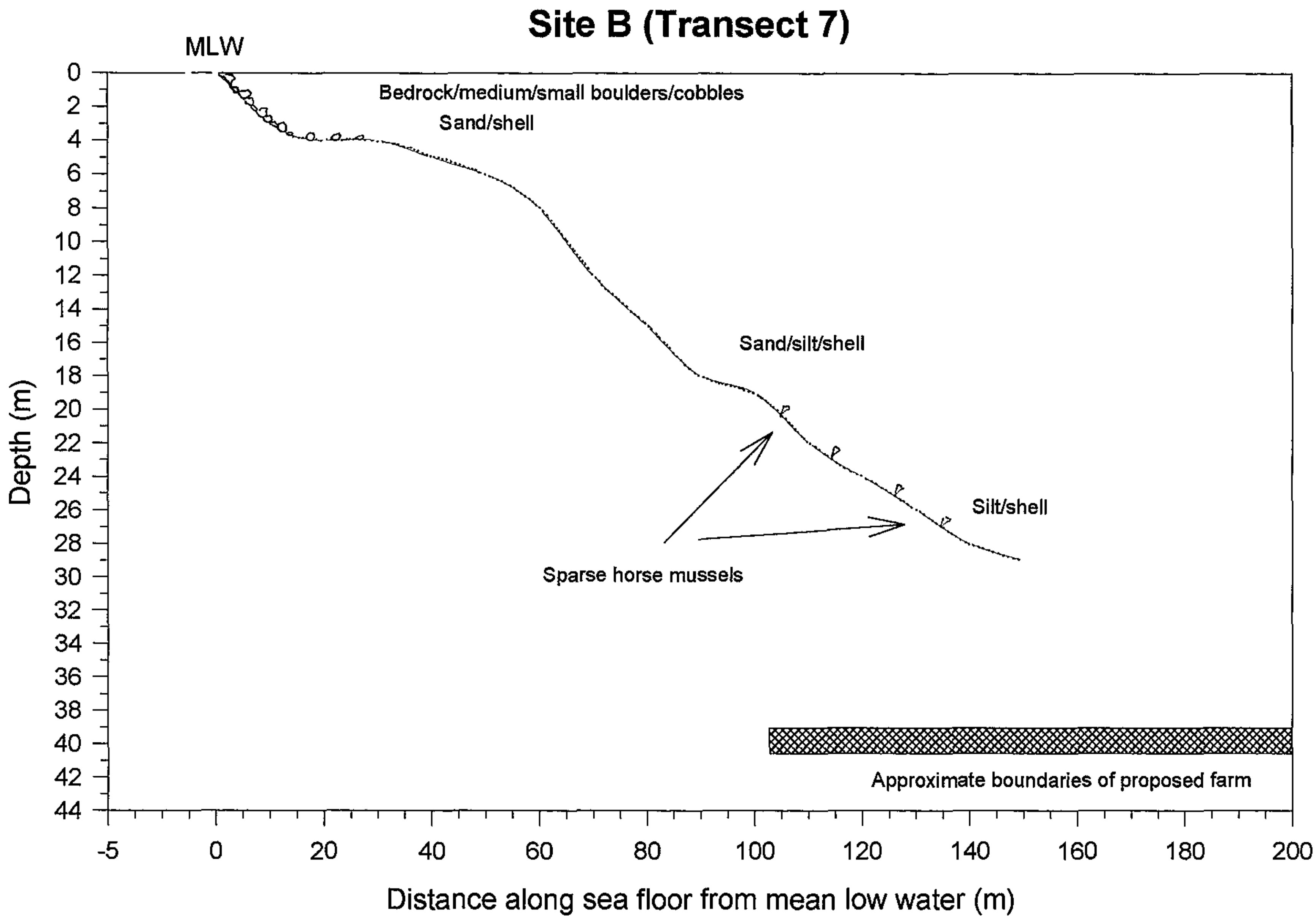


Figure 9 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

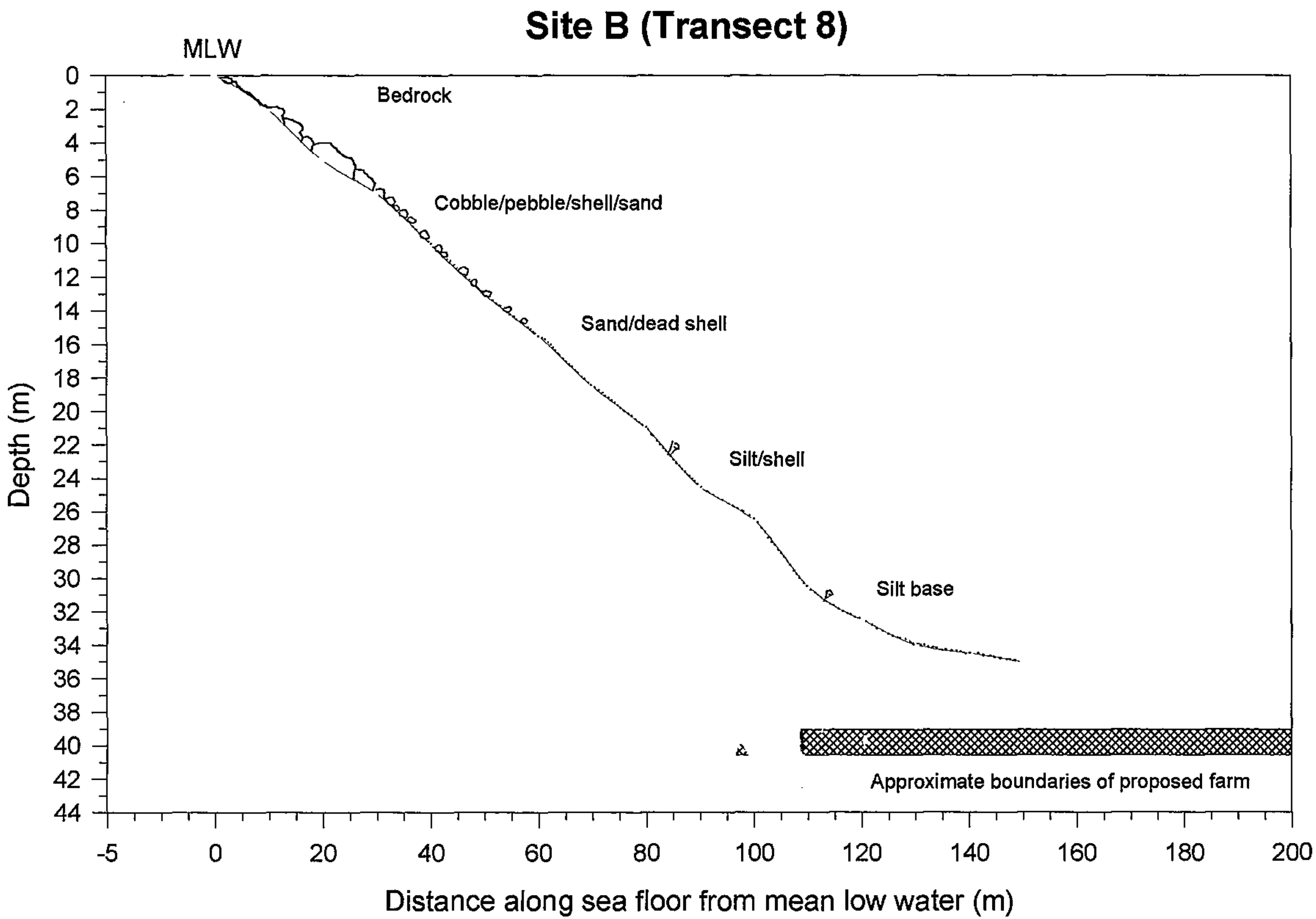


Figure 10 Subtidal shore profile and substratum from a proposed marine farm located south of Pig Bay, Port Gore.

