# 10 MARINE ECOLOGY

## 10.1 INTRODUCTION

This section of the report presents the findings of the marine ecological impact assessment. Baseline information on the potentially affected existing marine ecological resources and the findings of various field surveys conducted for the assessment are presented and evaluated.

The objectives of the assessment are as follows:

- to establish the ecological importance of the habitats affected by the works associated with the construction and operation of the Lamma Power Station Extension;
- to identify marine ecological sensitive receivers;
- to assess the scale of possible marine ecological impacts from the proposed project;
- to highlight any insurmountable impacts to marine ecological resources arising from the proposed project;
- to identify any mitigation measures and residual impacts; and
- to assess the need for a marine ecological monitoring and audit programme.

## 10.2 LEGISLATION AND STANDARDS

The criteria for evaluating marine ecological impacts are laid out in the *Technical Memorandum on Environmental Impact Assessment Process of the Environmental Impact Assessment Ordinance (Cap 499) (EIAO TM). Annex 16* sets out the general approach and methodology for assessment of marine ecological impacts arising from a project or proposal, to allow a complete and objective identification, prediction and evaluation of the potential marine ecological impacts. *Annex 8* recommends the criteria that can be used for evaluating marine ecological impacts.

Other legislation which applies to marine species includes:

- *The Wild Animals Protection Ordinance (Cap 170) 1980* which protects all cetaceans and sea turtles.

## 10.3 BASELINE CONDITIONS

### 10.3.1 *Literature Review*

The availability of literature on the marine ecology of the waters surrounding the existing power station is variable. As with the majority of Hong Kong it appears that certain areas have been comprehensively studied whereas others have not.

Due to the limited literature available for some areas, a number of comprehensive surveys were considered necessary to enable a complete and robust assessment of impacts to marine ecology to be performed. The findings of the field surveys are presented below as well as an outline of information on marine ecological resources based on information gathered through desk-top reviews of available literature.

*Soft Benthos Assemblages*

Epifaunal Assemblages

Before the present survey no studies focussing on the soft bottom epifaunal communities of the reclamation site have been conducted. As a result a survey of the epifaunal assemblages of the reclamation site was conducted as part of this Study. The results of these surveys are presented and discussed below.

Infaunal Assemblages

As with the majority of Hong Kong, the most comprehensive work on the marine ecology of the waters surrounding the existing power station and Lamma Island itself has been on the benthos.

A study of benthic assemblages throughout Hong Kong was undertaken by Shin & Thompson[1]. The study concluded that the southern waters of Hong Kong, an area inclusive of the Lamma Extension site, supports assemblages that are polychaete dominated (80.4 %). Species diversity was the second highest in Hong Kong (18.8 0.5$m^{-2}$), with values ranging from 16.2 to 19.2 0.5 $m^{-2}$. The mean number of individuals was 96.0 $m^{-2}$ which is lower than the average for Hong Kong (101.4 $m^{-2}$) and the mean biomass for the area was 20.2 g $m^{-2}$, which is low compared to the overall mean biomass for Hong Kong at 35.2 g $m^{-2}$.

One of the components of the EIA for the Lantau Port and Western Harbour Development [2] was a series of environmental surveys. These included a survey of marine benthic infauna. Samples were collected from two stations in the vicinity of the Lamma Power Station (APH-13 and APH-15 see *Figure 10.3a*). Three replicates were collected from each station, once in the dry season and once in the wet season.

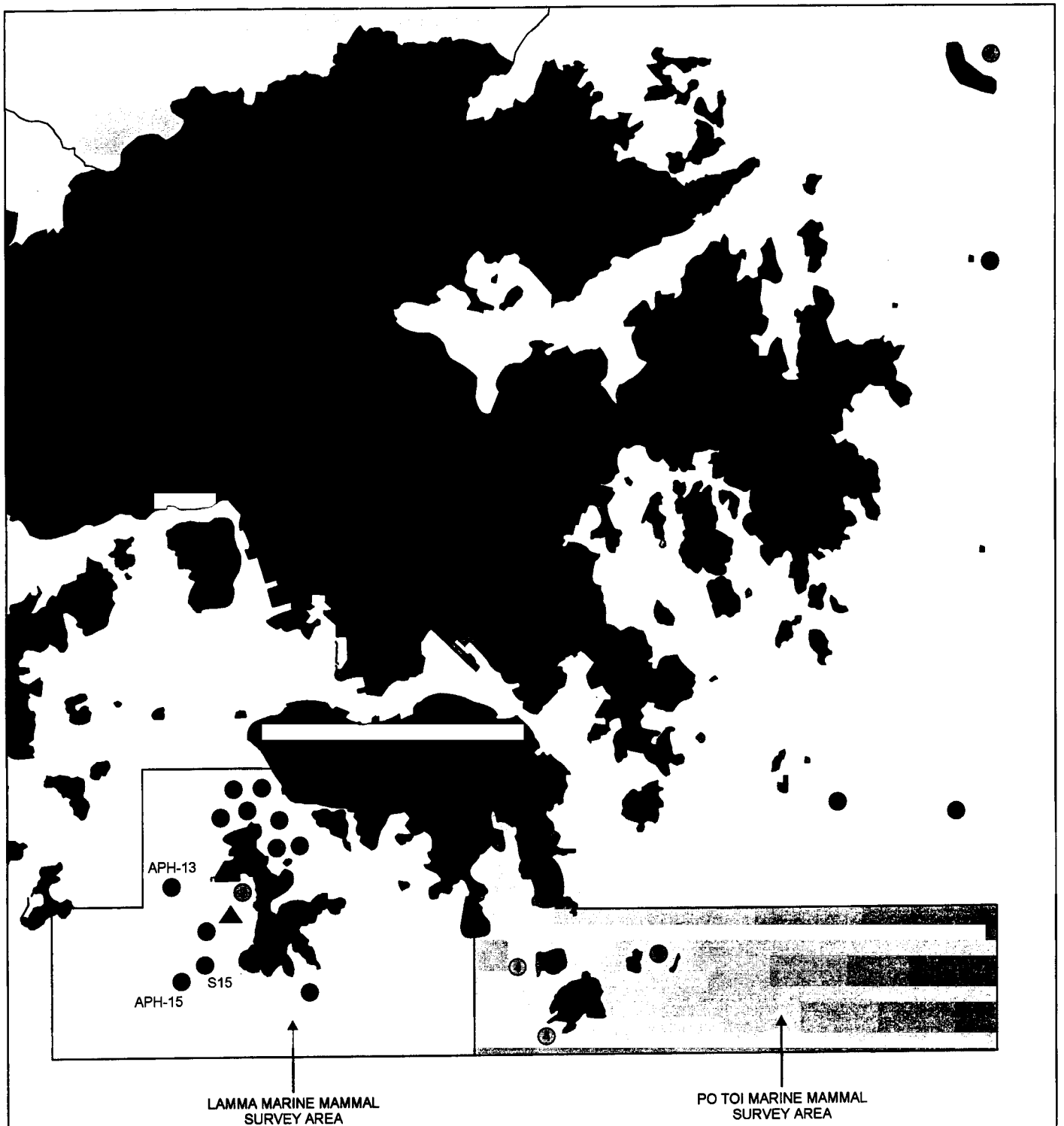
Polychaetes were the most abundant species collected from the sampling stations during both sampling events. In general more species and individuals were recorded in the winter than in the summer (*Table 10.3a*).

*Table 10.3a* ***Summary Information from Grab Survey in December 1991 and June 1992***

| Station | Number of Individuals (# $m^{-2}$) | | Total Biomass (g $m^{-2}$) | |
|---|---|---|---|---|
| | December | June | December | June |
| APH-13 | 106 | 33 | 14.86 | 3.93 |
| APH-15 | 73 | 46 | 13.13 | 7.53 |

(1) Shin PKS & Thompson GB (1982) Spatial Distribution of the Infaunal Benthos of Hong Kong. Marine Ecology Progress Series. Vol 10: 37-47

(2) APH Consultants (1992) Lantau Port & Western Harbour Development, Marine Baseline Studies, October 1992. Final Report submitted to CED.




**WATER**
▲ EPD

**SOFT BOTTEM**
- ERM 1997a
- ERM 1997b
- ERM 1997c
- APH CONSULTANTS 1992 (APH-13, APH-15)
- MOUCHEL 1998(S15)
- AXIS ENVIRONMENTAL 1994a
- BINNE CONSULTANTS 1994a

**INTERTIDAL**
- AXIS ENVIRONMENTAL 1994b

**SUBTIDAL**
- BINNIE CONSULTANTS 1994a
- BINNIE CONSULTANTS 1994b
- BINNIE CONSULTANTS 1996a
- BINNIE CONSULTANTS 1995
- BINNIE CONSULTANTS 1996a

FIGURE 10.3a PREVIOUS MARINE ECOLOGICAL STUDIES CONDUCTED IN OR IN CLOSE PROXIMITY TO THE LAMMA POWER STATION EXTENSION AND ASSOCIATED WORKS STUDY AREA

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Values reported for both the December and June surveys were lower than those reported previously for the area by Shin & Thompson. APH-13 recorded the highest biomass during the December survey of 14.86 g $m^{-2}$ which is considerably lower than the 20.2 g $m^{-2}$ values recorded by Shin & Thompson.

A benthic survey was conducted as part of an EIA study during September 1994 at the dredged navigation channel of the Lamma Power Station[3][4]. The survey involved collecting five replicate samples at each of ten sampling stations located along a 3,000 m transect running from the power station to the south of Lamma (*Figure 10.3a*). From the ten sampling stations a total of 30 species and 152 individuals were recorded.

*Table 10.3b* ***Organisms Collected in the AXIS 1994 Grab Sampling Survey***

| Phylum | Number of Identified Species | Total Number of Individuals Recorded |
|---|---|---|
| Annelida | 10 | 68 |
| Arthropoda | 10 | 26 |
| Echinodermata | 2 | 12 |
| Mollusca | 7 | 44 |
| Sipuncula | 1 | 2 |
| **Total** | 30 | 152 |

Polychaetes, crustaceans and molluscs were the most abundant infaunal organisms recorded from the survey area. The abundance of all infaunal organisms was calculated as a mean of 60.8 individuals $m^{-2}$ with a biomass of 22.2 g $m^{-2}$. This value is slightly higher than 20.2 g $m^{-2}$ recorded by Shin & Thompson.

As part of the monitoring programme conducted for SSDS Stage 1[5], grab samples were collected throughout Hong Kong waters during four sampling events, May and October 1996, February and May 1997. One of the stations sampled (S15) was located offshore of Lamma Island (*Figure 10.3a*). Five replicate grabs were collected from this station during the months listed above. The results of the surveys indicated that the sediments contained infaunal assemblages at a similar abundance to that reported by Shin & Thompson. The values ranged from 5 to 66 g $m^{-2}$ during the survey period with a mean value of 24.14 g $m^{-2}$.

As part of the Seabed Ecology Studies for CED, ERM conducted benthic surveys of a reference area to the south of Lamma Island[6] during April 1997 (*Figure 10.3a*). The reference area was divided up into five areas based on the results of a previous geophysical survey at the study site[7]. Samples were collected from within Sham Wan Bay (SHAM WAN), the dangerous goods anchorage (ANCH-IN and ANCH-OUT) area located south of Sham Wan Bay and the area of degraded dumped material (DDM-IN and DDM-OUT) located in the mouth of

(3) AXIS (1994) Navigation Channel & Jetty Modification Works at Lamma Power Station, Marine Benthic Ecology Survey, Draft Final Report submitted to HEC.
(4) This report was a confidential report submitted only to HEC and not to EPD or other Government Departments.
(5) Mouchel Asia Ltd (1998) Strategic Sewage Disposal Scheme Stage 1. Baseline Monitoring and Performance Verification, Draft Final Report to EPD.
(6) ERM (1997) Seabed Ecology Studies. South Lamma Final Report, submitted to Civil Engineering Department.
(7) EGS Ltd (1997) South Lamma Island Geophysical Surveys. Final Report. Report for the Geotechnical Engineering Office, Civil Engineering Department.

Sham Wan Bay. A total of 40 stations were sampled, 8 within each area (1 grab per station).

A total of 6,457 specimens, belonging to 60 families in ten Phyla were recorded from the South Lamma site. Polychaetes (phylum Annelida) were the most common group present, representing 57 % of all identified individuals and 31 % of the total biomass. The data set is summarised in *Table 10.3c.*

*Table 10.3c* ***Summary of Organisms Recorded from the South Lamma Study Site During the Grab Sampling Programme April 1997***

| Phylum | Total Number of Families Identified | Total Number of Individuals Recorded | Total Biomass (g) |
|---|---|---|---|
| Annelida | 38 | 3,664 | 37.01 |
| Arthropoda | 10 | 488 | 30.96 |
| Cnidaria | 1 | 4 | 5.31 |
| Echinodermata | 2 | 116 | 4.08 |
| Hemichordata | 1 | 38 | 10.18 |
| Mollusca | 4 | 1,648 | 16.05 |
| Nematoda | 1 | 376 | 0.37 |
| Nemertinea | - | 3 | 0.10 |
| Sipuncula | 1 | 23 | 0.09 |
| Total | 58 | 6,360 | 104.15 |

The overall mean abundance recorded from the South Lamma site was 161 individuals grab$^{-1}$ or 1674 individuals m$^{-2}$, which was higher than the abundances observed (previously) at other Seabed Ecology Study Sites. Abundances of 320 and 333 individuals grab$^{-1}$ (3327 and 3462 individuals m$^{-2}$) were recorded at SHAM WAN and DDM-IN respectively, which was considerably higher than those recorded at the DDM-OUT (67 individuals grab$^{-1}$ or 697 m$^{-2}$ ), ANCH-IN (41 individuals grab$^{-1}$ or 426 m$^{-2}$) and ANCH-OUT (30 individuals grab$^{-1}$ or 312 m$^{-2}$) areas.

Overall mean biomass levels recorded from the South Lamma Study site were 2.94 g grab$^{-1}$ or 30.57 g m$^{-2}$, which was within the 0.58 to 4.7 g grab$^{-1}$ range recorded at other sites in Hong Kong, but slightly lower than that recorded by Shin and Thompson in 1982 in southern waters (35 g m$^{-2}$). Biomass of 2.1 and 5.1 g grab$^{-1}$ (31.84 and 53.04 g m$^{-2}$) were recorded at SHAM WAN and DDM-IN respectively, which was considerably higher than those recorded at the DDM-OUT (1.6 g grab$^{-1}$ or 16.64 g m$^{-2}$), ANCH-IN (2.1 g grab$^{-1}$ or 21.84 g m$^{-2}$) and ANCH-OUT (1.3 g grab$^{-1}$ or 13.52 g m$^{-2}$) areas.

Polychaetes (phylum Annelida) were the most common group at all sites. Large numbers of the polychaetes Capitellidae, Spionidae, Pilargiidae, Pisionidae and Paraonidae and the amphipod Ampeliscidae (Arthropoda) were recorded at all sites within the DDM-IN area. High abundances of the bivalve mollusc Veneridae were also recorded.

Intertidal Sandy Shore Assemblages

In the lee of headlands or within shallow bays, wave action is reduced and there is an accumulation of sand and detrital material. Exposed sandy beaches are relatively unstable environments and the fauna is sparse. With increasing shelter, however, substrate stability allows for the development of a rich community of burrowing animals. Where a river or stream empties on to a

sandy shore, forming an estuary, a greater percentage of very small particles are found, due to the deposition of terrigenous material eroded by the river. Such shores retain water more readily, and the beach comprises black, sloppy or compacted mud. The west coast of Lamma Island contains two gazetted beaches at Lo So Shing and Hung Shing Ye. There are also sandy shores located at Tai Wan San Tsuen (adjacent to the existing power station) and north of Lo So Shing.

Beaches that have been developed for recreational use (such as the 42 gazetted swimming beaches in Hong Kong) appear almost devoid of life[8]. The exception to this are wave exposed beaches in the surf where unique assemblages of surf clams, mole crabs and hermit crabs are present[9]. The only beach of this type in Lamma Island can be found at Sham Wan far to the south of the proposed Power Station Extension.

*Hard Surface Assemblages*

There is little published information describing and evaluating the ecological importance of the intertidal assemblages of the west coast of Lamma. However, as part of the environmental impact assessment for the navigation channel and jetty modification works at the Lamma Power Station, an intertidal ecology survey was conducted[10]. Three transects were surveyed for this Study, each of them on the west coast of Lamma Island adjacent to the existing power station (*Figure 10.3a*).

The sites investigated during this survey were summarised as having low macroalgae cover due to the surveys being conducted during June when algal cover is commonly low as a result of high temperatures and high amounts of exposure to the sun. The majority of the species recorded were grazers feeding on the flora and fauna on the rock surface, however, these numbers were also low. Low numbers of filter feeders were found both on the lower shore and in the subtidal zone. The shoreline was regarded as of low ecological value and did not support any species of particular conservation value.

Prior to the present Study, no surveys had been conducted on the subtidal hard surface assemblages in the waters of the west coast of Lamma. As a result detailed subtidal surveys have been conducted as part of this Study with the results presented and discussed below.

*Marine Mammals*

The Chinese White Dolphin (*Sousa chinensis*) and the Finless Porpoise (*Neophocaena phocaenoides*) are the only species of marine mammal regularly sighted in Hong Kong waters. The population of *Sousa chinensis* is reported to be centred around the Pearl River Estuary and Hong Kong waters are thought to represent the eastern portion of its range[11]. North Lantau represents the major area of distribution of *Sousa* in Hong Kong waters, and is the only place in Hong Kong where dolphins are seen year round. Individuals are most frequently

[8] Morton B, Williams GA & Lee SY (1996) The benthic marine ecology of Hong Kong: A dwindling heritage. Pages 233-267, In: Coastal Infrastructure Development in Hong Kong: A Review. Civil Engineering Department.

[9] Wong ECK (1990) The fauna of exposed sand beaches in Hong Kong. Asian Marine Biology 7: 147-159.

[10] AXIS Environmental Consultants Ltd (1994) Navigation Channel and Jetty Modification Works at Lamma Power Station - Environmental Impact Assessment: Intertidal Ecology Survey Final Report. Submitted to The Hongkong Electric Co Ltd. October 1994.

[11] Jefferson TA (1998) Population Biology of the Indo-Pacific Hump-backed Dolphin (*Sousa chinensis* Osbeck, 1975) in Hong Kong Waters. Final Report to AFD.

sighted in the western part of these waters around the Sha Chau & Lung Kwu Chau Marine Park and the Chek Lap Kok platform.

The Lamma Island area does not appear to represent important habitat for *Sousa* in Hong Kong[12]. Lamma Island appears to be at the eastern edge of the population's range. Only four sightings of this dolphin have been made during extensive surveys in the Lamma Island area since early 1996. Of the four sightings, three of them occurred during August with the other during early September. Based on the above information, the Chinese White Dolphin is not considered as an issue of concern to the project and will not be discussed further.

The finless porpoise, *Neophocaena phocaenoides*, is a small cetacean endemic to southern and eastern Asia and is protected under CITES Appendix I. In Hong Kong, until recently, little information was available regarding the distribution and abundance of the finless porpoise in local waters. Surveys were conducted in southern waters for 12 months between December 1996 and November 1997. The surveys revealed that the finless porpoise is the most common and most important species of cetacean in the Lamma Island area and these waters appear to be the most important habitats in Hong Kong for this marine mammal. The presence of the porpoise in the waters around Lamma Island appears to vary on both a spatial and temporal basis.

