6. TERRESTRIAL AND MARINE ECOLOGY

6.1 Introduction

This chapter reviews existing information on the ecology of the Study Area and its surroundings and summarises additional data obtained through field surveys to establish an ecological baseline for the area. Thereafter, the chapter identifies potential ecological impacts of the project and proposes mitigation measures to keep these impacts within acceptable levels. The study area is defined as the intertidal and subtidal zones of Tai O estuary, and terrestrial habitats within 1 km of the Tai O saltpans.

6.2 Legislation and Assessment Criteria

This chapter takes note of the following Hong Kong SAR Government legislation and guidelines relevant to ecological impact assessment:

- the Forests and Countryside Ordinance (Cap. 96) and its subsidiary legislation, the Forestry Regulations;
- the Wild Animals Protection Ordinance (Cap. 170);
- the Animals and Plants (Protection of Endangered Species) Ordinance (Cap. 187);
- the Country Parks Ordinance (Cap. 208) and subsidiary legislation;
- the Marine Parks Ordinance and Marine Parks Regulations (Cap. 476);
- the Environmental Impact Assessment Ordinance (Cap. 499) and associated Technical Memorandum on Environmental Impact Assessment Process (the EIA TM);
- the Hong Kong Planning Standards and Guidelines (Chapter 10, Conservation); and
- "Guidelines for Implementing the Policy on Off-site Ecological Mitigation Measures" (PELB Technical Circular 1/97, Works Branch Technical Circular 4/97, dated 17 February 1997).

This chapter also takes note of the following relevant international agreements:

- the Convention on Wetlands of International Importance Especially as Waterfowl Habitat ("Ramsar Convention");
- the Convention on the Conservation of Migratory Species of Wild Animals ("Bonn Convention");
- the Convention on International Trade in Endangered Species of Wild Fauna and Flora ("CITES"); and
- the United Nations Convention on Biological Diversity.

6.3 Baseline Conditions

6.3.1 Data Sources

The following studies and reports have been reviewed for data on the existing ecological conditions at and around the Tai O Study Area:

- Categorisation of Agricultural Land (AFD 1995), regarding agricultural lands and fish ponds at Tai O;
- Dudgeon and Chan (1996), on the ecology of wetlands in the Study Area;
- GLA (1998), for information on noteworthy flora and fauna of the Tai O area;
- New Airport Master Plan EIA (Greiner Maunsell 1991), on marine ecology off north Lantau Island;
- The Hong Kong Bird Report (various years), for historical bird records at Tai O;
- Jefferson (1998), on distribution and ecology of Indo-Pacific Hump-backed Dolphins;
- Environmental Report for the North Lantau Development Study (Mott MacDonald *et al.* 1991), on ecological conditions of north Lantau and the need to mitigate for the loss of mangroves;
- Study on Tonggu Waterway (Scott Wilson 1998 a, b, c), for information on benthos and dolphins in the Pearl River Estuary near Tai O; and
- Tam and Wong (1997), for information on mangrove habitats, flora and fauna at Tai O and Yi O and on the history and condition of the salt pans.

Prior to this EIA field investigation of the ecology of Tai O was limited. Therefore, field surveys (as described in the IAR) were carried out for this EIA to fill data gaps which would otherwise hinder the assessment of the project's potential ecological impacts. Methodologies and results of the field surveys are reported in **Appendix 5** and are summarised in Sections 6.3.3 through 6.3.7.

6.3.2 Protected Areas

Part of the Lantau North Country Park lies close to the project site, directly to the south of the proposed sheltered boat anchorage. The Country Park is separated from the project site at all points either by open sea or by a band of village development. Project construction and operation is, therefore, unlikely to have any significant ecological impact upon the Country Park. No other terrestrial protected areas lie within 1km of the project site.

The Sha Chau and Lung Kwu Chau Marine Park, a marine area of 12km^2, lies approximately 8km north of the project site at its closest point (refer to **Figure 6.2**). The Marine Park was designated in November 1996 with the primary objective of protecting the Indo-Pacific Hump-backed Dolphin *Sousa chinensis* and its habitat. Due to the intervening distance, project construction and operation are not predicted to affect the Marine Park. No other designated marine conservation areas lie close to the site.

Morton (1998) proposed the designation of a Western Lantau Marine Park encompassing the waters of western, southern and south-western Lantau, including the Soko Islands. **Figure 6.2** shows how this proposal would extend the area covered by the Sha Chau and Lung Kwu Chau Marine Park. This proposal would protect unique coastal features and would greatly enlarge the area of habitat protected for the Indo-Pacific Hump-backed Dolphin.