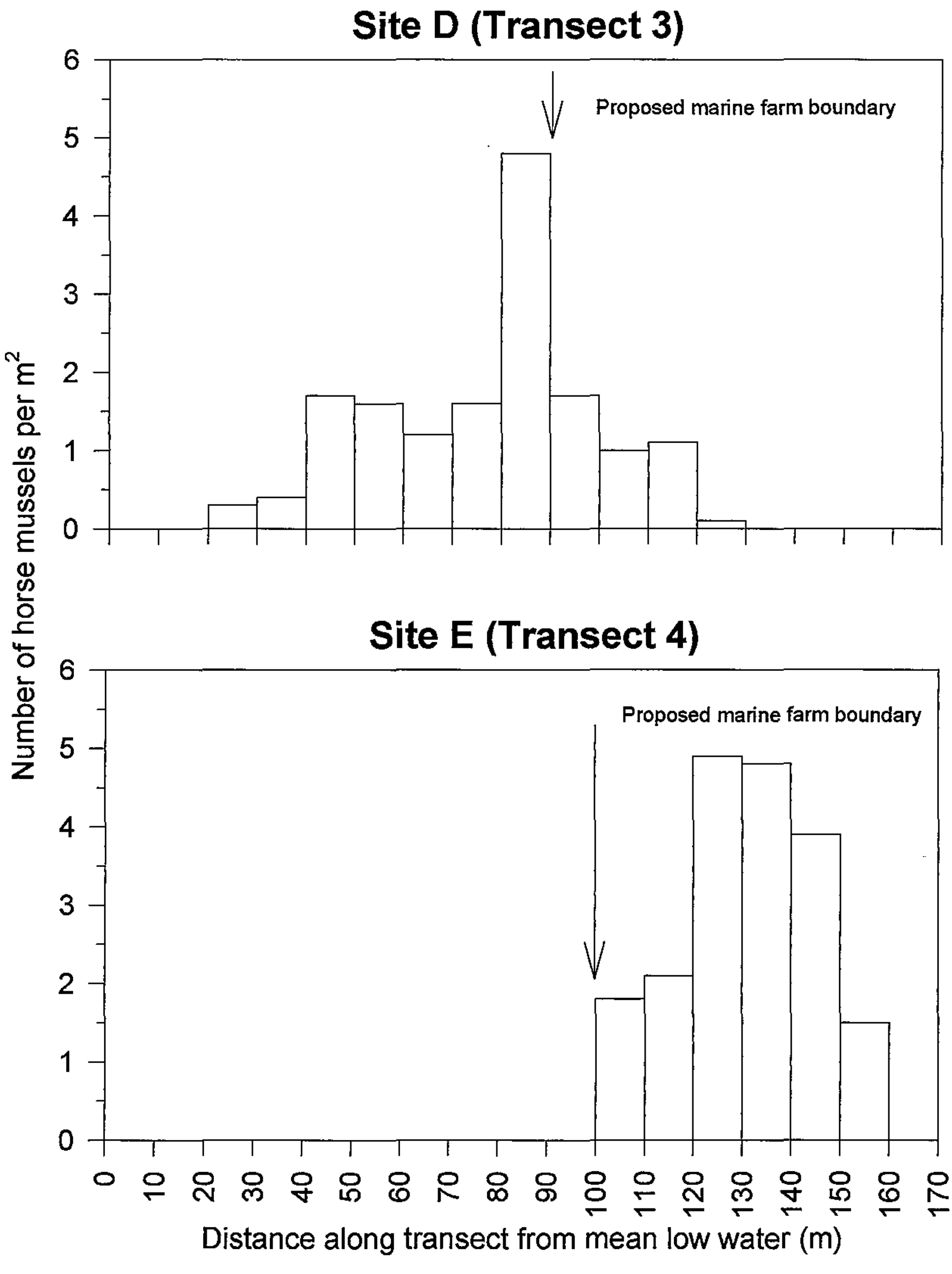


Figure 11 Density of horse mussels recorded from 10x1 m^2 quadrats along the length of each transect.