The East Lamma Channel does not appear to be an area frequently used by the porpoises, a finding attributed to the heavy shipping traffic in the channel. Few porpoises have been sighted to the north of Lamma Island or in the vicinity of the existing power station. The main areas used by the porpoises around Lamma Island are the nearshore waters off the southwestern coast (Ha Mei Tsui peninsula). The sightings to date of the porpoise in the waters around Lamma Island indicate that the only months of the year when this cetacean is absent are July and August. During these months the porpoise is thought to move east to the waters around Po Toi, Waglan and Sung Kong Islands.

For further details and distribution maps for *Neophocaena phocaenoides* in southern waters of Hong Kong the reader is referred to *Part D, Section 5.*

### *10.3.2 Field Surveys*

*Introduction*

West Coastal Area Surveys

As part of the Stage 1 EIA for a New Power Station, thermal plume modelling of the New Gas Fired Power Station on Lamma Island showed that temperature increases in the water column were predicted to affect the western coastline of Lamma Island. The modelling for the Stage 1 EIA indicated that shores on the northwestern coast of Lamma were more likely to be affected by thermal elevations than those on the southwestern coast. However, the shores on the southwestern coast are of greater concern due to their inclusion within the preliminary boundary of the potential South Lamma Marine Park. In response to these concerns five sites on the south western coast of Lamma have been selected for marine ecological surveys. These surveys will provide baseline information on the subtidal and intertidal habitats allowing an objective assessment of the effects of the predicted cooling water dispersion plumes to be

[12] Jefferson TA (1998) *op cit.*

made. These five west coast sites have been labelled T2 through to T6 and are shown in *Figure 10.3b*. A further site, referred to as T1, was also selected as the Stage I EIA indicated that it is currently affected by cooling waters from the existing power station (elevations of approximately 2°C). Information gathered during the surveys at this site will help to provide insight into the effects of temperature elevations in the water column on subtidal and intertidal assemblages.

Reclamation Site Surveys

The area which will be reclaimed as part of the power station extension was determined on the basis of the preliminary technical drawings of the proposed power station extension. This area has been labelled as the reclamation site R1 and is shown in *Figure 10.3b*. Surveys were carried out within this area in order to determine the ecological value of the epifaunal and infaunal assemblages present. Despite a large amount of information available from the literature for infaunal organisms from sites in proximity to the reclamation site there was none available for the site itself. In order to conduct a robust and defensible assessment surveys on infaunal organisms were conducted.

*Methodology*

West Coast Survey

**Intertidal Surveys:** The objectives in surveying the relevant intertidal rocky shores were to collect baseline ecological information on the habitat, identify and quantitatively assess the floral and faunal components of the intertidal community, and to document any seasonal changes. The sampling strategy at the west coast sites follows the same protocol adopted for the launching and landing site surveys (detailed in *Part C, Section 7.2* ).

**Subtidal Surveys - Remotely Operated Vehicle (ROV)[13]:** During late July and early August 1998, sites T2 through to T6 were surveyed using a Remotely Operated Vehicle (ROV). The ROV is a submersible video unit that transmits a video image in real time as viewed by the ROV to a video monitor on-board a mother vessel. As this is a remotely operated unit from the surface, it allows unlimited "bottom time" and can allow a detailed recordable picture of the seabed to be viewed and analysed on board. The ROV was deployed at the sites T2 to T6 following a linear route, whilst maintaining a depth between 5 and 10 m below Chart Datum. These depths were selected based on a review of literature of dive surveys throughout Hong Kong. It was then concluded that by following a depth range of 5 - 10 m the ROV would be able to view both hard corals, which are not generally found in Hong Kong at depths below 7 m, and soft corals which can be found at depths of up to 20 m, should they be present within the survey area[14]. The purpose of these surveys was to cover as much of the habitat as possible in order to investigate the subtidal habitats of the selected sites and

[13] ROV surveys have been used internationally in a variety of studies relating to marine ecology surveying. Examples include:
Donnan DW (1997) Using ROVs for marine nature conservation surveys. Proceedings of 4th Underwater Science Symposium for Underwater Technology.
O'Connell VM & Carlile DW (1994) Comparison of a remotely operated vehicle and a submersible for estimating abundance of demersal shelf rockfishes in the Eastern Gulf of Alaska, North American Journal of Fisheries Management 14: 196-201.
Bergström BI, Larsson J & Petterson JO (1987) Use of a remotely operated vehicle (ROV) to study marine phenomena: I. Pandalid shrimp densities. Marine Ecology Progress Series 37: 97-101.

[14] Binnie Consultants Limited (1995) Marine Ecology of Hong Kong - Report on Underwater Dive Surveys (October 1991 - November 1994) - Volume I. For the Geotechnical Engineering Office, Civil Engineering Department.

specifically identify areas of ecological value (eg corals). Sites that were found by the ROV to supporting coral assemblages, or assemblages of ecological interest were then surveyed by a local marine ecology specialist dive team.

As the primary purpose of the survey was to locate areas of ecological interest for further investigation, a modified technique from the common "search and record" methodology was used. Prior to deployment, a buoy that would be visible from the surface was attached to the ROV, this enabled a speed boat equipped with Differential Global Positioning System (DGPS) to follow the ROV at a close distance. Once any areas of ecological interest or value were viewed on the monitor on-board the mother vessel, the exact coordinates of coral assemblages (or similar) located by the ROV were logged by the team on the speedboat, and subsequently the team on the mother vessels. This allowed a detailed picture of the subtidal marine habitat to be constructed enabling a comprehensive assessment of value to be made.

**Subtidal Surveys - SCUBA:** The findings of the ROV indicated that all of the sites that were surveyed should be re-examined using a dive team to gather quantitative data using the line transect methods. A dive survey was also conducted at Site T1, not previously surveyed by the ROV, in order to examine the nature of assemblages predicted to have been impacted by cooling water discharged from the existing power station.

Reclamation Site Surveys

**Epifauna Survey:** As very little information is known regarding the habitat of the proposed reclamation site, an ROV survey was conducted to investigate the marine ecology of this area. The primary purpose of this investigation was to identify any benthic epifaunal assemblages within the reclamation site. In order to do this, the survey was conducted following the same protocol as that used for the west coast sites (*Figure 10.3b*).

**Infauna Survey:** The locations of the sampling stations are shown in *Figure 10.3c*. All sampling stations were located within the proposed reclamation site to ensure that a detailed assessment of the infaunal benthic ecology of that area was made. No reference stations were selected as comprehensive data provided from sampling stations in other recent benthic ecology studies, particularly the *Seabed Ecology Studies South Lamma Final Report*, was used as a reference (station locations presented in *Figure 10.3a*). A single grab sample was taken at each station using a modified Van Veen grab sampler (960 $cm^2$ sampling area; 11,000 $cm^3$ capacity) with a supporting frame attached to a swivelling hydraulic winch cable. A uniform amount of sediment (approximately 300 g) was then removed from the centre of each sample, double-bagged in a labelled ziplock bag, and stored for later grain size analyses in the laboratory. A further sample of sediment, of approximately the same size, was also removed and placed into an acid rinsed glass jar. This sample was then analysed for Total Organic Carbon content (TOC).

Remaining sediments in the grab were then washed into a sieve stack (comprising 1 $mm^2$ and 500 $\mu$m meshes) and gently rinsed with seawater by qualified ERM marine scientists to remove all fine material. Material remaining on the screens was rinsed separately into thick triple-bagged ziplock plastic bags, using a minimal volume of seawater. A 10 % solution of Borax buffered formalin in seawater was added to ensure tissue preservation. In addition Rose Bengal stain was added to the sample to aid sorting. Samples were triple-bagged,

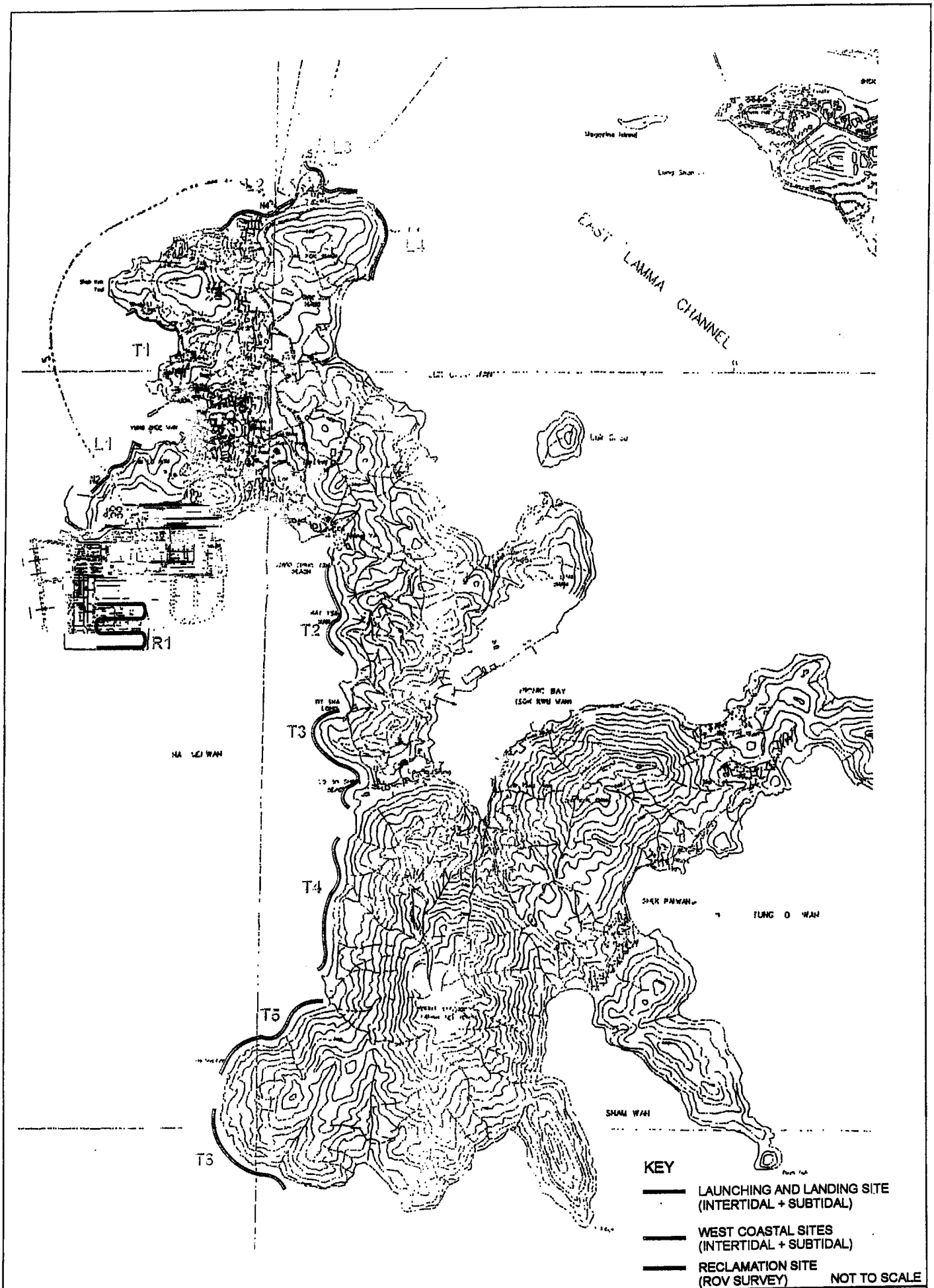


FIGURE 10.3b LOCATION OF LAUNCHING AND LANDING SITES, WEST COAST SITES AND THE RECLAMATION SITE FOR WET SEASON MARINE ECOLOGICAL SURVEYS

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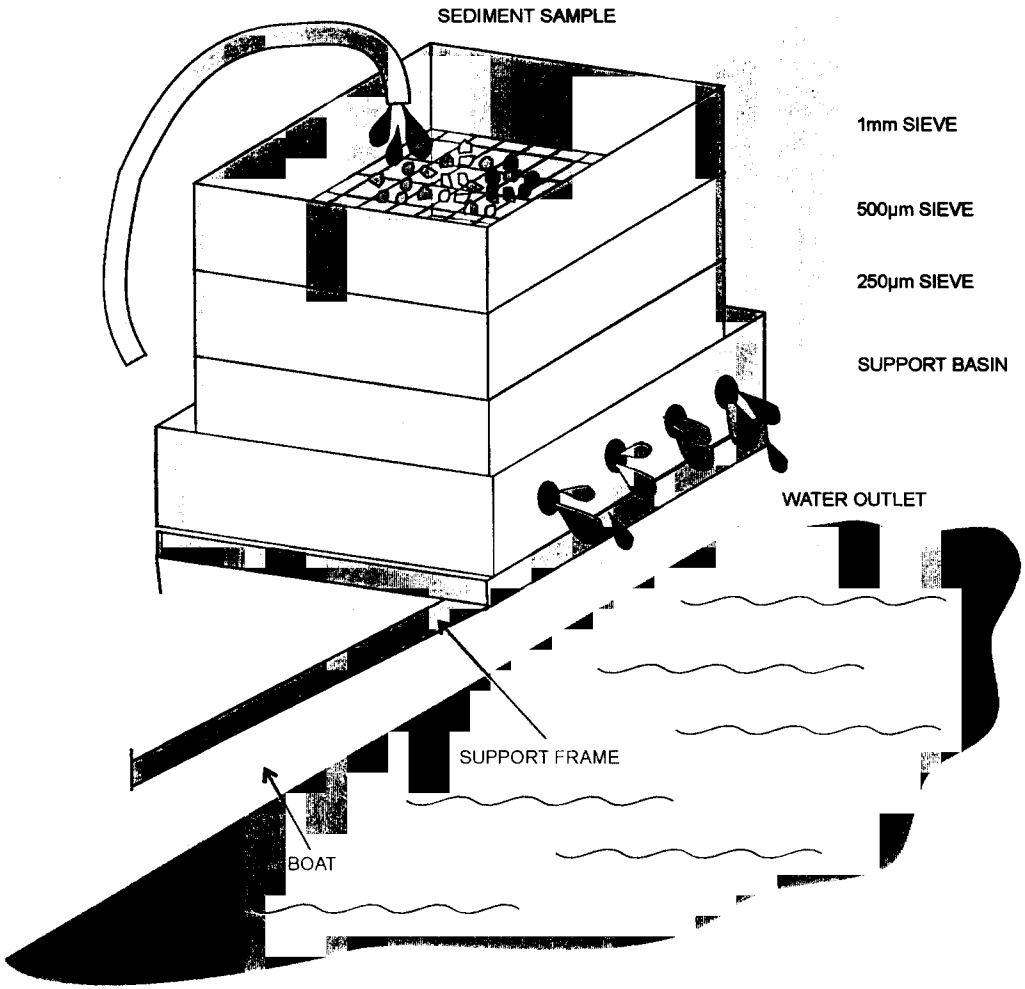
A) SIEVE TECHNIQUE




B) LOCATION OF STATIONS

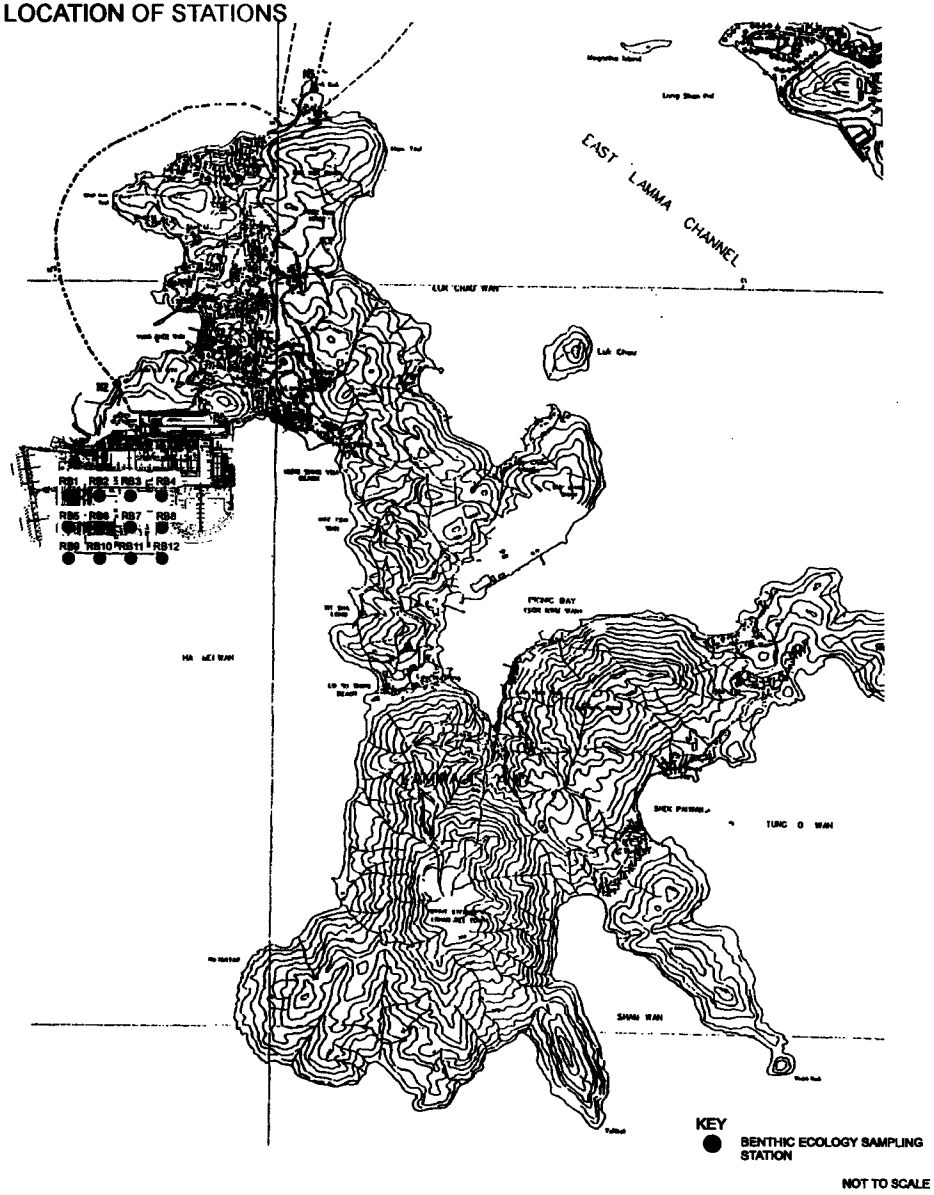



FIGURE 10.3c

DIAGRAM OF A) SIEVE TECHNIQUE AND B) LOCATION OF SAMPLING STATIONS

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labelled internally and externally with indelible ink and inventoried, before chain-of-custody forms were completed. Samples were then placed in plastic buckets for shipment to the taxonomy laboratory for sorting. Standard and accepted techniques were used for sorting organisms from the sediments. Small fractions of a sample were placed in a petri dish under a 10-power magnification dissecting microscope and scanned systematically with all animals and fragments removed using forceps. Each petri dish was sorted at least twice to ensure removal of all animals.

*Results*

West Coast Survey

**Intertidal Surveys:** In total 29 species of animals and 8 species of macroalgae were recorded at the 6 west coast sites. Except for T1 and T6 where animal species numbers were below 18, the number of animal species at the surveyed sites was > 19 and was highest at T4 where a total of 27 species was obtained (*Figure 10.3d*). The number of macroalgal species generally ranged from 4 to 6 with highest species number being recorded at T4.