The Agriculture and Fisheries Department (AFD) has identified southwest Lantau as a potential marine park, and has commissioned a study to assess the feasibility of this area for designation as a marine park or reserve.

Collectively, wetlands at Tai O including mangrove, mudflat, fish ponds and brackish marsh were proposed by the Green Lantau Association for designation as an SSSI (GLA 1998). Reasons cited in justification include the fact that they "are probably the best remaining site of their type on Lantau", the presence of the Tai O Egretry, the Rough-skinned Floating Frog, waterbirds and other species dependent on these wetlands, and the contribution of the wetlands to local habitat diversity which makes the Tai O area one of the most important bird breeding sites on Lantau (*ibid.*). GLA (1998) noted that the precise extent of the SSSI should be subject to further study.

6.3.3 Marine Habitats and Fauna

Benthos

A review of the available literature located no descriptions of the benthic fauna of the Tai O area. However, studies have covered several sites within 10km of Tai O, and these are reviewed below for reference.

Greiner Maunsell (1991) reported the results of 13 double-replicate trawls and grab-samples at 16 sites some 8km north-east of Tai O for the Chek Lap Kok airport EIA. They recorded 135 species in grab samples, dominated by 3 groups: polychaete worms, molluscs and crustaceans. They did not report quantitative data such as abundance or biomass, nor did they calculate diversity or other parameters for their samples. They concluded that the heterogeneity of sediment types and depths promoted high species richness and abundance of sublittoral infauna. Echinoderms were found to be the exception to the trend of high fauna diversity, presumably due to the freshwater influence of the Pearl River and the resulting low salinity. Two species new to science were reported. Dominant benthic species were found to be similar in many cases to those reported for the 1979 period by Wu and Richards (1981) despite the fact that the latter study used a beam trawl to collect samples rather than a grab, and thus sampled benthic epifauna rather than infauna. Greiner Maunsell (1991) concluded that the sublittoral benthos near Chek Lap Kok and The Brothers Islands were good examples of that expected in Hong Kong coastal waters.

For the Study on Tonggu Waterway, benthic grab sampling was conducted bimonthly over 12 months at three transects lying 6-15 km north of Tai O (Scott Wilson 1998b). Benthic samples at all stations were dominated by 3 groups - molluscs, polychaete worms, and crustaceans - which constituted over 80% of all species recorded (Scott Wilson 1998c). Total numbers of species recorded ranged from 54 to 69, and total number of individuals ranged from 1,102 to 1,687 (*ibid.*). Species recorded were common benthic infauna species of the South China Sea (*ibid.*). The bivalve *Potamocorbula laevis*, an estuarine species, constituted over 60% of total abundance and roughly 50% of total biomass (*ibid.*). No strong seasonal variation in benthic infauna communities was recorded (*ibid.*). Species diversity H' ranged from 0.80 to 3.69 (*ibid.*). The transect with the highest species diversity was Transect 3 (Stations 11-15), which lay closest to Tai O. Diversity here ranged from 3.31 to 3.69. Higher diversity at this station was suggested to be due to greater stability of environmental conditions (lower influence from the Pearl River) along this transect. This station lies some 6km from Tai O Bay and was located in open waters, hence conditions cannot be assumed to be similar to those at Tai O.

Baseline surveys of benthic fauna in the proposed sheltered boat anchorage, breakwater and channel areas in Tai O Bay were conducted during this Assignment in order to allow the assessment of project impacts. Methods and results of these baseline surveys are reported in **Appendix 5** (Sections A5.1.1 and A5.2.1 respectively). Grab sampling covered the sheltered boat anchorage site, the breakwater site and the two approach channel sites. Survey results indicated that the benthic fauna in Tai O Bay is dominated by polychaetes and molluscs, as is typical of Hong Kong in general. These two taxonomic groups comprised over 90% of the organisms collected. The number of species in each sample was low, below 10. Density was also low: only 271 individual organisms of 39 species were found in 24 samples (see **Appendix 5**, Section A5.2.1, **Table A5.1** and **Annex A5a**). Diversity was also markedly low: mean values of the diversity index H' for all eight sites ranged from 0.51 to 1.78. No rare species were recorded.