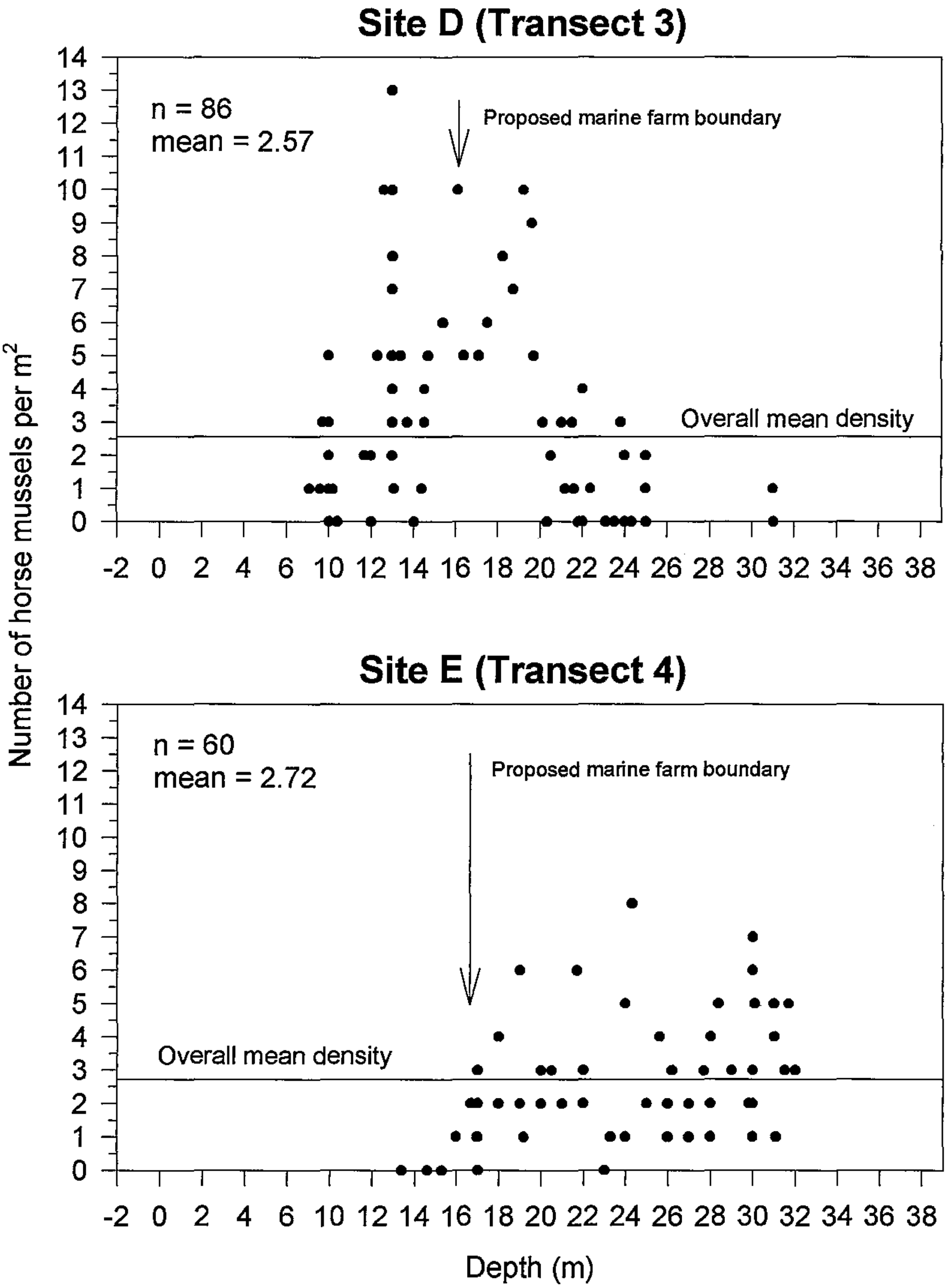


Figure 12 Density of horse mussels recorded from 1 m^2 quadrats plotted against depth (m).

5.6 Elephantfish egg cases

Two empty egg cases laid by adult elephant fish (*Callorhinchus milii*) were observed from transect 3. Both egg cases were observed inshore of the proposed marine farm in 10-12 m depth.

5.7 Tube worms

Occasional calcified tube building tubeworm mounds (*Galeolaria hystrix*) were observed from inshore rock habitats. No calcified mounds were observed within the marine farm boundaries.

Two species of sediment dwelling tubeworm were observed in sufficiently high numbers to represent a tubeworm bed. A species of *Owenia* (shell fragment building worm) was observed in sandy areas inshore of the proposed marine farms. A second unidentified species (Maldanidae sp?) often formed dense beds in the deeper areas in association with horse mussel beds and was located within the marine farm boundaries.

5.8 Red algal beds

Red algal beds were only observed growing in association with the horse mussel beds. Red algae abundance was estimated as percentage cover over the benthos. Percentage cover within red algal beds ranged from 5 % top 80 % cover (note: values >10% cover are above the trigger levels in the Department of Conservation guideline (Department of Conservation 1995).

6.0 ECOLOGICAL VALUES AND REPRESENTATIVENESS

6.1 Hard shores

Subtidal hard shores located in the Pig Bay area were relatively narrow and located in relatively shallow water. Species observed from these shores are widespread in the sheltered shores of the Marlborough Sounds (Dell 1951; Estcourt 1967; McKnight 1969, 1974; Roberts and Asher 1993; McKnight and Grange 1991; Davidson and Duffy, 1992; Davidson, 1995; Davidson and Brown 1994; Duffy *et al.* in prep; Chadderton *et al.*, in prep, Chadderton and Davidson in prep).

Most hard shore species recorded from Pig Bay are found throughout much of the Sounds, while particular species are often restricted to outer parts of Sounds or the outer Sounds (e.g. paddle weed, sea perch, oblique triplefin). No rare species or species with restricted distributions were observed from hard shore habitats.