Animals recorded on the shores at the surveyed sites were largely molluscs and crustaceans. The most abundant were herbivorous molluscs, including on the low and mid shore, the chiton (*Acanthopleura japonica*) and the limpets (*Cellana grata, C. toreuma, Patelloida pygmaea, P. saccharina, Siphonaria atra* and *S. sirius*), the snails (*Monodonta labio* and *Planaxis sulcatus*) and the nerites (*Nerita albicilla, N. chamaeleon, N. costata* and *N. lineata*), and on the high shore, the periwinkles (*Nodilittorina radiata, N. trochoides* and *N. vidua*) (*Figure 10.3e*). Predatory gastropods, the common dogwhelks (*Thais clavigera* and *Morula musiva*) were also recorded in the mid and low shore region (*Figure 10.3e*).

Although sites T4 and T5 were the more diverse (in terms of number of species), sites T1, T2 and T3 supported higher densities of organisms (*Figure 10.3f*). The reason for the difference appears to be the larger number of limpets present on the shores of sites T1, T2 and T3 (*Table 10.3d*). Cover of sessile invertebrates and macroalgae is highest at site T2 and lowest at site T5. There were substantial abundances of the sessile filter-feeding barnacles such as the stalked barnacle (*Capitulum mitella*) and the acorn barnacles (*Balanus amphitrite, Tetraclita japonica* and *T. squamosa*) (*Figure 10.3f*). Macroalgae were, in general, sparsely distributed, a pattern which is typical for Hong Kong rocky shores during the summer months when the survey was undertaken, as the low spring tide coincides with the hot noon time period. Of the algae present, encrusting algae *(Neogoniolithon misakiense, Corallina* sp. and *Hildenbrandia occidentalis)* and the filamentous green algae *Cladophora divergens* were of highest percentage cover.

The size structure of populations of the chiton *Acanthopleura japonica* were analysed at all six of the sites (*Figure 10.3g*). Evidence of recent recruitment to the populations at each site was noted (ie the presence of individuals less than 20 mm in length). The greatest range of sizes was observed at Site T6 in the south west of Lamma where individuals ranged from 10 - 70 mm in length. The smallest range of sizes of chitons was observed at Site T4 (15 - 55 mm). This indicates that conditions for chiton recruitment and growth are most favourable at site T6 and least favourable at site T4.

*Table 10.3d* ***Density ($m^{-2}$) of Intertidal Flora and Fauna Recorded at the West Coast Sites During the Wet Season***

| Species | T1 | T2 | T3 | T4 | T5 | T6 |
|---|---|---|---|---|---|---|
| **Chiton** | | | | | | |
| *Acanthopleura japonica* | 7.4 | 4.2 | 4.6 | 3.1 | 5.8 | 13.5 |
| **Limpet** | | | | | | |
| *Cellana grata* | 1.4 | 0.76 | 0.18 | 2.7 | 1.0 | 0.98 |
| *Cellana toreuma* | 1.5 | 2.6 | 2.9 | 0.76 | 2.8 | 2.6 |
| *Notoacmaea schrenkii* | - | 0.31 | 5.0 | 5.7 | 1.8 | 1.3 |
| *Patelloida saccharina* | 117.0 | 121.6 | 103.9 | 61.8 | 46.1 | 64.4 |
| *Patelloida pygmaea* | 0.62 | 4.4 | 3.5 | 0.71 | 1.1 | - |
| *Siphonaria atra* | 1.4 | 0.98 | 1.1 | 0.22 | 0.58 | 1.2 |
| *Siphonaria sirius* | 0.31 | 0.62 | 1.4 | 0.49 | 0.31 | - |
| **Snail** | | | | | | |
| *Monodonta labio* | 0.67 | 0.18 | 2.4 | 0.80 | 1.2 | 1.9 |
| *Nerita albicilla* | 3.6 | 2.8 | 3.1 | 2.8 | 2.0 | 4.6 |
| *Nerita chamaeleon* | - | 0.71 | - | 0.80 | 1.1 | 0.36 |
| *Nerita costata* | - | 0.13 | - | 0.40 | 0.27 | 0.09 |
| *Nerita lineata* | - | - | - | - | 0.09 | 0.13 |
| *Nodilittorina radiata* | 4.8 | 1.8 | 4.0 | 2.6 | 4.8 | 2.4 |
| *Nodilittorina trochoides* | 22.0 | 2.9 | 2.1 | 12.9 | 6.0 | 3.4 |
| *Nodilittorina vidua* | 1.3 | 2.5 | 5.2 | 3.8 | 0.44 | - |
| *Planaxis sulcatus* | 0.36 | 0.27 | 0.53 | 0.62 | 0.71 | - |
| *Thais clavigera* | 6.5 | 4.0 | 2.6 | 1.3 | 2.4 | 3.8 |
| *Morula musiva* | - | 0.44 | 0.84 | 0.27 | 1.1 | 0.71 |
| **Bivalve** | | | | | | |
| *Barbitia virescens* | 0.13 | 0.07 | 0.08 | 0.15 | 0.09 | 0.05 |
| *Brachidontes variabilis* | - | 5.2 | 0.04 | 0.08 | 0.31 | 0.07 |
| *Perna viridis* | - | 0.06 | - | - | - | - |
| *Septifer virgatus* | - | 0.25 | 0.13 | 0.10 | 0.08 | 0.18 |
| *Saccostrea cucullata* | - | 4.3 | 3.5 | 1.7 | 1.6 | 0.87 |
| **Barnacle** | | | | | | |
| *Balanus amphitrite* | 18.0 | 14.2 | 9.7 | 8.8 | 10.1 | 10.2 |
| *Capitulum mitella* | 0.6 | 2.5 | 1.6 | 1.2 | 0.90 | 1.4 |
| *Tetraclita japonica* | 1.3 | - | - | 0.79 | - | 0.09 |
| *Tetraclita squamosa* | 2.8 | 10.4 | 17.4 | 12.7 | 6.4 | 7.0 |
| **Sea anemone** | | | | | | |
| *Anthopleura japonica* | 0.01 | 0.01 | - | - | - | - |
| **Macroalgae** | | | | | | |
| *Endoplura aurea* | - | 1.0 | 0.95 | 0.19 | 2 0 | 1.3 |
| *Ralfsia expansa* | 0.33 | 0.24 | 0.11 | 0.07 | 0.23 | 0.1 |
| *Hapalospongidion gelatinosum* | - | - | - | 1.7 | - | - |
| *Hildenbrandia occidentalis* | - | 0.06 | 2.1 | 1.5 | 1.1 | 2.5 |
| *Hildenbrandia rubra* | 0.78 | 0.03 | 0.49 | - | - | 0.49 |
| *Neogoniolithon misakiense* | 0.22 | 4.5 | 4.8 | 7.1 | 3.0 | 7.5 |
| *Corallina* sp | 4.8 | 7.5 | 7.2 | 5.1 | 2.9 | 4.2 |
| *Pseudulvella applanata* | - | - | - | 2.1 | - | - |
| *Gloeocapsa* sp | - | - | - | - | - | - |
| *Kyrtuthrix maculans* | 2.6 | - | 0.04 | 0.11 | 0.04 | 0.18 |
| *Cladophora sp* | - | 14.3 | 2.8 | 0.49 | - | 1.8 |

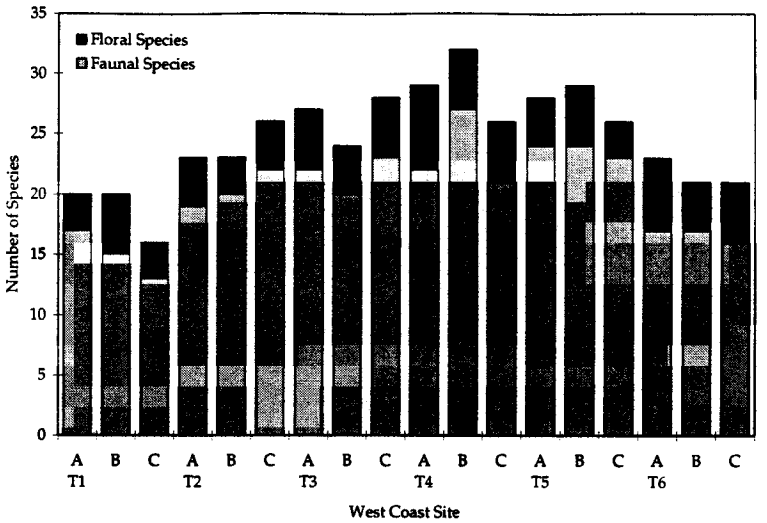



Figure 10.3d: Total number of animal and algal species of each transect sampled during wet season surveys of sites on the west coast of Lamma Island.

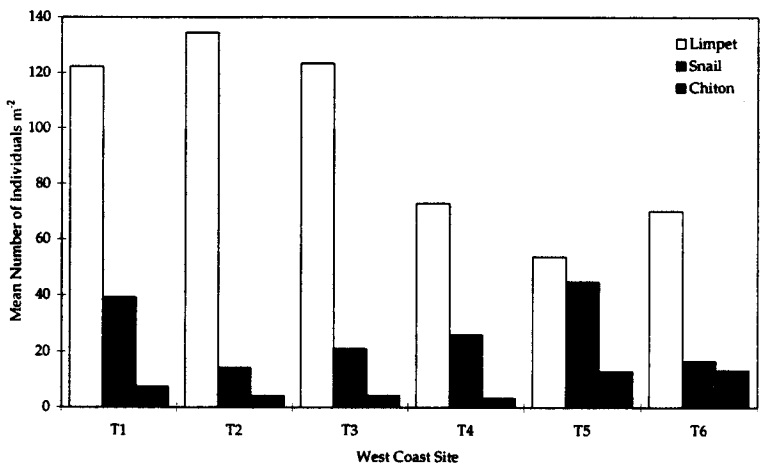



Figure 10.3e: Mean number of mobile molluscs $m^{-2}$ recorded during wet season surveys of sites on the west coast of Lamma Island.

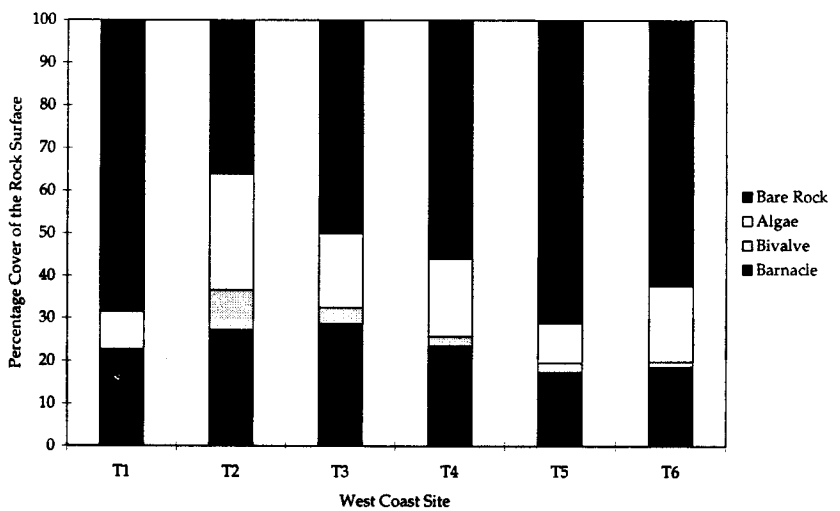
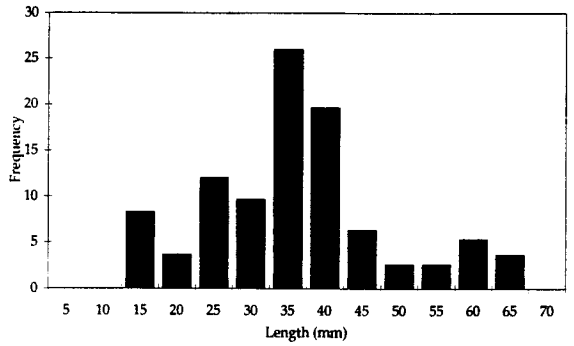
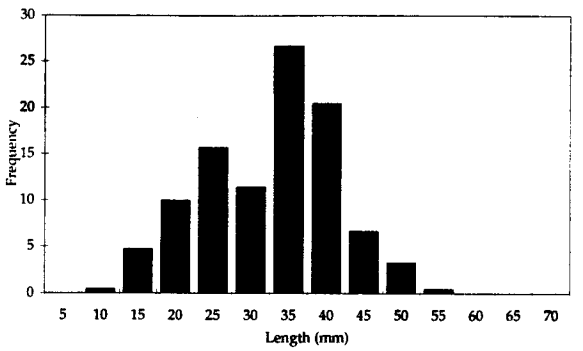


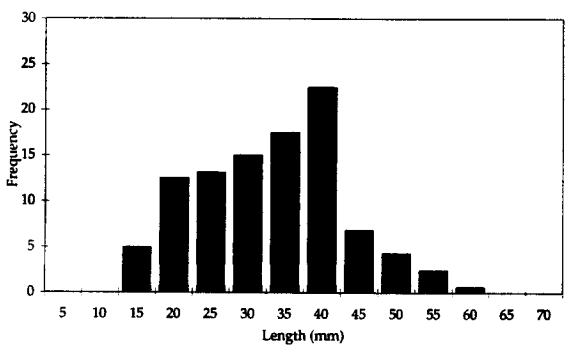

Figure 10.3f: Percentage cover on the rock surface of sessile invertebrates and macroalgae. Records were made during wet season surveys of sites on the west coast of Lamma Island.



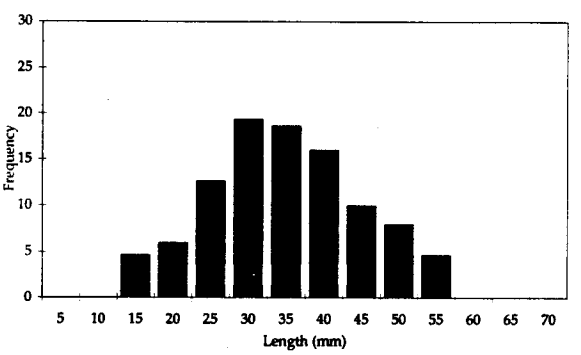

(i) Population Structure of chitons from west coast site T1



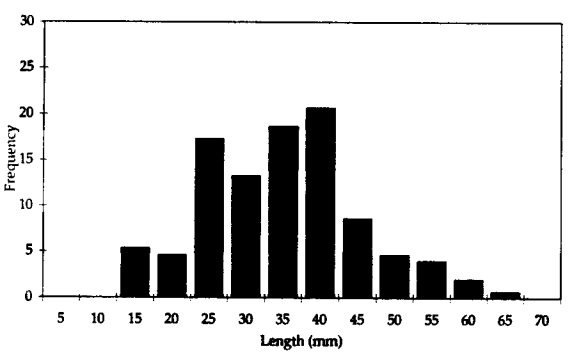

(ii) Population Structure of chitons from west coast site T2



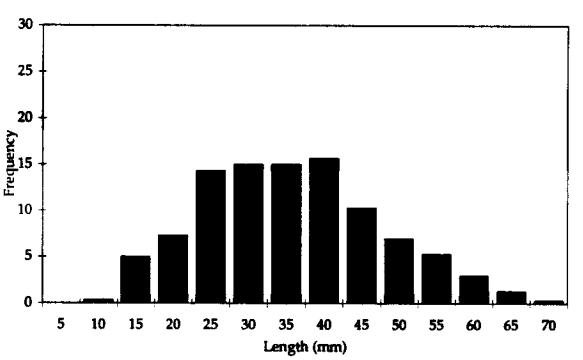

(iii) Population Structure of chitons from west coast site T3




(iv) Population Structure of chitons from west coast site T4




(v) Population Structure of chitons from west coast site T5




(vi) Population Structure of chitons from west coast site T6

Figure 10.3g - Population structure of the herbivorous mollusc, *Acanthopleura japonica*, sampled during August 1998 on shores on the west coast of Lamma Island. Data are % occurrence in the population.

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*MDS*: In order to examine differences between the assemblages present at sites, statistical analysis was carried out using Multi Dimensional Scaling (MDS). MDS is a method for creating a low dimensional picture (usually two dimensions) of the relationships between sites in a complex, multi dimensional problem. The data inputted into the MDS analysis represented abundance and percentage cover of six groups of intertidal fauna and flora (chiton, limpet, snail, barnacle, bivalve and algae - see *Annex B10 - 1*). The data was transformed to standardise the dataset and then the Bray Curtis metric was calculated.

The analysis first calculates the dissimilarity between the sites based on the parameters selected and produces a dissimilarity matrix. The values in the matrix are Euclidean distances that represent the dissimilarity between two sites. These dissimilarity data are then analysed to produce an MDS plot (*Figure 10.3h*). The plot illustrates that there are statistically identifiable differences in the characteristics of the assemblages.

The results of the MDS analysis show that there appears to be a difference between the southern sites (T5 and T6) and those on the western (T2 - T4) and northern shores (T1) of Lamma Island. This is demonstrated by the tightly clustered grouping of the southern sites T5 and T6 (*Figure 10.3h*). The other sites are separate from T5 and T6, and from each other, indicating that they are dissimilar. The separation of the southern sites from the western and northern sites is largely attributed to the low abundances of organisms recorded at these sites (T5 and T6) in comparison to the others (T1 to T4).

The differences between the sites can possibly be attributed to either of two factors, naturally occurring changes in physical parameters that affect the sites (ie north to south decreases in turbidity, increases in exposure and salinity) or as a result of the effects of cooling water discharged from the existing power station. It is not possible to specify exactly which of these effects is the primary cause of the observed difference between the southern and northern sites without conducting manipulative experiments. It is clear, however, that the effect is not detrimental to the ecology of the mid and northern sites, as on these shores higher abundances were recorded in the majority of taxa compared to the southern sites.

*ANOVA:* Observed differences between the sites T1 - T6 and additionally those surveyed at the landing and launching points (L1 - L4) were analysed using analysis of variance techniques (ANOVA). Although significant differences were observed between sites for all of the tested parameters (abundance of snails, abundance of limpets and abundance of chitons, percentage cover of algae, and percentage cover of barnacles) there were no consistent patterns that inferred a relationship between temperature elevated water and the tested parameters.

For example, the percentage cover of algae was lowest at site T1 in Yung Shue Wan bay an area that experiences a 2°C elevation in water temperature as a result of the discharges. However the percentage cover of algae did not differ significantly (using the multiple comparison procedure) with sites L1, which is close to the existing power station and experiences elevations of 4°C, and T5 which is located to the far south of the power station at Ha Mei Tsui and experiences only a 1°C elevation. A full presentation of the results of the ANOVA analyses is included in *Annex B10 - 3*.

The conclusions from the MDS analysis and the ANOVA tests are that the heated water does not appear to have had an adverse effect on the intertidal assemblages. For some of the groups tested abundances were higher in the unaffected sites, and for others abundances were higher in the affected sites. Overall, however, total abundance and percentage cover of fauna and flora appear highest at the sites affected by thermal discharges.

**Subtidal Surveys - ROV:** The term "coral" is used to describe a number of different organisms that are collectively linked in the class Anthozoa. Within the class Anthozoa, two subclasses are found, namely the Zoantharia and the Octocorallia. The Zoantharia is divided into five living orders, Actinaria (sea anemones), Zoanthidia (colonial anemones), Antipatharia (black corals), Ceriantharia (sand burrowing anemones) and the much larger order Scleractinia (hard reef building corals). The second subclass Octocorallia, is divided into three living orders, Alcyonacea (soft corals), Gorgonacea (sea fans and whips) and Pennatulacea (sea pens)[15].