As noted above, benthic surveys of Tai O Bay found 271 individual organisms of 39 species in 24 samples. This compares to the Study on Tonggu Waterway, which recorded 1,102 to 1,687 individuals of 54 to 69 species during each run of 45 benthic grab samples (Scott Wilson 1998c). Since grab sizes were the same in each study, density can be compared. Density of benthos as measured by abundance in grab samples was markedly lower in Tai O Bay than in the offshore waters surveyed for the Tonggu Waterway. The Study on Tonggu Waterway found species diversity H' to range from 0.80 to 3.69 at its three transect sites, and from 3.31 to 3.69 at Transect 3, the closest transect to Tai O (*ibid.*). Diversity indices for April 1998 samples at all transects ranged from 1.30 to 3.42, as compared with a range of 0.51 to 1.78 for samples taken in Tai O Bay in April 1999 for the current study. In brief, diversity recorded at the Tonggu Waterway sites was markedly higher than in Tai O Bay.

The benthos of the subtidal zone of the salt pans, a sheltered but generally marine environment, was also investigated through grab sampling (see **Appendix 5**, Section A5.1.5 for methods and Section A5.2.5 for results). (Intertidal fauna of the salt pans are discussed in Section 6.3.4 below.) The benthic fauna was found to be typical and heavily dominated by two species, *Mediomastus californiensis* and *Euclymene* sp. (constituting 203 and 105 individuals respectively out of the 390 organisms found). No rare species were recorded (see **Appendix 5**, **Table A5.7** and **Annex A5e** for detailed survey results).

Horseshoe crabs are occasionally sold in Tai O market (Mott MacDonald *et al.* 1991). Huang *et al.* (1998) reported that adult *Carcinoscorpius rotundicauda* are "frequently fished from the subtidal mud" of north-west Lantau, including Tai O and Yi O. The muddy bottom of Tai O Bay would appear to provide suitable habitat for horseshoe crabs, while in the intertidal zone soft shores usable by these species are found to a limited extent in inner Tai O Bay/the mouth of Tai O Creek. Horseshoe crabs, three species of which occur in the South China Sea, are thought to be at risk from over-harvesting and in Hong Kong possibly from loss of habitat (Huang 1997; Huang *et al.* 1998). During this Assignment, natural shores were surveyed and local fishers were interviewed to investigate the occurrence of horseshoe crabs in the proposed Tai O anchorage site. Methods and results are reported in **Appendix 5** (Sections A5.1.2 and A5.2.2 respectively). Interviews with fishers indicated that horseshoe crabs are occasionally observed or caught inside Tai O Bay and the intertidal portion of Tai O Creek (see **Appendix 7**, **Annex A7d**). Local fishermen noted that horseshoe crabs are more often seen on more sandy shores such as those at Yi O, indicating that while Tai O is a suitable habitat, it is not the most preferred habitat (see **Appendix 5**, Section A5.2.2).

Fish and Pelagic Invertebrates

Data on fish and pelagic invertebrates of Tai O Bay are addressed in Chapter 7. The fish and pelagic invertebrate fauna of the salt pans was surveyed in order to better establish baseline conditions (see **Appendix 5**, Section 5.1.5 for methods). (Intertidal fauna of the salt pans are discussed in Section 6.3.4 below.) Cast net sampling at all 7 former ponds of the salt pans recorded only 6 species, including 3 fish, 2 crab and 1 shrimp species. Yields were not large (see **Appendix 5**, Section A5.2.5, **Tables A5.9** and **A5.10** for detailed survey results).

Cetaceans

The Indo-Pacific Hump-backed Dolphin *Sousa chinensis* is the only cetacean considered likely to be found near Tai O. Finless Porpoises *Neophocaena phocaenoides* have been recorded off south-west Lantau within 6km of Tai O, but not at Tai O itself.

S. chinensis is protected by law in the Hong Kong SAR. It is a CITES Appendix I species and a Class I protected species in Mainland China (Huang 1997, Parsons 1997). This species has been the subject of considerable local study in the past 5 years (see e.g. Jefferson 1998). Results of systematic transect surveys over several years show that the range of *S. chinensis* in the SAR is centred on the waters around north and west Lantau and Urmston Road (Jefferson 1998). It appears that Lingdingyang proper is the core area for this species in the Pearl River Estuary, i.e. the waters around and to the west of Tai O. This supposition is supported by the fact that the dolphins are seen almost exclusively in the western waters of Hong Kong and concentrated in the most estuarine-influenced north Lantau waters.