6.2 Soft shores

Particular soft shores in the Pig Bay area support a relatively high number of species. Based on various criteria (DOC 1995, Davidson *et al.* 1995), particular soft shore assemblages/habitats should be considered ecologically important. Of particular note are the horse mussel beds, which appear widespread from 10 m depth up to 36 m depth and extend from between 40 m up to 160 m distance from shore. The abundance and distribution of horse mussels is poorly understood in New Zealand and the Marlborough Sounds. According to Hay (1990) densities of horse mussels range between 0.01 per m^{-2} to a maximum of 7-13 mussels per m^{-2}. Hay (1990) reported the highest densities were from areas inside the Marlborough Sounds (Wet Inlet in Pelorus Sound and Onahau Bay opposite Picton in Queen Charlotte Sound). Hay (1990) suggested that the largest beds were found on the outer coast of the Sounds particularly on the shallow banks situated on the northwestern and western approaches to Queen Charlotte Sound, Waitui Bay, Guards Bay and Port Gore. In these locations the author stated that densities ranged between 1–3 individuals per m^{-2}. Results from the present study showed that the beds recorded in the Pig Bay area are comparable to the dense outer Sounds sites recorded by Hay (1990).

Horse mussel beds are important on ecological, scientific and conservation grounds as they:

- enhance species diversity by providing a hard substrata to a large variety of species e.g. red algae, brown algae, and invertebrates;
- these communities often provide habitat or food for a variety of mobile species such as blue cod and gurnard; and
- dense beds exhibit a restricted distribution in the Sounds;

The substrata around horse mussel beds in the Pig Bay have been colonised by relatively high numbers of red algae, shell tubeworms and soft tube building tubeworms. Scallops were also recorded within these horse mussel beds as well as a variety of invertebrates. Blue cod (adults and juveniles) and leatherjackets were also observed within the horse mussel beds.

Overall, this horse mussel bed located along the north-western side of Port Gore represents an example of once widespread beds in the Sounds. In terms of ecological, scientific and/or conservation importance, it is my view that this area should be regarded as regionally important in the Marlborough Sounds as it supports a high quality example of an outer Sounds horse mussel dominated community.

Other features relevant to this ranking were the presence of juvenile blue cod (<10 cm length), elephantfish egg cases and giant lampshell.

Juvenile cod were observed within horse mussel beds and in deep areas of cobble and small boulder habitat. Up to six juvenile cod congregated around a diver on one occasion. Based on a recent study on juvenile blue cod, individuals appear widespread in particular years over many areas in the Marlborough Sounds, but are only common at particular sites (Cole, Villouta, Davidson, Abel and Grange in prep.). Reasons for this phenomenon are unknown, but are probably related to habitat requirements of these small fish.

Elephantfish are known to lay their egg cases in particular bays in the Marlborough Sounds. These areas are regarded as internationally important sites due to their scientific significance in the study of vertebrate systematics and evolution (Davidson *et al.* 1995, Didier, 1995). The presence of two egg cases in the Pig Bay area suggests that these primitive sharks occasionally use this area. Egg cases are usually laid between 3-20 m depth on specific types of substrata.

One giant brachiopod (*N. lenticularis*) was recorded during the investigation. This species is known from throughout New Zealand (Lee 1990), but until recently was presumed to only occupy the outer shelf habitat. SCUBA investigations have revealed the presence of shallow populations in Fiordland, Stewart Island (Richardson 1981) and in the Marlborough Sounds (Duffy *et al*, in prep). This group of brachiopods are currently under taxonomic review.

I now present video footage collected from Transect 3. Footage was collected from between approximately 24 m to 8 m depth. Footage was collected adjacent to the transect line. The site and footage is representative of horse mussel beds recorded from Transects 1, 2, 3, 4, 5, and 6

7.0 POTENTIAL IMPACT OF A BIVALVE MARINE FARM

A variety of authors in New Zealand and overseas have reported on the impact of mussel culture on soft bottom substratum (Dahlback and Gunnarsson 1981, Tenore *et al.* 1982, Mattsson and Linden 1983, Kaspar *et al.* 1985; Kautsky and Sverker 1987, Gillespie 1989, DeJong 1994, Hatcher *et al.* 1994, Grant *et al.* 1995, Davidson 1998). Findings from these studies have suggested that a shift from the initial marine ecological state to a new state occur due to the establishment of a mussel farm. These changes can be summarised as:

- increased levels of shell and fine sediment particles deposited onto the benthos (due to shell drop off, mussel harvesting, and float and warp cleaning);
- on a mud bottom, the diversity of species living on the surface most often increases (due to shell substratum providing additional habitat), while the diversity of species living within the sediment most often decreases (due to deposition of finer sediment and chemical changes);
- the anoxic layer moves closer to the surface (due to the deposition of fine sediment and organic material originating from the mussel farm); and
- an increase in sulphide and organic material, especially nitrogen which results in an increase in ammonium levels (due to organic material deposition).