The greatest diversity and abundances of corals are generally found in the northeastern waters of Hong Kong due to the optimal environmental conditions for settlement, growth and survival found in these waters[16]. The western and southern waters of Hong Kong are influenced by the Pearl River, greatly reducing salinities, increasing turbidity and therefore reducing light penetration. Ahermatypic octocorals, including the soft corals, which unlike the hermatypic hard corals do not require light for zooxanthellae photosynthesis, are more widely distributed and often occur at greater depths[17].

The results indicate that octocorals from the orders Gorgonacea and Alcyonacea make up the majority of the epifaunal assemblages of the subtidal at the sites surveyed. Six species of gorgonian were recorded, the sea whips *Euplexaura curvata, Euplexaura robusta, Hicksonella princeps, Ellisella gracilis,* and the sea fan *Echinogorgia complexa,* as well as one unidentified species. Four separate Alcyonacea were recorded, identified as *Dendronephthya* spp, however, no higher identification to species level could be made as this would require scanning electron microscope examination of the spicules[18].

These four soft corals have been characterised and are described as *Dendronephthya* spp A - large body with orange polyps, *Dendronephthya* spp B - large white body with red polyps, *Dendronephthya* spp C - small red/orange body with red/orange polyps and *Dendronephthya* spp D - pure white body with white polyps. A single species of hard coral, *Tubastrea* spp, was also recorded. This species is also ahermatypic and therefore is not a reef building coral. The coral colonies recorded by the ROV during the surveys at the west coast sites T2 to T6 are listed in *Table 10.3e.*

The ROV survey revealed that the physical environment of the seabed varied from flat sand (T2 and T3) to a steep rocky seabed comprised largely of boulders (T6). The variety in the substratum is reflected in changes in species abundance as recorded by the ROV.

(15) Morton B and Morton J (1983) *The Sea Shore Ecology of Hong Kong.* Hong Kong University Press

(16) Clark T H (1997) The Distribution of Ahermatypic Corals at Cape d'Aguilar, Hong Kong. The Marine Flora and Fauna of Hong Kong and Southern China IV ( ed. B Morton). Proceedings of the Eighth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong, 2 - 20 April 1995. Hong Kong: Hong Kong University Press, 1997.

(17) Clark T H (1997) *op cit.*

(18) Clark T H (1997) *op cit.*

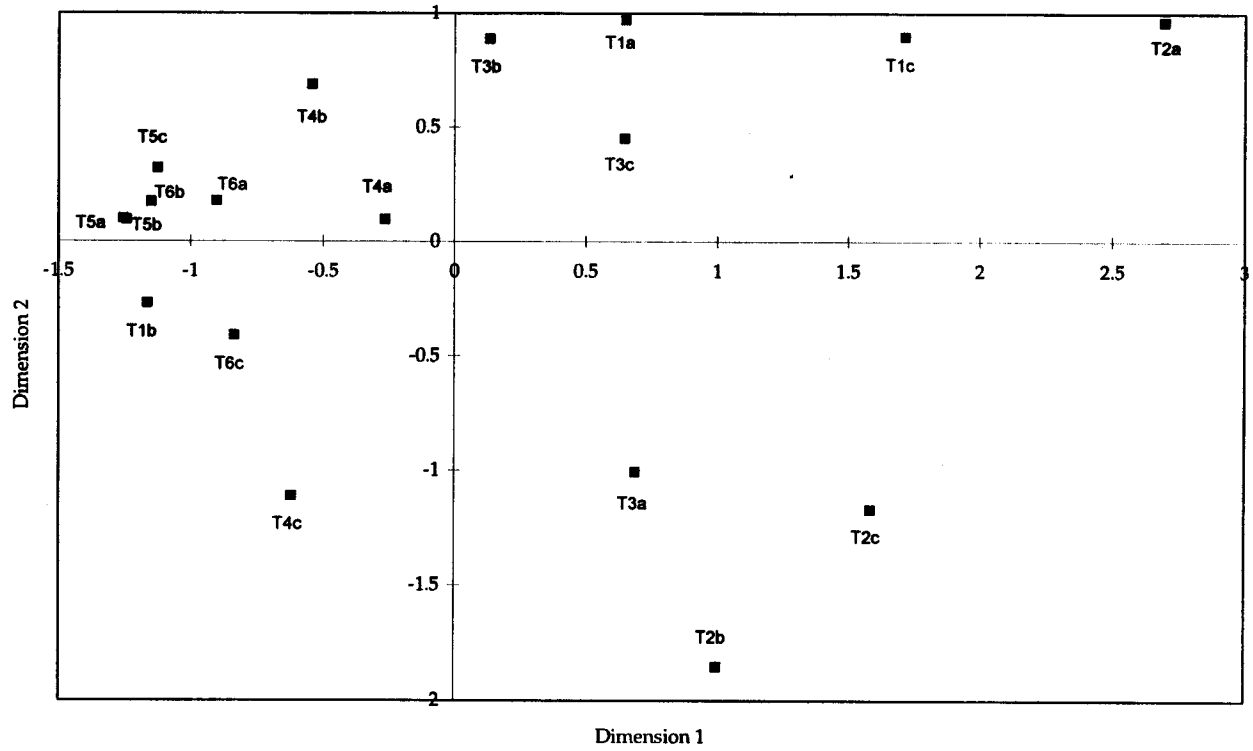


Figure 10.3h: Multi-dimensional scaling (MDS) plot of dissimilarities between west coastal sites on Lamma Island. Analysis was of the total number of individuals of intertidal organisms recorded during August 1998. Station groups that are plotted far apart are dissimilar, whereas stations plotted in proximity to each other exhibit similar assemblage structure. Stress value of MDS plot is 0.077 indicating a good representation.

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*Table 10.3e* ***Number of Coral Colonies (per Site and $m^{-2}$) Recorded in the ROV Survey at the West Coast Sites (T2 - T6)***

| Species | Number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T2 | $m^{-2}$ | T3 | $m^{-2}$ | T4 | $m^{-2}$ | T5 | $m^{-2}$ | T6 | $m^{-2}$ |
| Hard Corals | | | | | | | | | | |
| *Tubastrea* spp | - | - | - | - | - | - | - | - | 73 | 0.08 |
| Sea Whips | | | | | | | | | | |
| *Euplexaura curvata* | 1 | 0.001 | - | - | - | - | 5 | 0.005 | 170 | 0.19 |
| *Euplexaura robusta* | - | - | - | - | - | - | 11 | 0.01 | 12 | 0.01 |
| *Hicksonella princeps* | - | - | - | - | - | - | 1 | 0.0009 | - | - |
| *Ellisella gracilis* | - | - | - | - | - | - | - | - | 26 | 0.03 |
| Sea Fans | | | | | | | | | | |
| *Echinogorgia complex* | - | - | - | - | - | - | - | - | 171 | 0.19 |
| Soft Corals | | | | | | | | | | |
| *Dendronephthya* spp A | - | - | - | - | - | - | - | - | - | - |
| *Dendronephthya* spp B | - | - | - | - | - | - | - | - | 1 | 0.001 |
| *Dendronephthya* spp C | - | - | - | - | - | - | - | - | 45 | 0.05 |
| *Dendronephthya* spp D | - | - | - | - | - | - | 10 | 0.009 | - | - |
| Sea Pens | | | | | | | | | | |
| *Cavernularia* spp | - | - | - | - | - | - | - | - | - | - |
| *Pteroeides* spp | - | - | - | - | - | - | - | - | 1 | 0.001 |
| Unidentified Soft Coral | - | - | - | - | - | - | - | - | 5 | 0.006 |

From *Table 10.4e* there is a clear difference in the diversity and abundance of species recorded by the ROV. No corals were recorded at T3 and T4 with only a single sea whip, *Euplexaura curvata*, recorded at T2. The substratum at these sites appeared to be a flat muddy seabed interspersed with patches of sand and shell debris. Crab burrow holes were often recorded, however, no fauna was viewed as being associated with these holes. Occasional boulders covered with a heavy deposit of sediment were recorded at T2.

Further south at site T5 an increase in the amount of corals was recorded. Sea whips were more common, with the species *Euplexaura robusta* making up the majority of those recorded, with a density of 0.01 $m^{-2}$ for the site. An interesting feature was the colony of 10 individuals of the soft coral *Dendronephthya* spp D recorded in the northern section of the site but not recorded anywhere else. As a result, these individuals recorded a density of only 0.009 $m^{-2}$ for the site.

The site with the highest species diversity and abundance was T6. This site is more exposed than the other sites on Lamma Island, resulting in a greater influence by the more saline and less turbid oceanic waters of the south of Hong Kong. The effect of this exposure is shown in the substratum which consisted of a steep rocky habitat with many large boulders and slabs. The species diversity and abundance was greatest at this site in comparison to the others surveyed by the ROV. The most striking feature as viewed by the ROV was the large numbers of the Sea Fan *Echinogorgia complexa* (171 colonies at a density of 0.19 $m^{-2}$). These colonies appeared visually to be well established with some individuals possessing diameters of > 1 m. Sea whips were also very common (208 colonies), with the most abundant species being the unbranched sea whip, *Euplexaura curvata* (density of 0.19 $m^{-2}$ for the site). This is in contrast to the other sites surveyed which supported colonies of the branched sea whip, *Euplexaura robusta* (density of 0.01 $m^{-2}$ for the site). Although abundant, the colonies of *Euplexaura curvata* were generally individuals of a small size (< 20 cm in length).

The hard coral *Tubastrea* spp was frequently observed at this site (73 colonies and a density of 0.08 $m^{-2}$) with individuals found to be either solitary or in close proximity to the red bodied soft coral *Dendronephthya* spp C. Five individuals of an unidentified species of soft coral were also viewed on the video, however, due to bad visibility at the time of the surveys identification of these individuals was not possible.

The ROV footage from site T6 also revealed large numbers (> 30 individuals) of the holothurian or sea cucumber, *Colochirus crassus*. This sea cucumber was often found to be in large groups consisting of five or more individuals and was commonly found on the sea fan, *Echinogorgia complexa*. The long-spined sea urchin *Diadema setosum*, was also found to be present in high numbers at T6 (> 30 individuals). One sea pen, *Pteroeides* spp, was recorded by the ROV.

The relative abundance and density of the corals recorded by the ROV at the west coastal sites in comparison with other areas in Hong Kong appears to be low. A recent ROV survey as part of the ongoing Green Island Development Study has revealed that the coral colonies found in the subtidal zones on both Green Island and Little Green Island are found in considerably higher densities than those found during the present Study. This is especially apparent in the density of the soft coral *Dendronephthya* spp. This coral recorded a maximum density of 16.2 $m^{-2}$ (Green Island transect T4) for the Green Island survey yet was recorded as having a maximum density of only 0.05 $m^{-2}$ (west coastal site T5) in the present Study. Similarly, the sea whip *Euplexaura curvata* which was the second most abundant coral found in the west coastal sites with a total of 170 colonies. This species was recorded as having a maximum density of 0.19 $m^{-2}$ (west coastal site T6), whereas, in the Green Island survey the same species has been recorded as having a far greater maximum density of 3.13 $m^{-2}$ (Green Island transect T3) (*Table 10.3f*).

*Table 10.3f* ***Comparison of Number of Coral Colonies from Wet & Dry Season ROV Surveys at Green Island, Little Green Island and Hong Kong Island[1] and those at the West Coastal Sites and the Reclamation Site as part of the Present Study***

| Survey Area | Coral Species | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Dendronephthya spp* | | *Echinogorgia complex* | | *Euplexaura curvata* | | *Ellisella gracilis* | | *Hicksonella gracilis* | |
| *Wet Season* | No. | $m^{-2}$ | No. | $m^{-2}$ | No. | $m^{-2}$ | No. | $m^{-2}$ | No. | $m^{-2}$ |
| Little Green Island | | | | | | | | | | |
| T1 | 49 | 1.63 | 29 | 0.97 | 50 | 1.67 | - | - | 6 | 0.20 |
| T2 | 30 | 1.00 | 6 | 0.20 | 22 | 0.73 | 2 | 0.07 | - | - |
| Green Island | | | | | | | | | | |
| T3 | 11 | 0.37 | 1 | 0.03 | 94 | 3.13 | - | - | - | - |
| T4 | 42 | 1.40 | - | - | 15 | 0.50 | - | - | - | - |
| Hong Kong Island - no coral species recorded either at T5 or T6 | | | | | | | | | | |
| *Dry Season* | | | | | | | | | | |
| Little Green Island | | | | | | | | | | |
| T1 | 183 | 6.1 | 21 | 0.7 | 29 | 0.97 | 5 | 0.17 | - | - |
| *Wet Season* | No. | $m^{-2}$ | No. | $m^{-2}$ | No. | $m^{-2}$ | No | $m^{-2}$ | No. | $m^{-2}$ |
| T2 | 147 | 4.5 | 6 | 0.20 | - | - | 5 | 0.17 | - | - |
| Green Island | | | | | | | | | | |
| T3 | - | - | 5 | 0.17 | 15 | 0.5 | 3 | 0.1 | - | - |
| T4 | 467 | 16.2 | 4 | 0.13 | 3 | 0.1 | 1 | 0.03 | - | - |
| Hong Kong Island | | | | | | | | | | |
| T5 | 1 | 0.03 | - | - | - | - | - | - | - | - |
| T6 | 1 | 0.03 | - | - | - | - | - | - | - | - |
| *Present Study* | | | | | | | | | | |
| West Coastal Sites | | | | | | | | | | |
| T2 | - | - | - | - | 1 | 0.001 | - | - | - | - |
| none of these species were recorded at either T3 or T4 | | | | | | | | | | |
| T5 | 10 | 0.009 | - | - | 5 | 0.005 | - | - | - | - |
| T6 | 46 | 0.05 | - | - | 170 | 0.19 | - | - | - | - |
| Reclamation Site | 43 | 0.043 | - | - | - | - | 22 | 0.022 | - | - |

[1] Data from an ongoing study (Green Island Development - Studies on Ecological, Water Quality and Marine Traffic Impacts for TDD)

**Subtidal Surveys - SCUBA:** The majority of the substratum recorded for the thermal plume site T1 consisted of sand and shell debris, with up to 100 % of the total cover of line transect 4 (mean cover 55.3 %) (*Figure 10.3i*). Coral cover was low on the line transect with only one colony of the encrusting hard coral

*Psammocora superficialis* found (mean cover 0.28 %) as well as sporadic colonies of hard corals from the family Faviidae (mean cover 1.39 %) (*Table 10.3g*).

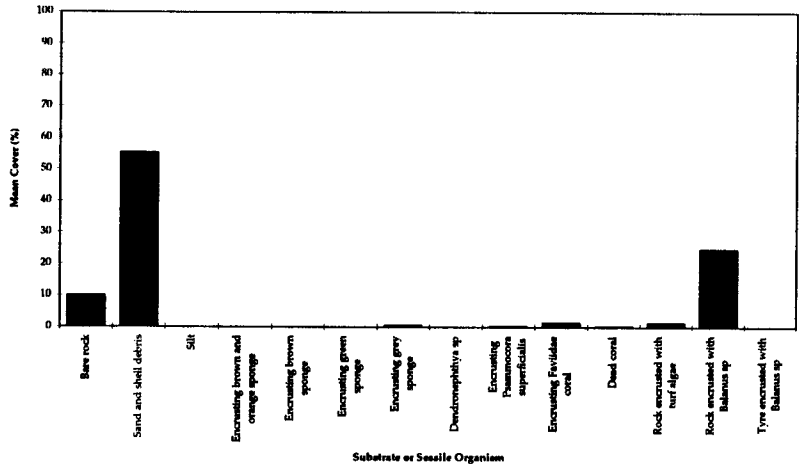
*Table 10.3g* ***Mean Percentage of Line Transect Cover by Coral Colonies Recorded at the West Coastal Sites***

| Coral Colony | Site | | | | | |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 |
| Hard Coral | | | | | | |
| *Psammocora superficialis* | 0.28% | 0% | 0% | 0% | 0% | 0% |
| Family Faviidae | 1.39% | 1.11% | 0% | 0% | 0% | 1.00% |
| Soft Coral | | | | | | |
| *Dendronephthya* spp | 0% | 0% | 0% | 0% | 0% | 0% |

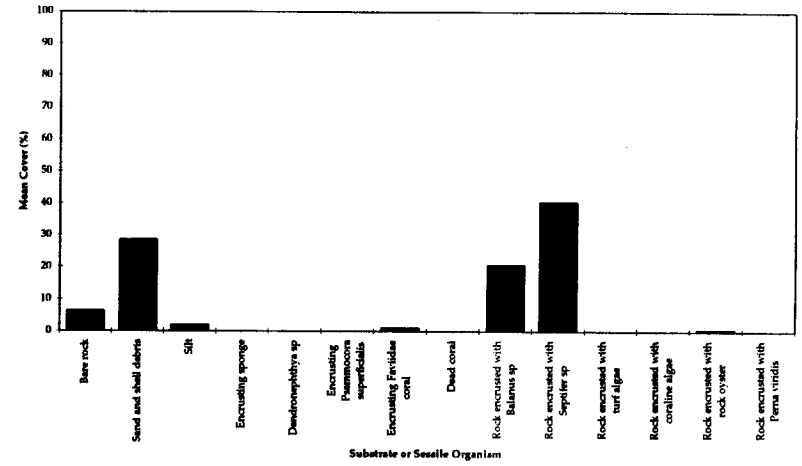
Substrates at site T2 ranged from rocks encrusted with the mussel, *Septifer virgatus* (mean cover 40.5 %) to sand and shell debris (mean cover 28.6 %) (*Figure 10.3i*). This species was not recorded at any of the launching and landing survey sites (Part C) or the northern west coastal site T1, but was commonly found to be encrusting the barnacle, *Balanus* spp, at the majority of the southern west coastal sites, particularly T2. The site had a very low percentage of coral cover with only three colonies of hard corals from the Faviidae family recorded at a mean cover of 1.11 % (*Table 10.3g*).

The most common substrates recorded at site T3 were boulders encrusted with the barnacle, *Balanus* spp (mean cover 67.5 %) (*Figure 10.3i*). The remaining areas surveyed at T3 were sand and shell debris (mean cover 25.3 %), bare rock (mean cover 2.2 %) and rock encrusted with the mussel *Septifer virgatus* (mean cover 4.7 %). No corals were found on any of the surveyed line transects (*Table 10.3g*). Site T4 was similar to the other sites in the sense that barnacle covered rocks were the main substrate type. However, unlike the other sites there were patches of the green lipped mussel, *Perna viridis* (mean cover 21.9 %) (*Figure 10.3i*). No corals were found on any of the line transects surveyed at this site.