Most transect sightings within approximately 1 km of Tai O and Fan Lau reported in Jefferson (1998) were made during summer and autumn months. Dolphin surveys conducted for the Study on Tonggu Waterway (Scott Wilson 1998b) produced sightings within approximately 5 km of Tai O in all seasons. To supplement these data, spring-season surveys were conducted during this Assignment to assess dolphin use of Tai O Bay, while local residents and fishers were interviewed regarding dolphin occurrence in Tai O Bay. Survey methods and results are reported in **Appendix 5** (Sections A5.1.3 and A5.2.3 respectively). Interview results are reported in **Appendix 7** (**Annex A7d**). Findings showed that dolphins do enter Tai O Bay, and may penetrate as far as the proposed breakwater site, but not in large numbers. Dolphins may regularly use outer portions of Tai O Bay in small numbers. One interviewee indicated that dolphin numbers in the bay peak when seabass are most available as prey. Most dolphin sightings during the spring 1999 survey were made 700m or more to the west of Tai O, in open waters.

6.3.4 Intertidal Habitats and Fauna

The Tai O area harbours a variety of intertidal habitats: boulder shores, mudflats, estuaries and mangroves - each of these is characterised below.

Boulder Shores

The only area of natural shore within Tai O Bay is a semi-exposed boulder shore in the south-west part of the bay, approximately 700 m in length. Other natural shores are found on the headland to the north of the sheltered boat anchorage site, outside the mouth of the bay. These are mainly composed of large boulders rounded by wave action and are bordered by steep cliffs. Similar beach profiles are found to the south of Tai O. The outer seawall of the salt pan and the partially submerged breakwater to the north-west of the salt pan area provide artificial habitats which may mimic natural boulder shores.

Baseline surveys of intertidal fauna on the natural boulder shore within Tai O Bay were conducted to allow the assessment of project impacts. Survey methods and results are reported in **Appendix 5** (Sections A5.1.4 and A5.2.4 respectively). Findings showed that this shore supports a typical boulder/rocky shore fauna, dominated by littorinid snails (see **Appendix 5**, Section A5.2.4, **Table A5.3**). No rare species were recorded. Diversity of the intertidal fauna here was considered to be typical for such a semi-exposed shore.

Salt Pans

The Tai O salt pans are dominated by a muddy bottom of variable depth, interspersed with former fish pond bunds the tops of which lie above the maximum tide level. The intertidal fauna is confined to a narrow band of mudflat 1 - 2 m wide on the verge of the former fish pond bunds and outer seawall. The area of intertidal mudflat within the salt pans is relatively constant because the outer seawall impedes tidal flows in both directions, resulting in extended retention during ebb tides and delayed flooding during flood tides.

Baseline surveys of intertidal fauna in the salt pans were conducted in order to allow the assessment of project impacts. Survey methods and results are reported in **Appendix 5** (Sections A5.1.5 and A5.2.5 respectively). Surveys of subtidal fauna in the salt pans are presented in Section 6.3.3 above. The intertidal zone of the salt pans was colonised by epibenthic fauna dominated by gastropods and crustaceans, typical of sheltered mudflat habitats throughout the SAR. All species recorded were common and widely distributed in the SAR. Fiddler Crabs *Uca* spp., dominated by *U. lactea, U. borealis,* and *U. arcuata*, were numerous. Mudskippers *Periophthalmus cantonensis* were also recorded. The gastropod *Cerithidea rhizophorarum* was the most abundant epifauna recorded in quadrat surveys. *Uca lactea* was the most common species in the visual estimate of crab abundance. Intertidal infauna was dominated by the polychaetes *Mediomastus* sp. (family Capitellidae), *Melinna* sp. (family Ampharetidae) and *Neanthes glandicincta* (family Nereidae) (see **Appendix 5**, Section A5.2.5, Table A5.5).

In contrast with the benthic fauna of the Tai O salt pans, Tam and Wong (1997) found the mangrove mudflat at Yi O to be the second-most species rich of their 23 sampling sites in Hong Kong. They recorded 40 species of crustaceans, molluscs and fish in this mangrove (*ibid*.). The density of benthic macrofauna was 80.1/m^2, whilst Simpson's diversity index of 0.88 was the highest of all 23 sampled sites. Sea and weather conditions influencing the Yi O site are similar to those at Tai O, but the Yi O site is subject to considerably less water pollution and human disturbance/harvesting.

A total of 22 species of intertidal infauna and epifauna were recorded in the salt pans during all surveys (combined total from preliminary qualitative and subsequent quantitative surveys). This is markedly lower than the 40 species recorded at Yi O (Tam and Wong 1997). Average density of epifauna in the salt pans was 72.5 individuals m^{-2}, compared to 80.1 individuals m^{-2} in the Yi O mangrove (*ibid.*). However, quantitative comparisons between the intertidal fauna of the Tai O salt pans and the Yi O mangrove cannot be made reliably due to the different characteristics of the two sites (narrow intertidal zones fringing former fish ponds at Tai O versus an established mangrove at Yi O), and the different intensity, duration and seasons of sampling between this study and Tam and Wong (1997).