DeJong (1994) showed that at a Coromandel mussel farm, the overall spatial effect of the mussel farming activity was located under the farm structures and up to 10 m to 20 m distance from these structures. Gillespie (1989) suggested that the area of seabed affected was limited to within a few metres from the perimeter of the farm, but the impact of fine sediment particles, although less severe, would be spread out over a wider area where strong currents existed. Based on Mattsson and Linden (1983) and Forrest (1991) ecological effects are often limited to approximately 30 m or less from the edge of farm stock.

These studies have not differentiated between environmental impacts associated with particular farming activities. In a report prepared by Gillespie (1989) for the Department of Conservation, the author considered that "the greatest share of the benthic accretion of shell and fouling debris occurred during harvesting" and he considered that the associated impact of this debris production would vary depending on environmental characteristics of a particular farm site (e.g. current velocities, water depth, bottom slope, substratum). These environmental variables were also discussed by Forrest (1995) in a report prepared by Cawthron for Sanford South Island. Forrest (1995) considered that substratum texture, depth and tidal currents were important variables influencing the environmental impacts associated with mussel farms.

Davidson (1998) investigated the impact of harvest discharge in the Marlborough Sounds. The author suggested that sediment, and animal and plant material dominated harvest discharge. He stated that the relative composition of these constituents varied between the final harvest and re-seeding harvest events.

Davidson (1998) stated that harvest discharge material was dominated by:

- fine substrata that had settled onto mussels from the water column (e.g. silt and clay). Observations suggested that the particle size varied between locations, the size of mussels at harvest or the time period lines had spent in the water column (i.e. mussels that had spent more time in the water often appeared to accumulate more sediment);
- psuedofaeces that had settled onto lines and mussels; and
- animal and plant material dominated by mussels (e.g. *Mytilus edulis aoteanus, P. canaliculus*), tube worms (e.g. *Galeolaria hystrix*), ascidians, bryozoans (e.g. *Watersiporia cucullata, Bugula* sp.), crustaceans, and seaweeds (e.g. *Codium fragile, Colpomenia sinuosa, Cystophora* sp. and several filamentous and encrusting species). In particular areas in the Marlborough Sounds, the introduced alga (*Undaria pinnatifida*) was attached to floats ropes and mussels (Weeber and Gibbs 1998) in depths less than approximately 6 m. In most parts of the Marlborough Sounds, blue mussels appeared to represent the dominant animal in the harvesting related discharge.

Davidson (1998) presented preliminary data on sediment loading in the water column as a result of re-seeding and final harvesting discharges collected on one occasion from one water depth. It appeared that for both activities, suspended solid levels in the surface layer were highest close to the discharge point. These levels declined dramatically by 25 m to 30 m distance from the point of discharge. By 25 m distance for the re-seeding operation and 90 m distance for the final harvest, suspended solid levels in the water surface layer dropped to ambient levels (control samples). These preliminary results suggested that elevated levels of suspended solids in surface waters was restricted to a 30 m radius from the discharge points. For the majority of the plume, levels were close to those recorded from control sites (i.e. areas free of the discharge). The author suggested that the reasons for this result were related to the rate sediment falls in the water column. In areas greater than 30 m from the discharge, diver observations suggested that sediment dropped below the surface layer where samples were collected.

Soft bottom substrata dominated the area under the proposed marine farms. These soft bottoms could be divided into two major types:

- soft bottoms dominated by the horse mussel bed and a variety of associated species; and
- soft bottoms dominated by mud substrata with a proportion of dead whole and broken shell.

Based on transect data, horse mussel beds extended to a maximum of 160 m distance from shore. This suggests that the proposed farms cover a considerable area of this community type. No published studies in New Zealand have documented the impact of a mussel farm of a horse mussel bed and associated species. Based on observations under marine farms located in a variety of locations, it is probable that the horse mussel bed and its associated community would ultimately be replaced by a layer of dead mussel shell. This shell would in turn trap fine sediment falling from the farmed mussels.

Considerations relevant to this soft bottom assemblage of species include:

- the inability of horse mussels to move or re-establish if disturbed;
- the vulnerability of filter feeders (horse mussels, scallops, tubeworms) to their feeding parts being smothered by fine sediment; and
- the vulnerability of small, soft bodied organisms to physical disturbance by shell deposition (e.g. tubeworms and red algae)

REFERENCES

Chadderton, W. L.; Davidson, R. J.; Brown, D. A. in prep: Report on a quantitative investigation of subtidal sites in Pelorus Sound, Marlborough Sounds. Department of Conservation, Nelson/Marlborough Conservancy.