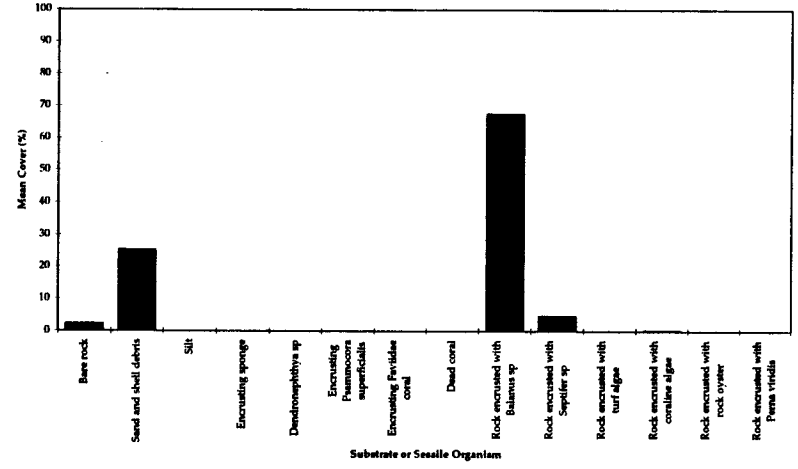
Rocks encrusted with the barnacle, *Balanus* spp, were the most common substrate type recorded at site T5 (mean cover 71.4 %) (*Figure 10.3j*). Unidentified rock oysters were also recorded (mean cover 4.4 %). No corals of any class were found on the line transects (*Table 10.3g*). As reported during the ROV survey at T6, the substrate recorded during the dive survey was a very rocky seabed typically with large boulders and slabs, commonly encrusted with the barnacle, *Balanus* spp (mean cover 72.2 %). A feature of this site differing from the others surveyed during the study, was the presence and extent of cover of turf algae and coralline algae (mean cover 13.6 % and 11.1 % respectively) (*Figure 10.3j*). Hard corals from the family Faviidae, as well as sponges, were sporadically found within the line transect at this site during the survey (*Table 10.3g*). Photographs of representative substrates as well as organisms of interest observed within the belt transects at each of the west coastal sites are shown in *Annex B10 - 2*. It must be noted, however, that the photographs of the representative substrates and / or organisms of interest were taken within the entire area of the belt transects and are, therefore, not a visual representation of the results of the line transect survey.



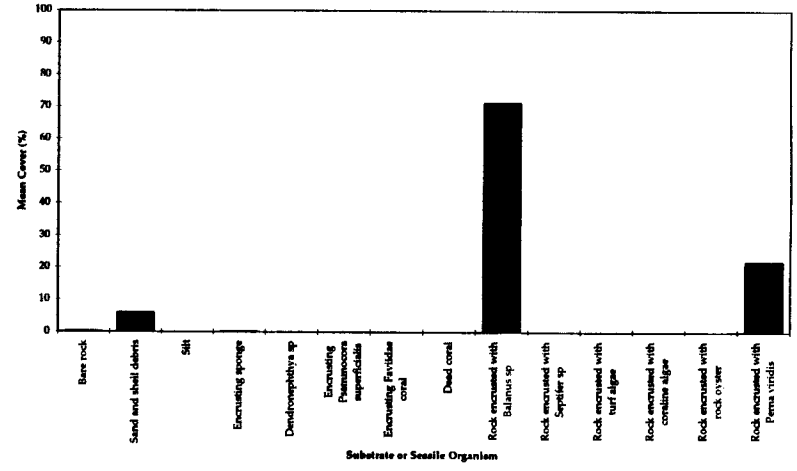

(i) Mean cover (%) for substrate or sessile organism for west coastal site T1




(ii) Mean cover (%) for substrate or sessile organism for west coastal site T2




(iii) Mean cover (%) for substrate or sessile organism for west coastal site T3




(iv) Mean cover (%) for substrate of sessile organism for west coastal site T4

Figure 10.3i - Mean cover (%) for substrate or sessile organism recorded during the subtidal surveys during August 1998 at the west coastal sites T1 to T4 at Lamma Island.

FILE: C1830/MARINE/SUBTIDAL/Mean Cover Graphs (T1 - T6).doc
DATE: 24-10-98

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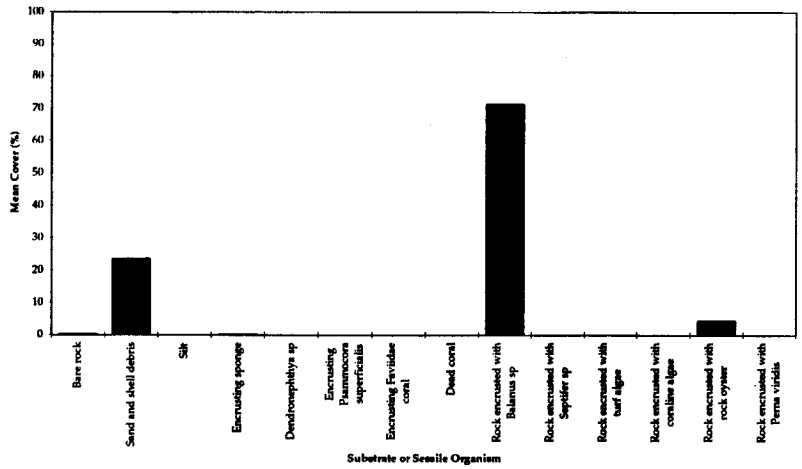
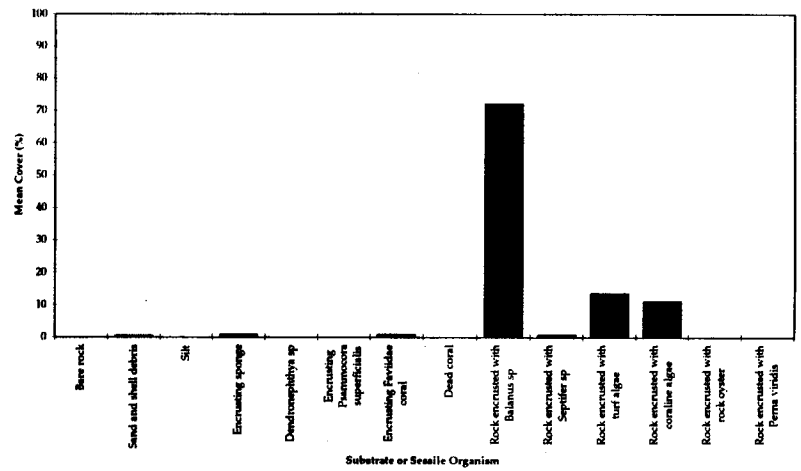



(i) Mean cover (%) for substrate or sessile organism for west coastal site T5




(ii) Mean cover (%) for substrate or sessile organism for west coastal site T6

Figure 10.3j - Mean cover (%) for substrate or sessile organism recorded during the subtidal surveys during August 1998 at the west coastal sites T5 and T6 at Lamma Island.

FILE: C1830/MARINE/SUBTIDAL/Mean Cover Graphs (T1 - T6).doc
DATE: 24-10-98

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For each of the west coastal sites the highest abundance of mobile organisms were from the class Gastropoda (*Table 10.3h*). The majority of gastropods recorded were dogwhelks, tusk shells and turban shells. T6 recorded the highest abundances of these organisms with a mean of 237.3 individuals per transect. Other organisms recorded in abundance during the surveys were hermit crabs (Paguridae), swimming crabs (*Charybdis* spp), occasional records of sea cucumbers (*Holothuria leucospilota* and *Colochirus crassus*) as well as the sea urchins, *Diadema* sp and *Anthocidaris crassispina*.

*Table 10.3h* ***Mean Number of Mobile Individuals (> 1 cm) 30 m Transect$^{-1}$ (± SD) for each West Coastal Site***

| Fauna | Site | | | | | |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 |
| Decapoda | 1.8 (1.5) | 25.0 (18.2) | 20.7 (13.5) | 25.3 (7.5) | 23.0 (13.4) | 27.8 (11.9) |
| Gastropoda | 31.8 (32.6) | 54.5 (46.7) | 20.3 (16.1) | 73.8 (32.5) | 64.3 (86.5) | 237.3 (93.1) |
| Holothuroidea | 2.0 (3.5) | 0.8 (1.2) | 2.2 (3.4) | 1.33 (1.2) | 3.0 (4.0) | 1.0 (1.6) |
| Echinoidea | 0.3 (0.8) | 2.7 (1.9) | 0.7 (1.6) | 4.7 (3.1) | 11.0 (12.7) | 40.2 (32.8) |

As with the intertidal survey results, statistical analysis of the results of the subtidal SCUBA surveys was conducted using MDS to examine differences between sites based on the composition of the assemblages. The input parameters for this analysis are presented in *Table A2* of *Annex B10 - 1* and the MDS plot is shown in *Figure 10.3k*.

The distribution of the MDS appears to support the findings of the surveys that the southernmost site T6 is different to the other west coastal sites. Although the clustering of the other sites is not very tight, showing that most of the sites appear to be dissimilar, site T6 is clearly separate. This dissimilarity originates from the high abundances of gastropods, and the greater cover of algae recorded at this site in comparison to the others surveyed (*Annex B10 - 1*).

**Summary of Subtidal Surveys:** The findings of the ROV and SCUBA surveys conducted at the west coastal sites indicate that with the exception of T6, the sites are of low ecological value. Although many of the sites (T1 - T5) do support species of ecological and conservation value (ie gorgonian sea whips, soft corals and hard corals) these organisms occur as isolated colonies. In comparison with other areas in Hong Kong, the assemblages on the west coast of Lamma are regarded as of low ecological value. Surveys conducted at Pak Kok[19] on the northern tip of Lamma recorded soft corals and gorgonians with a cover of 13.09 %. The highest percent cover of corals (both hard and soft) for the west coastal sites recorded during the dive surveys was 1.67 % (T1), which is considerably lower than that recorded at Pak Kok. Furthermore, comparison with an area of high conservation value, ie the coral colonies at Ping Chau emphasises the low ecological value of the sites on Lamma. The surveys at Ping Chau recorded coral covers (both hard and soft) of 55.9 % and 61.9 % in different areas[20].

[19] Binnie Consultants Limited (1995) *op cit.*

[20] Binnie Consultants Limited (1996) Ping Chau Quantitative Survey Final Report. For the Geotechnical Engineering Office, Civil Engineering Department.

The results of the ROV and dive surveys show that of all the west coastal sites T3 and T4 were found to be of the lowest ecological value, especially site T4 with no epifaunal organisms recorded at all during the ROV survey. No soft corals were found on any of the sites during the dive surveys and only solitary colonies of hard corals were recorded on line transects at site T2 and T6. Colonies of hard corals were recorded in belt transects throughout the sites, however, these were found to be sporadic and isolated.

The southernmost west coastal site T6 was found to support the highest diversity, abundances and densities of organisms of ecological value, with colonies of corals recorded by the ROV at this site. It must be noted that although large individual colonies of soft corals, particularly of the sea fan, *Echinogorgia complexa*, were observed at this site, their presence was found only between 8 to 12 m below Chart Datum. It is unlikely that at this depth and remote distance that these corals will be impacted by either suspended sediment dispersed during construction of the power station or cooling water discharged during operation of the power station. This issue is discussed further in *Sections 10.4 & 10.5.*

Reclamation Site Surveys

**Epifauna Survey:** The footage taken in this survey by the ROV revealed that there is an abundant assemblage of soft corals and gorgonians localised at a distance of approximately 50 - 100 m to the south and the west of the sea wall of the ash lagoon. The majority of the seabed of the reclamation area is soft fine sediment. Apart from a high number of burrow holes recorded by the ROV, the substratum was featureless. Within the survey area a number of octocorals were recorded and the results presented in *Table 10.3i.* As the soft corals and gorgonians were found only within a 1 km length of transect, the density of cover is calculated based on this length and not over the entire transect (approximately 5 km). All coral species identification and classification was conducted as carried out in the west coast site surveys.

The most abundant group of corals recorded were the sea whips, of the order Gorgonacea, particularly the species *Euplexaura robusta.* As previously mentioned the largest concentrations of this species were located surrounding the southern and western sea walls of the existing ash lagoon of the power station. The high numbers of sea whips is in contrast to the thermal plume sites where lower numbers were recorded, of which the majority were another species *Euplexaura curvata.*

The area around the lagoon was also shown to be supporting diverse colonies of soft corals of the *Dendronephthya* spp A, B and C. Without exception these individuals were surrounded by sea whips. These colonies also appeared to only be present in the areas where the habitat had changed to a more heterogeneous substrate. The occasional solitary hard coral, *Tubastrea* spp, and sea pens, *Cavernularia* spp and *Pteroeides* spp, were also recorded by the ROV during the survey at this site.

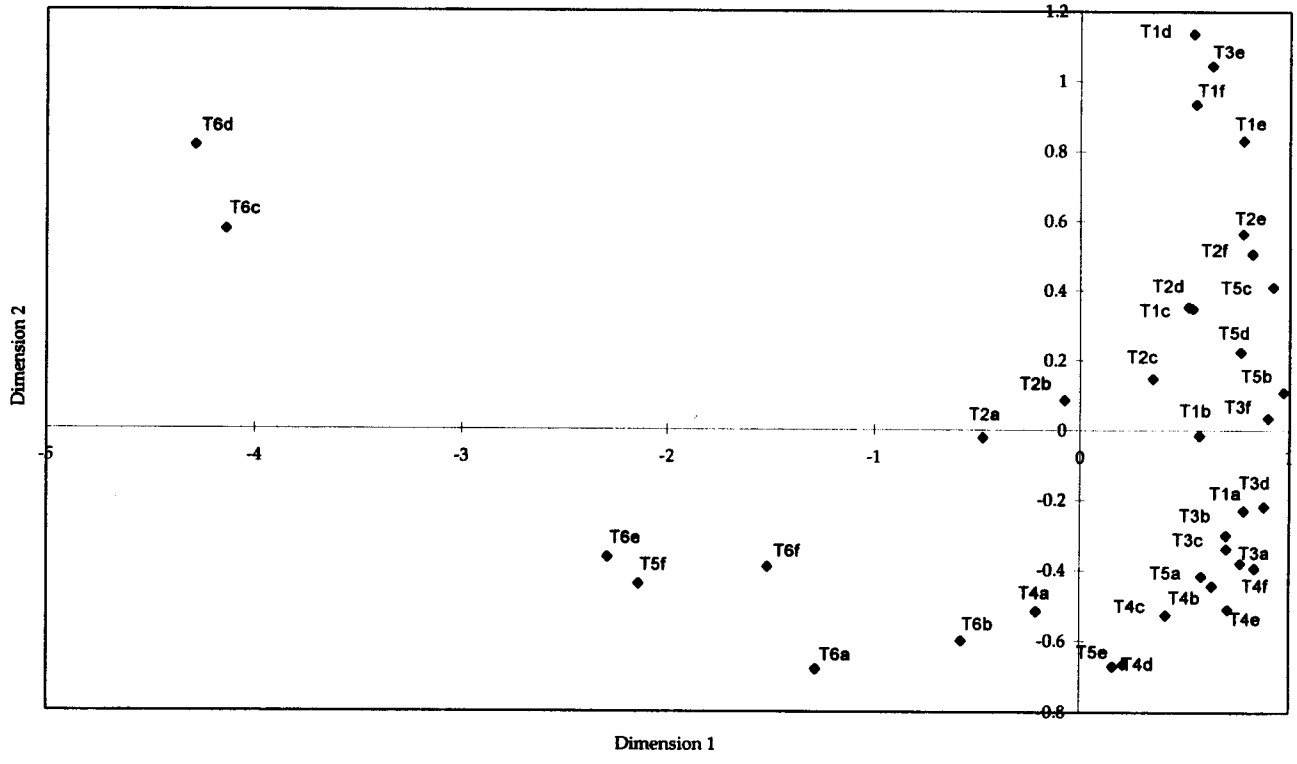


Figure 10.3k: Multi-dimensional scaling (MDS) plot of dissimilarities between west coastal sites on Lamma Island. Analysis was of the total number of individuals of subtidal organisms and substrate type recorded during August 1998. Station groups that are plotted far apart are dissimilar, whereas stations plotted in proximity to each other exhibit similar catch parameters. Stress value of MDS plot is 0.056 indicating a good representation.

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*Table 10.3i* ***Coral Colonies Recorded in the August 1998 ROV Survey at the Reclamation Site***

| Species | Total Number Recorded | Number $m^{-2}$ |
|---|---|---|
| Hard Corals | | |
| *Tubastrea* spp | 3 | 0.003 |
| Sea Whips | | |
| *Euplexaura robusta* | 815 | 0.815 |
| *Hicksonella princeps* | 31 | 0.031 |
| *Ellisella gracilis* | 22 | 0.022 |
| Soft Corals | | |
| *Dendronephthya* spp A | 17 | 0.017 |
| *Dendronephthya* spp B | 14 | 0.014 |
| *Dendronephthya* spp C | 12 | 0.012 |
| Sea Pens | | |
| *Cavernularia* spp | 1 | 0.001 |
| *Pteroeides* spp | 1 | 0.001 |

Apart from the soft coral assemblages to the east of the site, no other organisms were recorded by the ROV indicating an isolated assemblage of ecological interest. However, it should be noted that the densities of the soft coral assemblages within the reclamation site are low in comparison with those found at other sites in Hong Kong. For example, an ongoing study found that colonies of the soft coral *Dendronephthya* spp located in the subtidal at Green Island were recorded at a maximum density of 16.2 $m^{-2}$ whereas for the reclamation site in this study, the combined density of each of the *Dendronephthya* spp is considerably less than the Green Island density at 0.043 $m^{-2}$ (see *Table 10.3f*). The highest density recorded by corals in the reclamation site was found to be the species *Euplexaura robusta* at 0.815 $m^{-2}$. A different species of *Euplexaura* (*E. robusta*) was recorded at Green Island at a density of 3.13 $m^{-2}$ (*Table 10.3f*).

**Infauna Survey:** A total of 371 specimens were obtained from the 12 grab stations at the extension site. The specimens belonged to 6 animal Phyla (*Table 10.3j*).

*Table 10.3j* ***Organisms Collected in the September 1998 Grab Sampling Survey***

| Phylum | Number of Identified Families | Total Number of Individuals Recorded | Total Biomass (g) |
|---|---|---|---|
| Annelida | 18 | 289 | 1.73 |
| Arthropoda | 7 | 21 | 3.16 |
| Echinodermata | 1 | 3 | 0.22 |
| Mollusca | 7 | 13 | 1.46 |
| Nemertinea | 0 | 16 | 0.08 |
| Sipuncula | 1 | 29 | 0.10 |
| Unidentified Fragments | - | - | 0.18 |
| **Total** | **34** | **371** | **6.93** |

Specimens from the Phyla Nemertinea were not identified to family level due to the lack of taxonomic reference material and the need for histological analyses during the identification process. Thirty-four animal families were identified, most of them belonging to the Phyla Annelida (these all being polychaete worms), Arthropoda and Mollusca.

The sediment samples contained on average 30.92 individuals station$^{-1}$ (± 16 SD), equivalent to 321 m$^{-2}$, and every station contained at least 10 individuals. The mean biomass of the samples was 0.60 g m$^{-2}$ (± 0.54 SD). Taxonomic richness, measured as number of families, varied from 6 to 17 families grab$^{-1}$ with a mean of 12.0 m$^{-2}$ (± 3.3 SD).

A breakdown of the data revealed large differences between stations in terms of numbers of individuals, biomass and taxonomic richness. In general, stations located further away from the existing power station contained a larger number of individuals and had higher taxonomic richness than stations located closer to the power station.

Three of the stations, RB8, RB10 and RB12 were different from the other stations in that the assemblages were not composed almost entirely of polychaete worms (Phylum Annelida). Sediments from station RB8 contained very high numbers (22) of peanut worms (Phylum Sipunculida) as well as four bivalve molluscs belonging to the Order Veneroida. The grab sample collected from station RB12 contained 5 crabs of which 3 were porcellanid pea crabs which live commensally in the tubes of burrowing polychaete worms. Three brittle stars from the Family Amphiuridae were recorded from sediments obtained at station RB10. Amphiurid brittle stars are unusual in that, unlike other brittle stars, they burrow into the sand by excavating a mucous lined burrow that contains a tubelike channel to the surface within which they extend their "arms" so as to filter particles suspended in the water column above.

The data collected during the Seabed Ecology Studies at South Lamma during 1997 was compared with data collected at the survey stations during September 1998 in the proposed reclamation site. Comparisons were made, using one-way analysis of variance techniques, between the two surveys for the following three parameters:

- Mean biomass per grab;
- Mean number of individuals per grab; and
- Mean taxonomic richness per grab.

The mean biomass of samples differed significantly between the three areas sampled. Samples from the South Lamma site (DDM-IN, SHAM WAN, ANCH-IN and DDM-OUT) contained significantly higher biomass of infaunal organisms than the remaining South Lamma site (ANCH-OUT) and the reclamation site (1998) which did not differ significantly (*Table 10.3j*).

Spatial differences were also detected for mean number of individuals per grab and for taxonomic richness (*Table 10.3k*). The majority of the South Lamma sites supported significantly higher number of individuals and taxonomic richness than the reclamation site.

*Table 10.3k* ***Summary Information of Statistical Analyses of Grab Sample Parameters***

| Parameter | Area | Notes |
|---|---|---|
| Biomass | ** | Mean weight of individuals per grab was significantly higher at the majority of South Lamma sites than the reclamation site. |
| Number of Individuals | ** | Mean number of individuals per grab was significantly higher at the majority of South Lamma sites than the reclamation site. |
| Taxonomic Richness | ** | Mean taxonomic richness per grab was significantly higher in the SHAM WAN and DDM-IN South Lamma sites than the reclamation site. |

** significant difference at $p < 0.01$

The data indicate that in general the sediments from the reclamation site contain lower number of infaunal organisms, lower biomass and lower diversity than sediments from South Lamma. The assemblages from the reclamation site were similar, however, to those from one of the southern Lamma sites (ANCH-OUT). This site was characterised as having many anchorage scars with sediments containing low Total Organic Carbon content and fine sediment particles.

The benthic samples collected during the September 1998 survey were analysed for sediment grain size composition and total organic carbon (TOC) content. This was conducted to determine whether there was any relationship between the structure of the infaunal benthic assemblages and sediment physical parameters. The results of the analysis indicated that the sediments with the coarsest particles and lowest TOC content were those collected from stations in the southeastern (shallow) portion of the survey area. Linear regression analyses were performed on the data and indicated that there was little relationship between the total number of individuals in grab samples and the two physical parameters measured.

The benthic sediments of the reclamation site support infaunal assemblages mainly composed of polychaetes. This is typical of the majority of sediments in Hong Kong. The biomass of infaunal organisms from the reclamation site is compared with other areas around Lamma Island and in Hong Kong waters in *Table 10.3l* below.

*Table 10.3l* ***Biomass of Benthic Assemblages from the Lamma Island Area & Elsewhere in Hong Kong***

| Study | Area/Date | Biomass g $m^{-2}$ |
|---|---|---|
| Shin & Thompson 1982 | West Lamma Channel | 20.20 |
| | Hong Kong Mean | 35.20 |
| APH Consultants 1994 | APH-13 December 1993 | 14.86 |
| | APH-13 June 1994 | 3.93 |
| | APH-15-December 1993 | 13.13 |
| | APH-15 June 1994 | 7.53 |
| AXIS Consultants 1994 | Navigation Channel September 1994 | 22.20 |
| Mouchel 1998 | S15 (W Lamma) May 1996 | 66.83 |
| | S15 October 1996 | 5.45 |
| | S15 February 1997 | 12.06 |
| | S15 May 1997 | 23.02 |
| | S15 Mean | 24.14 |
| ERM 1996-7 Seabed Ecology Studies | East Sha Chau (August) | 7.50 |
| | Basalt Island (August) | 6.10 |
| | East of Ninepins (August) | 12.80 |
| | Soko Islands (November) | 35.70 |
| | South Cheung Chau (November) | 47.20 |
| | Eastern Waters (April) | 32.90 |
| | Tathong Channel (April) | 35.70 |
| | South Lamma (April) | 30.60 |
| ERM 1998 | Power Station Reclamation Site (September) | 6.00 |

Although all of the surveys above differ in both time of sampling and the location in which the samples were taken, the values for the reclamation site are consistently low. The results indicate that in the context of other sediments around Lamma Island and elsewhere in Hong Kong those collected from the reclamation site support lower biomass of infaunal organisms.

### 10.3.3 *Ecological Importance*

According to the Technical Memorandum of the *EIAO (EIAO TM) Annex 8* the ecological value / importance of a habitat can be evaluated using the following criteria:

- Naturalness;
- Size;
- Diversity;

- Rarity;
- Re-creatability;
- Ecological Linkage;
- Potential value;
- Nursery Ground;
- Age; and
- Abundance.

The criteria listed above have been applied to the information gathered or reviewed on the marine ecology of the intertidal habitats on the west coast of Lamma Island in order to determine the ecological value. The application of these criteria has led the intertidal rocky shores to be classified as medium, whereas, the intertidal sandy shores have been classified as low (*Table 10.3m*).

*Table 10.3m* ***Ecological Value of Intertidal Habitats on the West Coast of Lamma Island***

| Criteria | Rocky Shore | Sandy Shore |
|---|---|---|
| Natural-ness | The habitat is undisturbed by human impact due to the steep rocky terrain of much of the intertidal zone. | Some of the shores are highly disturbed by human impacts through development for recreation as gazetted beaches. Other sandy shores on the west coast, although not gazetted, are popular recreational beaches and thus disturbed. |
| Size | The area is of a large size covering the majority of the intertidal zone of the west coast of Lamma Island (> 500m). | The sandy shores cover the remainder of the west coast of Lamma Island not occupied by rocky shores. |
| Diversity | Wet season results indicate that the intertidal communities appear to be typical of semi-exposed shores in Hong Kong. | Reviewed literature indicates that beaches that are frequently used for recreational purposes support low diversity assemblages. |
| Rarity | None. | None. |
| Re-creatibility | The habitat can be re-created. | The habitat can be re-created. |
| Ecological Linkage | The surrounding environment contains similar intertidal habitats. | The surrounding environment contains similar intertidal habitats. |
| Potential Value | In terms of typical undisturbed semi-exposed shores in Hong Kong the shores have conservation interest. | High levels of human disturbance signify that it is unlikely that the shores could develop conservation interest. |
| Nursery Area | None identified during the literature review or field surveys. | No nursery areas identified on the shores in proximity to the power station. |
| Age | n/a for these assemblages as the life cycle of the fauna and flora is very short. | n/a for these assemblages as the life cycle of the fauna and flora is very short. |
| Abundance | Assemblages appear to be typical of other semi-exposed shores in Hong Kong. | Reviewed literature indicates that beaches that are frequently used for recreational purposes support low abundance of intertidal organisms. |
| **SUMMARY** | The fauna of the intertidal appears to be typical of semi-exposed shores in Hong Kong. The sites appear to have suffered little human disturbance. **Ecological Value - Medium.** | Literature reviews indicate that the sandy shores on the west coast of Lamma support low diversity and depauperate assemblages typical of other recreational beaches in Hong Kong. **Ecological Value - Low.** |

Note: n/a: Not Applicable

The same assessment criteria have been applied to the hard surface subtidal habitats of the west coast of Lamma Island. The habitats have been classified as of low to high ecological value and are discussed separately(*Table 10.3n*).

*Table 10.3n* ***Ecological Value of Subtidal Hard Substrate Habitats on the West Coast of Lamma Island***

| Criteria | Yung Shue Wan - Lo So Shing (T1 - T4) | Ha Mei Tsui North (T5) | Ha Mei Tsui South (T6) |
|---|---|---|---|
| Natural-ness | There is evidence at some of the sites of indirect human impact through poor water quality (high SS levels). | The subtidal area is almost entirely in its natural state. | |
| Size (large > 500m). | The area is of a large size covering the west coast of Lamma Island. | The area is of a large size covering the southwest coast of Lamma Island. | |
| Diversity | Wet season results indicate that these sites support few soft or hard corals. | The site at Ha Mei Tsui North (T5) has a medium diversity of soft corals sea whips (gorgonians) and other organisms. | The site at Ha Mei Tsui South (T6) has a high diversity of soft corals sea whips (gorgonians) and other organisms. |
| Rarity | None. | Although the species of soft corals and gorgonians are not rare they are of conservation interest. | |
| Re-creatibility | The habitat can be re-created. | | |
| Ecological Linkage | The surrounding environment contains similar subtidal habitats. | | |
| Potential Value | It is unlikely that the site can develop conservation interest. | The site has conservation interest due to the abundance of soft corals and sea whips. | The southernmost coast (Ha Mei Tsui) has conservation interest due to the abundance of soft corals and sea whips. |
| Nursery Area | None identified during the literature review or field surveys. | | |
| Age | The subtidal fauna is generally short lived. | The subtidal fauna is generally short lived apart from the isolated colonies of hard corals which are slow growing and long lived. | |
| Abundance | Low abundances of soft corals and other marine organisms. | Abundances of soft corals and sea whips are medium for this part of Hong Kong. | Abundances of soft corals and sea whips are high for this part of Hong Kong. |
| **SUMMARY** | The subtidal fauna appears to be of low diversity and abundance with few or no soft and hard corals present. **Ecological Value - Low.** | The subtidal fauna appears to be diverse and abundant with some soft and hard corals present. **Ecological Value - Medium.** | The subtidal fauna appears to be diverse and abundant with many soft corals and sea whips present. **Ecological Value - High.** |

Note: n/a: Not Applicable

The same assessment criteria have been applied to the soft bottom habitat of the reclamation site for the power station extension. This habitat has been classified as of low ecological value (*Table 10.3o*).

*Table 10.3o* ***Ecological Value of the Soft Bottom Habitat at the Reclamation Site***

| Criteria | Soft Bottom Habitat |
|---|---|
| Naturalness | The habitat is bounded on the east and north by artificial seawalls put in place during construction of the existing power station and ash lagoon. The western edge of the habitat is a navigation channel that is dredged for maintenance periodically. This indicates that the assemblages present within the reclamation site have at some point in the passed been disturbed. |
| Size | Total area of the reclamation site and associated dredging works will involve the loss of approximately 22 hectares of seabed. |
| Diversity | *Infaunal* - Low compared to other sites around Lamma Island and in Hong Kong.<br>*Epifaunal* - Patchy diversity with most valuable areas rated as medium compared to other areas around Lamma Island. |
| Rarity | *Infaunal* - No organisms were found that are considered as rare.<br>*Epifaunal* - No organisms were found that are considered as rare, although sea whips and soft corals were present at the eastern edge of the site. |
| Re-creatibility | The habitat cannot be recreated on site. |
| Ecological Linkage | The surrounding environment contains many other areas of soft substrate. |
| Potential Value | Unlikely that the site can develop conservation interest. |
| Nursery Area | None identified in the review. |
| Age | The fauna, although less abundant, appear to be typical of those present in Hong Kong's soft benthos. The sediments in the habitat are constantly accreting and eroding and the fauna present there are typically short lived. |
| Abundance | Abundances appear to be lower than other areas around Lamma Island and elsewhere in Hong Kong. |
| **SUMMARY** | The sediments support low diversity and abundance of infaunal and epifaunal organisms that are typical to Hong Kong's benthos.<br>**Ecological Value - Low.** |

Note: n/a: Not Applicable

The same assessment criteria have been applied to the marine waters to the south of the proposed reclamation site for the power station extension. This habitat has been classified as of low and high ecological value depending largely on the use of the area by protected species of marine mammals (*Table 10.3p*).

*Table 10.3p* ***Ecological Value of the Marine Waters South of the Power Station***

| Criteria | Marine Waters Immediately South of the Power Station | Marine Waters off the SW Coast of Lamma Island |
|---|---|---|
| Naturalness | Disturbed through residential and industrial discharges. Close proximity to some of the busiest shipping lanes in Hong Kong. | Largely undisturbed. Main disturbances through navigation to the south and west, and fishing activities. |
| Rarity | The finless porpoise (*Neophocaena phocaenoides*) and the Chinese white dolphin (*Sousa chinensis*) have been recorded in these waters. | |
| Re-creatibility | The habitat cannot be recreated after it has been reclaimed. | n/a |
| Ecological Linkage | Marine mammal habitat occurs to the west and south of this area. | Marine mammal habitat occurs to the west and south of this area. |
| Potential Value | Limited value due to heavy navigational use of the area. | High potential value as a marine park/reserve due to the presence of the finless porpoise. |
| Nursery Area | No nursery areas were identified in the review of marine ecology baseline conditions. | Known calving area for the finless porpoise during spring. |
| Abundance | Marine mammals are rarely sighted within 2 km of the power station. | Available information indicates that large populations of finless porpoise gather in the area off Ha Mei Tsui (3.5 km from the power station). |
| SUMMARY | Few marine mammals have been sighted in the area which is known as important for navigational use. **Ecological Value - Low.** | The waters support a seasonal breeding population of finless porpoise. **Ecological Value - High.** |

## *10.4* *IMPACT ASSESSMENT & PREDICTION*

Impacts associated with the power station are divided into those occurring during the construction phase, and those in the operation phase.

### *10.4.1* *Construction Phase*

Impacts to marine ecological sensitive receivers arising from the construction works may be divided into those due to direct disturbances to that habitat and those due to perturbations to key water quality parameters.

*Direct Impacts*

Direct impacts to marine ecological resources include habitat loss due to the dredging and reclamation associated with the proposed power station extension. The construction of the extension will lead to the permanent loss of 22 hectares of seabed. Impacts to benthic organisms are dependent upon the location of the assemblages in relation to the reclamation site. Within the reclamation site, primary impacts will be the smothering and burial of organisms which are present there. These impacts will necessarily occur during dredging and sandfilling operations associated with the reclamation works. It is important,

therefore, to determine whether the reclamation site contains unique or otherwise noteworthy benthic assemblages which will be lost.

As stated above in *Section 10.3.2*, comparison of the assemblages within the reclamation site and other assemblages around Lamma Island and elsewhere in Hong Kong suggested that the benthic fauna within the reclamation site comprised a similar species composition, lower species diversity and lower density of individuals. Although the surveys identified sparsely distributed colonies of gorgonians and soft corals of ecological interest no rare or environmentally sensitive species were recorded within the reclamation site. The surveys indicated that the soft corals and gorgonians were present within an area of 0.03 $km^2$ at the southeastern edge of the area to be dredged for the reclamation, and also, within an area of 0.03 $km^2$ outside of the reclamation area to the south of the ash lagoon seawall. The latter area of soft corals will not suffer direct disturbance as a result of construction of the power station extension. *Section 10.3* has illustrated that the density of soft corals and gorgonians is lower than other sites in Hong Kong of known conservation value.

*Indirect Impacts*

Indirect impacts to marine ecological resources during the construction phase include sediment release associated with the above construction projects. Potential impacts to water quality from sediment release are listed below:

- increased concentrations of suspended solids (SS);
- a resulting decrease in DO concentrations; and,
- an increase in nutrient concentrations in the water column.

Suspended Solids (SS)

**Subtidal Hard Surface Habitats:** Soft corals, gorgonians, hard corals and anemones may be injured by both high suspended sediment concentrations and high deposition rates. Damage (sublethal effects) or mortality (lethal effects) occurs as reduction in light penetration kills the photosynthesizing symbiotic algae associated with the hard corals, and also as the deposition of sediment onto the corals surface physically blocks the respiratory and feeding apparatus. An assessment of the effects of backfilling in Mirs Bay[21] assumed that prolonged turbidity and a sustained sedimentation rate of 20 mg $cm^{-2}$ $day^{-1}$ (= 0.2 kg $m^{-2}$ $day^{-1}$) was damaging to corals. Impacts to corals are unlikely to occur as only small areas were predicted to be affected by sediment deposition. Levels of deposited sediment are predicted (under the maximum allowable dredging rate discussed in *Part B - Section 5*) to be 0.0003 kg $m^{-2}$ $day^{-1}$ throughout the northern part of Ha Mei Wan. Further south of the reclamation (ie at T5 and T6 where medium and high ecological value assemblages have been identified) (> 2km) sediment deposition is lower at less than 0.0001 kg $m^{-2}$ $day^{-1}$. These deposition levels are not predicted to cause unacceptable impacts to the assemblages at T5 and T6. Sediment will be deposited at a rate of < 0.0007 kg $m^{-2}$ $day^{-1}$ on to the low density assemblages of soft corals and gorgonians identified to the south of the ash lagoon seawall. These deposition levels are not predicted to cause unacceptable impacts to these soft coral and gorgonian assemblages.

Negative impacts to corals may also arise from increased SS in the water column. A threshold value is, however, unavailable for corals specific to Hong Kong

[21] Binnie Consultant Ltd (1992) South Mirs Bay Borrow Area. IAR

waters. The only habitat surveyed where corals were recorded in sufficiently high abundances to warrant classification as high ecological value (and thus a marine ecological sensitive receiver) was site T6. This site was represented in the water quality modelling as sensitive receiver location *South Lamma Marine Park* 2. Elevations of SS at this location were predicted to be 2.6 mg $L^{-1}$ above ambient (bed layer ambient = 21 mg $L^{-1}$ derived from the 90th percentile of EPD routine water quality monitoring data at station SM5) based on the maximum allowable dredging rate. An elevation of this magnitude is small and the total SS level of 23.6 mg $L^{-1}$ is within the WQO for this part of the southern water control zone. It is thus expected that unacceptable impacts to corals arising from elevated SS levels will not occur.

High SS elevations of 32 mg $L^{-1}$ are predicted to occur during dredging operations in the vicinity of the power station and will affect the soft coral and gorgonian assemblages close to the ash lagoon seawalls. Due to the lack of information on tolerance thresholds of species in Hong Kong it is not possible to determine the severity of this impact on the soft corals and gorgonians. For the purposes of this Study the worst case scenario (that all of the soft corals and gorgonians will be lost) is assumed. However, due to the low ecological value of the assemblages and the high probability that they will recolonise after construction works have ceased, this impact is not considered to be unacceptable.

**Subtidal Soft Benthos:** Sessile organisms within the benthos will be susceptible to the effects of increased sediment loads. Effects can be lethal or sublethal (eg reduction in reproductive potential due to stress incurred by constantly having to flush out the depositing material). The effects of sedimentation on organisms will also depend on other factors, such as an organism's tolerance, growth orientation of sessile organisms and water movement.

Impacts to benthic assemblages outside of the reclamation site are unlikely to occur as only small areas were predicted to be affected by sediment deposition. Levels of deposited sediment are predicted (under the maximum allowable dredging rate with silt curtains discussed in *Part B - Section 5*) to be less than 0.0003 kg $m^{-2}$ $day^{-1}$ throughout the northern part of Ha Mei Wan. Further south of the reclamation (> 2km) sediment deposition is lower at 0.0001 kg $m^{-2}$ $day^{-1}$. These predicted deposition levels are not likely to impact the natural benthic assemblages as this area is often disturbed by demersal trawling and storms, and the organisms present are thus assumed to be adapted to seabed disturbances. The modelling scenarios indicate that impacts outside the reclamation area are predicted to be minimal and confined to small areas. Based on the assumption that eventually these affected areas will be recolonised by fauna typical of the area, then the temporary loss of this low ecological value assemblage is deemed acceptable.

**Intertidal Habitats:** Intertidal habitats within the study area which may be affected by the reclamation activities include two gazetted beaches located at Lo So Shing and Hung Shing Ye, and rocky shores along the west coast of Lamma Island. Sediment transport modelling results predict that SS concentrations will exceed the water quality objectives at both of the gazetted beaches. However, these exceedances have led to the requirement that silt curtains are deployed on the eastern and southern sides of the reclamation area during dredging operations.