Dell, R. K. 1951: Some animal communities of the sea bottom from Queen Charlotte Sound. New Zealand Journal of Marine and Freshwater Research B 33(1), pp. 19-29.

Dahlback, B; Gunnarson, L.A.H. 1981: Sedimentation and sulphate reduction under a mussel culture. Marine Biology Vol. 63, pp. 269-275.

Davidson, R. J. 1995: Long Island-Kokomohua Marine Reserve: subtidal biological baseline. Department of Conservation, Occasional publication.

Davidson, R. J. 1998: Preliminary report on ecological issues related to mussel harvesting activities. Report prepared for the Department of Conservation, Wellington by Davidson Environmental Ltd. Survey and Monitoring Report No. 158, 23p.

Davidson, R. J.; Preece, J.; Rich, L.; Brown, D.; Stark, K.; Cash, W.; Waghorn, E.; Rennison. G. 1990: Coastal resource inventory, Nelson/Marlborough Conservancy. Published by Department of Conservation. 416 p.

Davidson, R. J.; Millar, I. R.; Brown, D. A.; Courtney, S. P.; Deans, N. A.; Clerke, P. R.; Dix, J. C. 1995: Ecologically important marine, freshwater, Island and mainland areas from Cape Soucis to Ure River, Marlborough, New Zealand: recommendations for protection. Department of Conservation report, Nelson/Marlborough Conservancy.

Davidson, R. J.; Brown, D. A. 1994: Ecological report on the marine reserve options in the D'Urville Island area. Nelson Marlborough Department of Conservation Occasional Publication.

DeJong, R. J. 1994: The effect of mussel farming on the benthic environment. Master of Science Thesis, University of Auckland. 150 p.

Department of Conservation 1995: Guideline for ecological investigations of proposed marine farm areas in the Marlborough Sounds. Nelson/Marlborough Conservancy, Occasional publication No. 25, 21 p.

Duffy, C. A. J.; Davidson, R. J.; Cook, de C. S. in prep: Shallow subtidal habitats of the Marlborough Sounds, New Zealand. Department of Conservation, Nelson/Marlborough Conservancy.

Didier, D.A. 1995: Phylogenic systemics of extant chimaeroid fishes (Holocephali, Chimaeroidei). **American Museum Novitates** 3119: 1-86.

Estcourt, I. N. 1967: Distribution and associations of benthic invertebrates in a sheltered water soft-bottomed environment (Marlborough Sounds, New Zealand). New Zealand Journal of Marine and Freshwater Research 1(5), pp. 352-370.

Kaspar, H. F; Gillespie, P. A.; Boyer, I. C.; MacKenzie, A. L. 1985: Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound, Marlborough Sounds, New Zealand. Marine Biology, Vol. 85, 127-136.

Kaspar, H. F.; Hall, G. H.; Holland, A. J. 1988: Effects of sea cage salmon farming on sediment nitrification and dissimilatory nitrate reductions. Aquaculture 70, 333-344.

Kautsky, N.; Evans, S. 1987: Role of biodeposition by Mytilus edulis in the circulation of matter and nutrients in a Baltic coastal ecosystem. Marine Ecology Progress Series. Vol. 38, pp. 201-212.

Forrest, B. 1995: Overview of ecological effects from shellfish farms in the Marlborough Sounds. Report prepared for Sandford Ltd.

Grant, J,; Hatcher, A.; Scott, D. B.; Pocklington, P.; Schafter, C. T.; Winters, G. V. 1995: Multidisciplinary approach to evaluating impacts of shellfish aquaculture on benthic communities. Estuaries 18, No. 1A, p. 124-144.

Hatcher, A.; Grant, J.; Schofield, B. 1994: Effects of suspended mussel culture (Mytilus spp.) on sedimentation, benthic respiration and sediment nutrient dynamics in a coastal bay. Marine Ecology Progress Series Vol. 115, p. 219-235.