However, the model predictions will be verified in the field during construction using the monitoring and audit programme (M&A). Should the M&A show

unacceptable impacts (with reference to exceedances of the WQO) then mitigation measures in the form of further reduction in dredging rates will be employed. Based on these conditions impacts to the low ecological value assemblages present at these beaches are not predicted to be unacceptable.

Higher than normal sediment loads arising from nearby dredging works were deposited on an assemblage of coralline algae at Cape d'Aguilar to the south of Hong Kong. This resulted in overgrowth of the coralline assemblage by the red turf alga, *Gelidium pusillum*, which became the most abundant species[22]. Scouring, due to very high SS levels (eg > 100 mg $L^{-1}$) may inhibit the survival of algae, thereby reducing the food supply to the numerous rocky shore herbivores and causing intolerant or less competitive species to become locally extinct.

The modelling results indicate that elevated SS levels and minor exceedances of the WQO will occur at rocky coastal areas near to the two gazetted beaches. However, these exceedances have led to the requirement that silt curtains are deployed on the eastern and southern sides of the reclamation area during dredging operations. However, the model predictions will be verified in the field during construction using the monitoring and audit programme (M&A). Should the M&A show unacceptable impacts (with reference to exceedances of the WQO) then mitigation measures in the form of further reduction in dredging rates will be employed. It is thus expected that unacceptable impacts to these medium ecological value intertidal assemblages arising from elevated SS levels will not occur.

**Marine Mammals:** Mobile animals such as marine mammals have the ability to avoid areas where SS levels have increase, thus avoiding any impacts. Impacts can occur to these mammals as an indirect result of increased SS levels. The construction of the power station extension may cause perturbations to water quality which have the potential to impact the fisheries resources of the southwest Lamma area. *Neophocaena phocaenoides* is thought to be an opportunistic feeder with known prey including crustaceans (shrimps and prawns), cephalopods (squids and octopus) and small pelagic fish of low commercial value (anchovies - Engraulidae, croakers - Sciaenidae, sardines - Clupeidae). They are thus likely to be affected by changes in key water quality parameters (such as SS and DO) arising from the development. A deterioration in water quality is likely to cause these mobile fish to move out of the area thus interfering with the porpoises normal feeding patterns. As mentioned above for corals, the elevations of SS in areas where finless porpoises are frequently sighted (ie S Lamma Marine Park 1 - 4 in *Part B Section 5 - Figure 5.4g*) are small and within environmentally acceptable levels (as defined by the water quality objectives for the southern water control zone). It is thus expected that unacceptable impacts to the high ecological value finless porpoise habitat off the SW coast of Lamma Island arising from elevated SS levels will not occur.

Dissolved Oxygen

The relationships between SS and DO are complex, with increased SS in the water column combining with a number of other effects to reduce DO concentrations in the water column. Elevated SS (and turbidity) reduces light penetration, lowers the rate of photosynthesis by phytoplankton (primary productivity) and thus lowers the rate of oxygen production in the water

[22] Kaehler S & Williams GA (1996) Distribution of algae on tropical rocky shores: spatial and temporal patterns of non-coralline encrusting algae in Hong Kong. Marine Biology 125: 177-187

column. There have been no published studies in Hong Kong on the DO requirements of local marine species, therefore it is not possible to set critical thresholds for this parameter. Depletions of DO as a result of construction activities for the power station extension are very small (< 0.5 mg $L^{-1}$) and compliant with the WQO. It is evident that the small depletion in DO is within environmentally acceptable levels (as defined by the WQO of 4 mg $L^{-1}$). It is thus expected that unacceptable impacts to the marine ecological habitats and populations present in the vicinity of the power station extension arising from very small depletions in DO levels will not occur.

Nutrients

High levels of nutrients in seawater can cause rapid increases in phytoplankton often to the point where an algal bloom occurs. An intense bloom of algae can lead to sharp decreases in the levels of dissolved oxygen in the water as dead algae fall through the water column and decompose on the bottom. Anoxic conditions may result if DO concentrations are already low or are not replenished. This may result in mortality to marine organisms due to oxygen deprivation. Increases in nutrient concentration ( $NH_4$) as a result of construction activities for the power station extension are predicted to be very small (< 0.005 mg $L^{-1}$) and compliant with the WQO. It is thus expected that unacceptable impacts to the marine ecological habitats and populations present in the vicinity of the power station extension arising from very small elevations in nutrient levels will not occur.

High & Low Frequency Noise

Cetaceans are animals that rely heavily on acoustic information to communicate and to explore their environment. Therefore, any noise that disrupts communication or echolocation channels would be potentially harmful. In general, low frequency noise would be of little consequence to the finless porpoises, which are relatively insensitive to sounds within and below our hearing range (ie, less than about 20 kHz). If there is a high frequency noise component (especially in the range of 100 - 140 kHz) to the construction activities, this would be a serious concern. Dredging and large vessel traffic generally results in mostly low frequency noise and, therefore, would not likely cause problems. Percussive piling work will be involved in the construction process but only on reclaimed land and will not be used to construct the sea walls. The presence of mud and reclamation fill material will act to dampen noise from percussive piling and prevent any disturbances to the marine environment.

Vessel Traffic

A moderate increase in the number of large, slow-moving (less than 10 knots) vessel traffic in the area should not cause a significant impact to dolphins or porpoises. Smaller, faster outboard-driven boats would be more of a concern, because of the fast approach speeds and higher potential for high frequency noise. However, it is not anticipated that vessels associated with construction and operations of the power stations will be of the latter type. As a measure of precaution it is recommended that all vessels approaching the power station and the extension do so via the East Lamma Channel or from the north. In this way critical habitats to the finless porpoise, such as the southwest coast of Lamma, will be avoided by vessels involved in the construction or operation of the power station.

Impacts to the South Lamma Potential Marine Park / Marine Reserve

AFD are at present conducting a feasibility study examining the potential for the south Lamma area to be designated as a marine park or marine reserve. Although a boundary for the marine park has yet to be proposed it is likely that it will encompass the coastal habitats running south and east from Ha Mei Tsui headland on the southwest of Lamma Island to Tung O Wan on the east. This area would likely include the green turtle nesting area on the sandy shore at Sham Wan and the finless porpoise habitat off Ha Mei Tsui. Although not in proximity to the power station extension the impacts to the marine park/reserve have been assessed. Dispersed plumes of suspended sediment reach the likely area for the marine park/reserve but as discussed above for marine mammals and corals the elevations are within environmentally acceptable levels (defined under the WQO and the assessment criterion discussed in *Part B - Section 5*). Sediment plumes are not predicted to reach the southern Lamma coast and will, therefore, not impact Sham Wan. As discussed above nutrient elevations and DO depletions are very small and are not predicted to affect the potential marine park/reserve.

### 10.4.2 *Operation Phase*

*Cooling Water - Temperature*

The existing power station uses seawater in the cooling system resulting in the discharge of large volumes of heated water. The heated waters are rapidly dispersed by surface mixing and tidal currents resulting in a body of offshore water with a surface elevated temperature of 2°C. The *Water Quality Section* of this report (*Part B - Section 5*) discusses this issue in more detail and presents plots illustrating the dispersion of plumes of cooling water from the existing power station.

Cooling water will be discharged during operation of the proposed power station extension. The cooling waters are expected to be discharged along with the waters discharged from the existing power station. The effects of water being discharged into the surrounding sea water at a higher temperature than ambient levels can have a marked impact on the surrounding marine ecology.

Firstly, high increases in the temperature of the water may result in a reduction of plankton in water directly surrounding the outlet which in turn results in a reduction of primary productivity and subsequently oxygen production decreases. Secondly, elevated temperatures, remote from the outfall, can lead to algal blooms, resulting in an oxygen depletion in the water column due to eventual decomposition of the algae on the seabed, as discussed above. Information presented in *Section 11* of this EIA (*Fisheries Impact Assessment*) indicates that Harmful Algal Blooms are unlikely to occur solely as a result of discharges from the power station.

However, the results of the thermal plume modelling for the power station show that the cooling water effluent is not predicted to raise the temperature of the water column to any levels other than those that are already present from the existing power station (*Figure 10.4a*). An examination of the predicted future discharges indicates that some areas will experience reductions in temperature elevated water (eg Hung Shing Ye and Lo So Shing beaches). Temperature

elevations are most likely to affect the low value ecological assemblages in the vicinity of the power station. High ecological value habitats (such as the corals and finless porpoises of Ha Mei Tsui, and the south Lamma potential marine park/reserve) to the far south of the power station are largely unaffected by the discharges from the power station extension as conditions remain the same as existing. A statistical analysis (ANOVA - *Section 10.3.2*) comparing intertidal assemblages on shores that experience elevated temperatures as a result of the existing discharges exhibited no significant differences that indicate adverse impacts on affected shores. Heated discharges did not appear to affect the recruitment of intertidal organisms as a normal recruitment pattern was observed (*Section 10.3.2*).

In view of the relatively small changes in the quantity of cooling water predicted to be discharged into the water column, and the resulting temperature increases, it is expected that the environmental impact of this cooling water to the marine ecology in the area will be minimal. Temperature elevations are not thought to impact marine mammal populations as aggregations of the Chinese white dolphin are frequently observed around the discharge point for cooling waters from the Castle Peak Power Station[23].

*Cooling Water - Entrainment & Impingement*

Mortalities of marine organisms can occur during the operation of power station through entrainment (organisms being drawn into the cooling system along with the cooling water) and impingement (organisms being trapped on screens that are employed to prevent large objects from entering the cooling water system)[24]. These types of impacts are mostly associated with fisheries resources and plankton which are discussed in full in the *Fisheries Impact Assessment* of this EIA report.

*Cooling Water - Biocides*

There are considerable operational and ecological problems caused by organisms within, and passing through power station water systems. Operationally these problems can be costly[25]. Mussels, oysters and other marine organisms growing within cooling water circuits have resulted in losses in thermal efficiency and even total shutdowns. To counteract settling and actively growing fouling organisms, cooling water circuits are usually dosed with biocides (usually chlorine) in large amounts. This causes mortalities of both the fouling and non-fouling organisms in the circuit. The discharge of the resulting chlorinated effluents together with dead organisms may in turn have effects on the habitat beyond the outfalls. There is by necessity a close relationship between operationally necessary antifouling procedures within systems and the wider ecological consequences of the discharge.

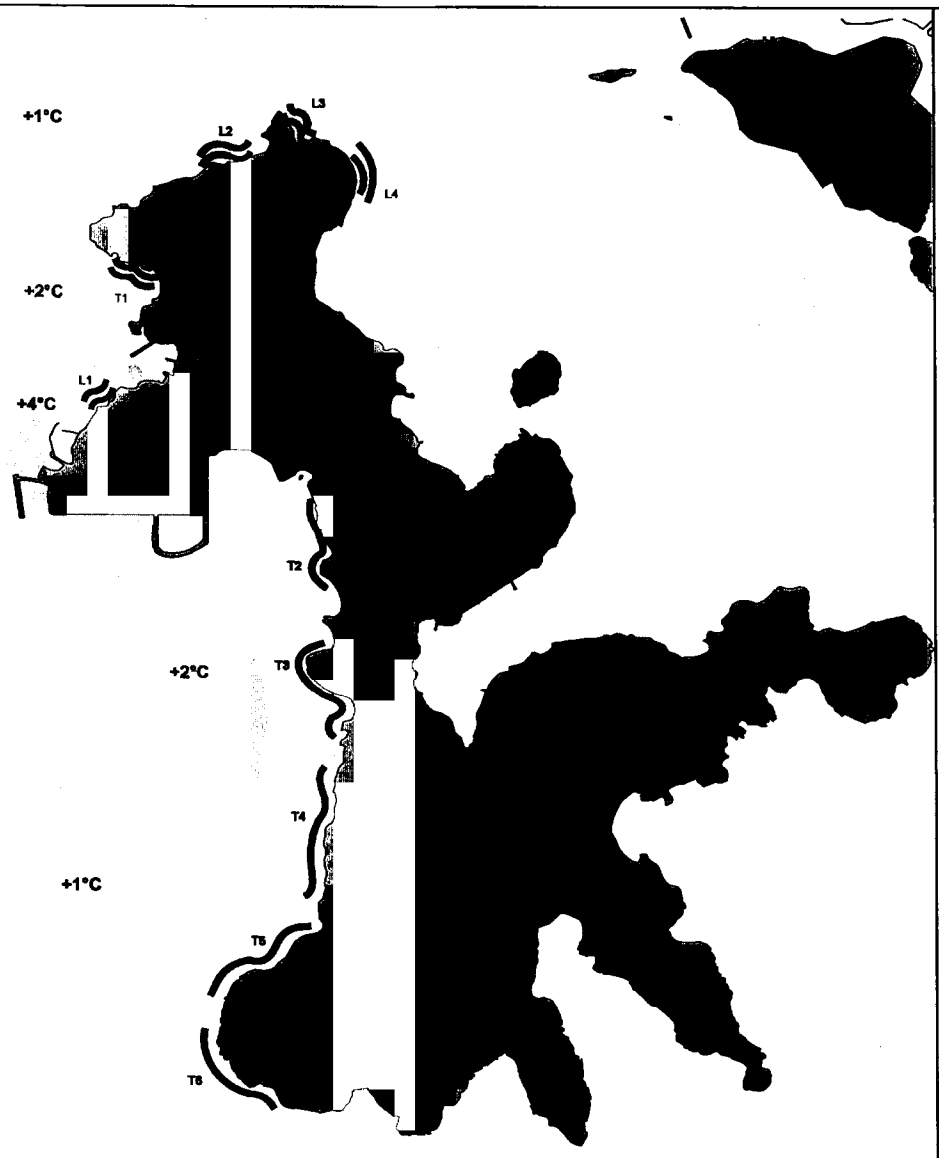
The power station extension is predicted to discharge total residual free chlorine continuously at an initial concentration of 0.3 $mgL^{-1}$ to the sea. This concentration is the same as the existing power station and is below EPD's[26] set licence condition for discharge of 0.5 $mgL^{-1}$. Specific values for observed toxic

(23) ERL (Asia) Limited (1991) EIA of the Proposed 6000MW Thermal Power Station at Black Point. Draft Initial Assessment Report. Volume 3 : Operational Phase. For the China Light and Power Company Limited.

(24) Ambrose RF *et al* (1996) Predicted and Observed Impacts: can we foretell ecological change? In - Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats. Edited by RJ Schmitt and CW Osenberg Pages 345 - 369. Academic Press Inc.

(25) Langford TE (1983) Electricity generation and the ecology of natural waters. Liverpool University Press.

(26) Technical Memorandum for Effluents, Section 21 Water Pollution Control Ordinance, Cap 358.




EXISTING CONDITIONS
(SPRING TIDE WET SEASON)

KEY
SURVEY TRANSECT
NOT TO SCALE


FUTURE CONDITIONS WITH EXTENSION
(SPRING TIDE WET SEASON)

KEY
SURVEY TRANSECT
NOT TO SCALE

FIGURE 10.4a

DISPERSION OF COOLING WATER FROM THE EXISTING POWER STATION & FROM THE POWER STATION EXTENSION (SURFACE LAYER)

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Table 10.4a - Toxic Responses of Marine Organisms to Residual Free Chlorine in Discharges
*[Information gathered from references contained in Langford (1983) Electricity Generation and the Ecology of Natural Waters]. * - species present in Hong Kong.*

| Organism | Toxic Responses | Cl ($mg\ L^{-1}$) |
|---|---|---|
| Phytoplankton | Photosynthesis of marine phytoplankton depressed by 70 - 80 %. | 0.02 - 0.04 |
| Zooplankton | Short term exposure has led to rapid but temporary responses demonstrated through depression in metabolic rate and reproductive activity. | 0.01 |
| Oyster Larvae (*Ostrea edulis*) | Tolerant of short term exposure with no demonstrated toxic response. | 0.2 - 0.5 |
| Barnacle Larvae (*Elminius modestus*) | Tolerant of short term exposure with no demonstrated toxic response. | 0.2 - 0.5 |
| Lobster Larvae (*Homarus americanus*) | Respiration rate increased after 60 minute exposure to 0.1 $mg\ L^{-1}$ and after 30 minute exposure to 1.0 $mg\ L^{-1}$. | 0.01<br>0.1 |

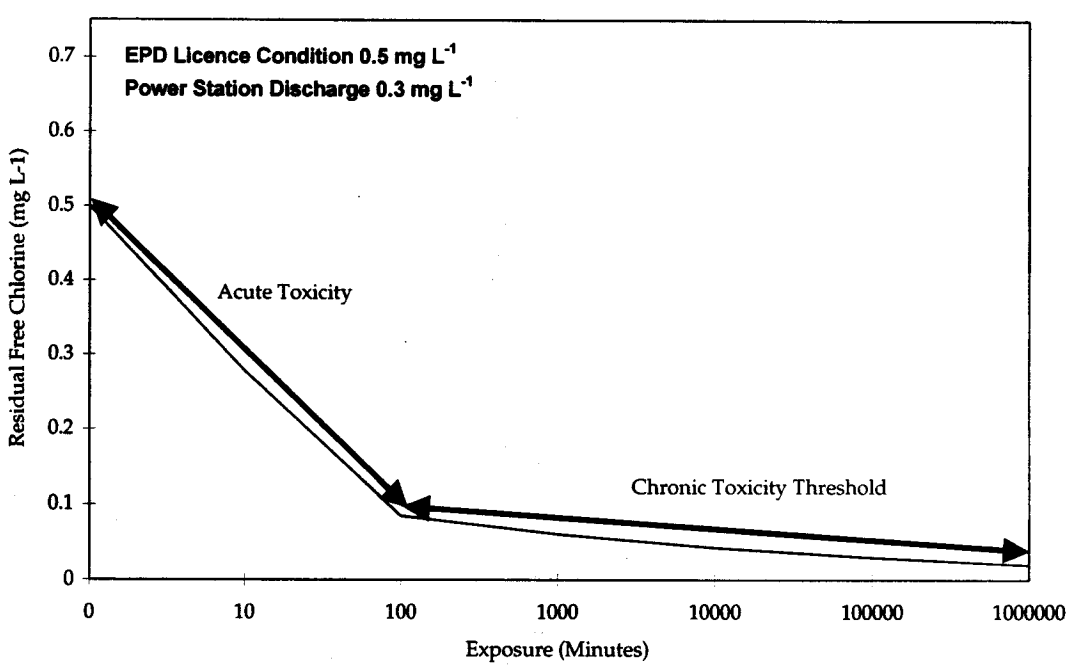


Figure 10.4b: Acute and chronic toxicity thresholds for marine organisms exposed to chlorine.
*[Redrawn after Mattice and Zittel (1976) Site Specific Evaluation of Power Plant Chlorination, Journal of Water Pollution Control. 48(10) 2284-2308]*

effects of chlorine are not available for organisms under conditions typical to Hong Kong. However, values are available from the literature which can be used for reference purposes (*Table 10.4a*). It should be noted that none of the organisms listed in the table are of marine conservation interest locally. For the majority of organisms the toxicity of residual free chlorine depends on the concentration and exposure time. Short exposure to high concentrations often leads to lethal effects as does long term exposure to low concentrations (*Figure 10.4b*).

Although toxic effects of chlorine are increased synergistically[27] by the increases in temperature associated with cooling waters, the concentrations of residual chlorine diminish rapidly with time and distance from the discharge point as a result of dilution in the water column and decay[28]. The modelling results indicate that the largest area covered by a concentration of 0.01 $mgL^{-1}$ (the lower value on *Table 10.4a*) extends approximately 700m offshore indicating a very localised impact which does not impinge on any of the water quality or marine ecology sensitive receivers (minimum distance from any marine ecology sensitive receiver > 2km). Full details are presented in *Part B - Section 5*.

## 10.5 IMPACT EVALUATION SUMMARY

### 10.5.1 *Marine Ecology Sensitive Receivers*

Information presented in the review of literature and in the results of the comprehensive field surveys has indicated that the Study Area (defined in *Figure 11.3a* of *Part B Section 11*) contains the following marine ecology sensitive receivers:

- high ecological value subtidal habitat at Ha Mei Tsui (SW Lamma);
- finless porpoise habitat in the coastal waters off southwest Lamma (as defined by the main area where the finless porpoise population has been observed); and
- the potential south Lamma marine park or reserve.

The list of marine ecological sensitive receivers includes only habitats/populations of high ecological value. It is considered crucial to the environmental acceptability of the project that construction and operational activities of the proposed power station extension do not impact these sensitive receivers. The following section discusses and evaluates the impacts to marine ecological habitats, specifically focussing on the aforementioned sensitive receivers.

### 10.5.2 *Impacts Summary*

From the information presented above the marine ecological impact associated with the construction and operation of the power station extension is considered to be low. An evaluation of the impact in accordance with the *EIAO TM Annex 8*

[27] Cairns J *et al* (1978) Effects of temperature on aquatic organisms sensitivity to selected chemicals. Virginia Water Resources Research Centre Bulletin 106 Virginia, USA.

[28] Mattice JS & Zittel HE (1976) Site specific evaluation of power plant chlorination. Journal of Water Pollution Control. 48 (10): 2284 - 2308.

Table 1 is presented as follows:

- *Habitat Quality*: No impacts are predicted to the medium value intertidal habitats identified from the field surveys (T1 - T6). Subtidal assemblages of high ecological value (T6) are also not predicted to be impacted by either the construction or operation of the power station extension. Although the soft bottom habitat within the area to be reclaimed will be permanently lost, this habitat is of low ecological value. Critical habitats utilised by the finless porpoise (eg coastal waters of southwest Lamma) are not predicted to be affected by either construction (dispersion of sediment plumes, vessel traffic, construction underwater noise) or operation (dispersion of cooling water and biocides, and vessel traffic) of the power station extension. The potential south Lamma marine park / marine reserve is not predicted to be impacted by either the construction or operation of the power station extension.

- *Species:* The only organisms of ecological interest recorded on hard bottom habitats in the vicinity of the power station extension are corals (hard and soft) on the west shore, particularly the southwest of Lamma Island which are not predicted to be impacted. These corals were recorded in much lower densities than colonies at sites that are recognised as important to corals (refer to discussion in *Section 10.3.2*). The finless porpoise is often seen to the far south of the reclamation where it is thought to breed. Neither impacts from the construction of the power station extension or its operations are predicted to cause unacceptable impacts to the preferred habitat and population of the finless porpoise.

- *Size:* The low ecological value benthic assemblages within the 22 ha dredging and reclamation area will be directly lost. Areas outside the dredging area will experience short term impacts as a result of small amounts of sediment deposition.

- *Duration:* Increases in SS levels in the vicinity of sensitive receivers are expected to be low and temporary, and due to constraints on dredging operations, within environmentally acceptable limits. Impacts to benthic assemblages within the reclamation site will be permanent. Discharges of residual free chlorine and heated water are not predicted to exceed the levels and duration of the discharges produced by the existing power station.

- *Reversibility:* Impacts to benthic assemblages within the reclamation site are irreversible.

- *Magnitude:* The impacts to the ecologically sensitive habitats defined in this review will be of low magnitude during both construction and operation of the power station extension.

## 10.6 SUMMARY OF MITIGATION MEASURES

In accordance with the guidelines in the TM on marine ecology impact assessment the general policy for mitigating impacts to marine ecological resources, in order of priority, are:

Avoidance: Potential impacts should be avoided to the maximum extent practicable by adopting suitable alternatives.

Minimisation: Unavoidable impacts should be minimised by taking appropriate and practicable measures such as constraints on intensity of works operations (eg dredging rates) or timing of works operations.

Compensation: The loss of important species and habitats may be provided for elsewhere as compensation. Enhancement and other conservation measures should always be considered whenever possible.

### 10.6.1 *Marine Ecological Resources: General*

Operational constraints during construction of the power station extension have been recommended in order to avoid impacts to marine ecological resources by minimising impacts to water quality. This has been achieved through the following:

- establishing a maximum allowable dredging rate for the power station extension (3 large grab dredgers with a maximum rate of 300,000 $m^3$ $month^{-1}$ and one small grab dredger at 200,000 $m^3$ $month^{-1}$ operating continuously);
- conducting all dredging operations behind silt curtains deployed on the southern and eastern sides of the reclamation area;
- conducting sand filling for the power station extension behind completed sea walls; and
- for scenario 2, reducing the number of large grab dredgers by one during flood tide.

Should adverse impacts to water quality be detected during the construction activities then the appropriate mitigation measures will be introduced (ie a reduction of the allowable dredging rate). These constraints, recommended to control water quality impacts to within acceptable levels, are also expected to control impacts to marine ecological resources.

In order to assist in post-construction rehabilitation of the area of the power station extension it is recommended that a seawall design such as the rubble mound at Chek Lap Kok is used. The proposed seawall layout plan indicates that rubble mound seawalls will be used on the southern and western faces of the proposed extension. It is has been demonstrated that marine organisms have recolonised such seawalls after construction[29]. It is anticipated that assemblages of soft corals and gorgonians will settle on and recolonise the newly constructed seawalls, as environmental conditions (water temperature and residual free chlorine levels) of that area would be similar to existing conditions that have allowed the growth of the soft corals and gorgonians recorded in the field surveys of this study. The potential habitat provided by the total surface area of the rubble mound seawalls on the western and southern end of the extension (greater than 31,000 $m^2$) is expected to effectively mitigate for the loss of low density assemblages of gorgonians and soft corals within the reclamation site (approximately 30,000 $m^2$).

[29] Binnie Consultants Ltd (1997) Chek Lap Kok Qualitative Survey Final Report. For the Geotechnical Engineering Office, Civil Engineering Department, December 1997.

### 10.6.2 *Marine Ecological Resources: Marine Mammals*

Measures to mitigate the impact of the construction and operation of the power station extension have been developed in consultation with Dr Tom Jefferson of the Ocean Park Conservation Foundation.

*Noise*

Noise impacts to marine mammals from construction works or operational activities are not predicted and, therefore, no mitigation measures are required.

*Vessel Traffic*

It seems unlikely that construction will require much in the way of small, outboard motor boats. Large, slower moving vessels would more likely be required. The most important mitigation measure would be to avoid using vessel lanes off Ha Mei Tsui (an important porpoise habitat area), and the imposition of a 10 knot speed limit for all vessel traffic involved in construction activities off the west coast of Lamma.

There should be a strictly enforced and well publicized policy of no dumping of construction waste or chemicals in the water. HEC have undertaken to insist that all vessels approach the extension site from the north and via the East Lamma Channel thereby avoiding southern waters where the porpoises are abundant.

Impacts to marine ecological resources during operation of the power station extension are predicted to be within environmentally acceptable levels in ecologically important areas. Hence no marine ecology specific mitigation measures are required during operation of the power station extension.

## 10.7 *RESIDUAL IMPACT*

Taking into consideration the ecological value of the habitats discussed in the previous sections and the resultant mitigation requirements the residual impact can be determined. The residual impacts occurring as a result of construction and operation of the power station extension are:

- The loss of the subtidal assemblages present within the reclamation site; and
- The potential loss, through elevations of suspended solids in the vicinity of the construction works, of 30,000 $m^2$ of soft corals and gorgonians located outside of the reclamation site adjacent to the ash lagoon seawall.

The loss of the subtidal assemblages within the reclamation site can be partially mitigated through the provision of rubble mound seawalls on which soft corals and gorgonians assemblages (lost during the reclamation) can colonise and grow. The residual impact is considered to be acceptable as the habitat is of low ecological value and because soft corals and gorgonians are expected to colonise the extension seawalls after construction. The potential habitat provided by the total surface area of the rubble mound seawalls on the western and southern end of the extension(> 31,000 $m^2$) is expected to effectively mitigate for the loss of low density assemblages of gorgonians and soft corals within the reclamation site (approximately 30,000 $m^2$).

High SS elevations of 32 mg $L^{-1}$ are predicted to occur during dredging operations in the vicinity of the power station and will affect the soft coral and gorgonian assemblages close to the ash lagoon seawalls. Due to the lack of information on tolerance thresholds of species in Hong Kong it is not possible to determine the severity of this impact on the soft corals and gorgonians. For the purposes of this Study the worst case scenario (that all of the soft corals and gorgonians will be lost) is assumed. However, due to the low ecological value of the assemblages and the high probability that they will recolonise after construction works have ceased, this residual impact is not considered to be unacceptable.

As an additional habitat enhancement measure HEC have undertaken to deploy a minimum of $400m^{3(30)}$ of Artificial Reefs (AR) in Hong Kong waters at a site (or sites) to be decided upon consultation with the Director of Agriculture and Fisheries. There is the potential that more than 400 $m^3$ of ARs will be deployed, the exact amount will be decided on the basis of the severity of impacts and extent of recolonisation of soft corals and gorgonians onto the rubble mound and ash lagoon seawalls. At present the Agriculture and Fisheries Department (AFD) is conducting a programme to enhance existing marine habitats and fisheries resources through the siting, construction and deployment of ARs. ARs act as fish aggregation devices and provide hard bottom, high profile habitat in areas without natural cover. Colonisation of ARs occurs through settlement of the spores and larvae of algae, corals and other benthic organisms. The AR subsequently will provide food, shelter and a nursery ground for commercial fish and, over the long term enhance fishery stocks.

## 10.8 *EM&A REQUIREMENTS*

### 10.8.1 *Construction EM&A Requirements*

The dredging operations include constraints which act as appropriate mitigation measures to control environmental impacts to within acceptable levels. Actual impacts of construction activities will be monitored through impacts to water quality. Monitoring and audit activities designed to detect and mitigate any unacceptable impacts to water quality will serve to protect against unacceptable impacts to marine ecological resources. The water quality monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the project.

According to the EIAO TM Section 8.3 an EM&A programme would be required in a situation where:

"the project involves mitigation measures of which the effectiveness may require a long period to establish"

and/or, according to Annex 20, Section 8 if there are any uncertainties regarding the scale of impacts. Both of these sections of the TM are applicable in this situation as the effectiveness of providing rubble mound seawalls for the recolonisation of soft corals and gorgonians will take time to evaluate, and also because the severity of the impact of elevated SS levels on the soft corals and

(30) Information from the AFD's *Artificial Reef Deployment Study* has reported that Japanese researchers have claimed that for ARs to be effective in enhancing marine resources they should have a minimum volume of 400 $m^3$. The Study also determined that the stocking density of ARs should be no less than 1,500 $m^3$ $km^{-2}$. ERM (1998) *Artificial Reef Deployment Study*: Draft Final Report - 7 August 1998 to AFD.

gorgonians adjacent to the reclamation site is uncertain (though assumed to be the worst case).

In response to this it is recommended that an Ecological M&A programme be conducted to determine both the severity of the impact to soft corals and gorgonians and to monitor the process of recolonisation of the area once the construction works have been completed. The following text presents the preliminary Objectives, Methodology and Rationale for the ecological monitoring. Before monitoring can begin details of the monitoring programme should be agreed with AFD and EPD.

*Ecological Monitoring Objectives*

The objectives of the ecological monitoring programme are as follows:

- to determine the severity of impacts arising from construction activities on soft corals and gorgonians located adjacent to the proposed extension site;
- to determine the rate and effectiveness of colonisation of the rubble mound seawall by soft coral and gorgonian assemblages; and
- to determine the rate and effectiveness of recolonisation of existing habitats indirectly impacted during construction by soft coral and gorgonian assemblages.

*Ecological Monitoring Methodology & Rationale*

Ecological monitoring will consist of subtidal surveys during the dredging and reclamation works for the power station extension and for a period after reclamation works have ceased. Specific requirements of the ecological monitoring programme are presented below:

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| Baseline Data: | Subtidal surveys using a remotely operated vehicle (ROV) have been conducted as part of this EIA compiling an extensive database on the abundance and diversity of the soft coral and gorgonian assemblages in the vicinity of the power station. However in order to update this baseline a survey following the exact methodology presented in this EIA will be conducted 3 months before construction works begin. A Baseline Survey Report will be produced and submitted to EPD and AFD. This data will serve the purpose of a baseline with which the severity of impacts and rate of colonisation can be gauged. |
| Location: | Once the extension has been constructed the ROV should be used to survey the southern and western rubble mound seawalls as well as the sites surveyed in the baseline survey adjacent to the reclamation site. |
| Monitoring Frequency: | Once the seawalls are constructed the frequency of monitoring should be at six monthly intervals for a period of two years. This monitoring will be used to assess the extent of recolonisation of soft corals and gorgonians adjacent to the reclamation site, and the extent of colonisation of the extension rubble mound seawalls by soft corals and gorgonians. |

Results of these surveys are to be reported to EPD and AFD and will form the basis for deciding the quantity of artificial reefs that HEC have established a commitment to deploy (above and beyond a minimum deployment of 400 $m^3$).

### 10.8.2 *Operation EM&A Requirements*

Impacts of operational activities will be monitored through on-site monitoring of water quality parameters (including residual chlorine or alternative biocide and temperature) of the discharged cooling waters. Monitoring and audit activities designed to detect and mitigate any unacceptable impacts to water quality will serve to protect against unacceptable impacts to marine ecological resources.

The discharge monitoring programme will provide management actions and supplemental mitigation measures to be employed should impacts arise, thereby ensuring the environmental acceptability of the project. As no unacceptable impacts to marine ecological resources are predicted to occur, the development and implementation of a monitoring and audit programme specifically designed to assess the effects of operational activities on marine ecological resources is not deemed necessary.

## 10.9 *Summary and Conclusions*

Literature reviews of existing information coupled with extensive field surveys of marine ecological resources have been undertaken for this impact assessment. Information in baseline conditions indicate that intertidal and subtidal hard surface habitats range from low to high ecological value depending on their location. Soft bottom habitats identified in the review were regarded as of low ecological value. High ecological value marine ecological sensitive receivers were identified as:

- high ecological value subtidal habitat at Ha Mei Tsui (SW Lamma);
- finless porpoise habitat in the coastal waters off southwest Lamma (as defined by the main area where the finless porpoise population has been observed); and
- the potential south Lamma marine park or marine reserve.

Potential impacts to marine ecological resources and sensitive receivers during the construction phase of the project may arise from direct disturbances to habitats, or through changes to key water quality parameters, as a result of the reclamation for the Lamma Power Station Extension. No impacts are predicted to the medium value intertidal habitats identified from the field surveys (T1 - T6). Subtidal assemblages of high ecological value (T6) are also not predicted to be impacted by either the construction or operation of the power station extension (including discharges of heated water and residual free chlorine). Although the soft bottom habitat within the area to be reclaimed will be permanently lost, this habitat is of low ecological value. Critical habitats utilised by the finless porpoise (eg coastal waters of southwest Lamma) are not predicted to be affected by either construction (dispersion of sediment plumes, vessel traffic, construction underwater noise) or operation (dispersion of cooling water and biocides, and vessel traffic) of the power station extension. The potential south Lamma marine park / marine reserve is not predicted to be impacted by either the construction or operation of the power station extension.

Potential impacts to marine ecological resources during operation of the power station extension may arise as a result of the following activities:

- Intake of cooling waters causing entrainment and subsequent mortality of planktonic organisms as well as the eggs and larvae of marine organisms;
- Discharge of temperature elevated cooling waters causing mortality of eggs, larvae and adult marine organisms; and
- Discharge of residual free chlorine as a result of antifouling measures causing lethal or sublethal effects to eggs, larvae and adult marine organisms.

Entrainment of eggs and larvae, and impingement of adult marine organisms are predicted, in the worst case situation, to remain the same as that caused by the existing power station once the extension is in operation. This is a result of the shift of the majority of baseload generating capacity from the existing coal-fired plant to the gas-fired extension which uses less cooling water. Impacts to eggs, larvae and adult marine organisms are, therefore, not considered to be of concern to the project.

The temperature of the waters surrounding the power station are predicted to be elevated to a lesser degree than they are at present as a result of cooling water discharges from the existing power station. Findings from the intertidal surveys indicate that the assemblages presently contacted by cooling waters discharged from the existing power station show no adverse impacts. The assemblages were no less diverse than nearby shores unaffected by cooling waters and supported higher abundances of marine algae and fauna. This indicates that impacts to marine ecological resources are considered acceptable and not of concern, as perturbations to key water quality parameters are predicted to be within environmentally acceptable levels (water quality objectives).

Residual free chlorine is likely to be present in cooling water discharges arising from the operation of the power station extension. However, the maximum discharge concentration of chlorine is predicted to remain at or below the existing level of 0.3 mg $L^{-1}$. It is worth noting that Hongkong Electric will undertake to investigate the possibility of reducing the current discharge concentrations of residual chlorine and the potential for the use of alternative biocides. Although toxic effects of chlorine have been demonstrated to occur in marine organisms at levels less than 0.3 mg $L^{-1}$[31] and the toxicity of chlorine is synergistically increased at higher temperatures, these impacts are not predicted to be of concern because chlorine concentrations in the water column are predicted to decrease rapidly with time and distance from the outfall and do not impact any of the identified marine ecological sensitive receivers.

Marine ecological impacts arising from the operation of the power station extension are predicted to be within environmentally acceptable limits (WQOs or EPD discharge standards). Mitigation measures specific to marine ecology include the provision of rubble mound seawalls on the western and southern edges of the reclamation to facilitate colonisation by soft corals and gorgonians, low density assemblages of which will be lost as a result of the construction of the reclamation. Other mitigation measures designed to mitigate impacts to water quality to acceptable levels (compliance with water quality objectives), including constraints on dredging and filling operations, are also expected to

[31] Langford (1983) *op cit.*

mitigate impacts to marine ecological resources. Mitigation measures designed to avoid impacts of vessel traffic to marine mammals include the rerouting of all vessels involved in construction or operation of the power station extension so they approach the power station from the north or via the East Lamma Channel. This is expected to mitigate impacts to the finless porpoise centred off the southwest coast of Lamma Island.

The residual impacts occurring as a result of construction and operation of the power station extension are the direct loss of the low ecological value subtidal assemblages present within the reclamation site and the indirect loss of the low ecological value assemblages outside of the reclamation site. The loss of the habitat within the reclamation site can be partially mitigated through the provision of rubble mound seawalls on which soft corals and gorgonians assemblages (lost during the reclamation) can colonise and grow. This mitigation measure coupled with the finding that the habitat is of low ecological value combine to reduce the magnitude of the residual impact to acceptable levels. The assemblages lost outside of the reclamation site are of low ecological value and are expected to recolonise once construction works have ceased. In the light of this the residual impact is not considered to be unacceptable.

An ecological monitoring programme involving the use of a remotely operated vehicle will be conducted to confirm the severity of impacts to the soft corals and gorgonians adjacent to the reclamation site, and to report on the progress of recolonisation of the rubble mound seawalls once construction works have ceased. As an additional habitat enhancement measure HEC have undertaken to deploy a minimum of 400m$^3$ of Artificial Reefs (AR) in Hong Kong waters at a site (or sites) to be decided upon consultation with the Director of Agriculture and Fisheries.

Further monitoring and audit activities specific to marine ecology are not deemed necessary as those conducted to detect and mitigate any unacceptable impacts to water quality will serve to protect against unacceptable impacts to marine ecological resources.