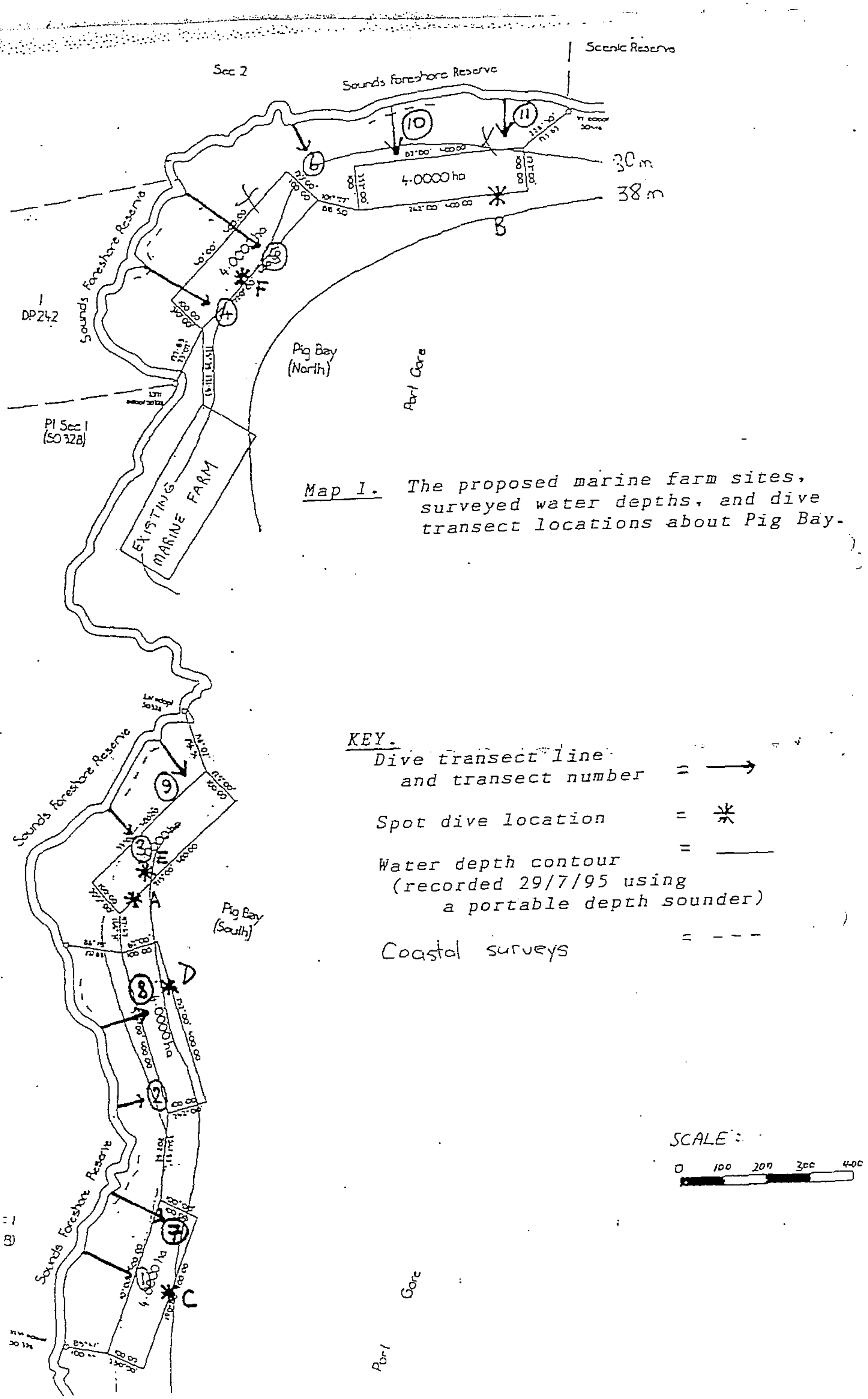
Lee, D.E. 1990: Aspects of the ecology and distribution of the living Brachiopods of New Zealand. In. Brachiopods through time. Ed. MacKinnon, Lee and Campbell, Balkema, Rotterdam.

Mattsson, J.; Linden, O. 1983: Benthic macrofaunal succession under mussels, Mytilus edulis, cultured on hanging long-lines. Sarsia, Vol. 68, pp. 97-102.

McKnight, D. G. 1969: Infaunal benthic communities of the New Zealand continental shelf. New Zealand Journal of Marine and Freshwater Research 3(3), pp 409-444.

McKnight, D. G.; Grange, K. R. 1991: Macrobenthos-sediment-depth relationships in Marlborough Sounds. NZ Oceanographic Institute, prepared for Department of Conservation, No. P 629, 36 p.

Tenore, K.R.; Boyer, L.F.; Corral, R.M.; Garcia-Fernandez, J; Gonzalalez, N. 1982: Coastal upwelling in the Rias Baja, north-west Spain: contrasting the benthic regimes of the Rais de Arosa and de Muros. Journal of Marine Research Vol. 40, pp. 701-772.



Map 1. The proposed marine farm sites, surveyed water depths, and dive transect locations about Pig Bay.