Tai O Creek Estuary

The intertidal estuary of Tai O Creek lies to the east and north of the salt pans. In the immediate vicinity of Tai O where the stream meanders through the village, water quality is adversely affected by wastewater discharges (refer to Section 5.6). Further upstream, the stream banks support mangroves and riparian vegetation. The estuarine section of interest is the area lying upstream of Tai O Village proper, but still in the tidal zone, approximately as far as the Tai O Road bridge. Baseline surveys of estuarine fauna in this zone were conducted to allow the assessment of project impacts. Survey methods and results are reported in **Appendix 5** (Sections A5.1.8 and A5.2.8 respectively). Surveys showed that fish inhabiting this part of the creek were mainly brackish water or marine species. Samples were dominated by juvenile Pony fish *Leiognathus daura*, suggesting that the creek's tidally influenced zone may provide nursery functions for this species (see **Appendix 5**, Section A5.2.8, **Table A5.15**).

Mangroves in Hong Kong

A total of 43 mangrove stands covering an area of 178ha, excluding Mai Po Nature Reserve, remains in Hong Kong despite the tremendous reclamation work and infrastructural development carried out in the past 40 years (Tam and Wong 1997). These mangroves are mainly distributed in five districts: Sai Kung, north-east New Territories, Tolo Harbour, Deep Bay and Lantau Island. The sizes of stands (discounting Mai Po) vary from Lut Chau (over 50ha) to Chi Ma Wan (0.22ha) - most stands are 1 - 3 ha in size. Mai Po Nature Reserve has 172ha of mangrove according to Young and Melville (1993), but only 85ha according to Tam and Wong (1997). The difference in estimated mangrove area arises from inclusion of *gei wai* mangroves and Tsim Bei Tsui mangroves in the former estimate.

The distribution of mangroves is mainly governed by topography, tidal height, substratum and salinity. Salinity and substratum texture vary significantly within Hong Kong. For instance, mangrove stands in Deep Bay are rather muddy and greatly affected by freshwater influxes from the Pearl River, especially during the summer. Heavy siltation occurs in this area, resulting in an extensive gradual intertidal slope. The salinity in this region fluctuates from 1‰ to ＞30‰, with an average around 10 - 15‰. In contrast, the stands on the eastern coastlines of Hong Kong are more oceanic and have more consistent and higher salinity. The substratum is stonier and less muddy, with a relatively shallow soil layer. These variations in texture and salinity suggest that mangroves in Hong Kong have a wide range of tolerance to these two factors.

Eight exclusive or true mangroves and five mangrove associate species are found in Hong Kong mangrove stands. The true mangroves occurring in the Hong Kong SAR, in descending order of abundance, are *Kandelia candel*, *Aegiceras corniculatum*, *Excoecaria agallocha*, *Acanthus ilicifolius*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Lumnitzera racemosa* and *Heritiera littoralis*. The associate mangrove species are *Clerodendrum inerme*, *Hibiscus tiliaceus*, *Cerbera manghas*, *Acrostichum aureum* and *Thespesia populnea*. The average tree density in most stands is around 1.4 trees/m^2, ranging from 0.4 to 4 trees/m^2.

The zonation of plants from landward to seaward in most mangrove stands is not clearly defined. Nevertheless, in some stands, *Avicennia marina* (a pioneer species) is more common at the seaward edge, *Excoecaria agallocha* dominates the landward zone and *Kandelia candel* and *Aegiceras corniculatum* colonise the intertidal mudflat.

Over 100 species of benthic fauna have been recorded in Hong Kong mangroves, belonging to 5 phyla and 18 orders. Most belong to Phylum Mollusca, Classes Gastropoda and Bivalvia (70% of species) and Phylum Arthropoda, Class Crustacea (26%). Crabs, including *Uca*, *Chiromanthes, Metopograpsus, Scylla, Macrophthalmus* and *Helice* spp., are commonly found on mangrove mudflats. Other common mangrove invertebrates include *Periophthalmus cantonensis* (mudskipper), *Alpheus brevicristatus* (snapping shrimp), *Ligia exotica*, *Cerithidea djadjariensis*, *Cerithidea rhizophorarum, Terebralia sulcata*, *Clithon oualaniensis, Batillaria, Littoraria, Monodonta, Nerita* and *Clypemorus* spp. The average density of benthos in Hong Kong mangroves is 116 individuals/m^2. Seasonal variations in animal species diversity and abundance are observed in some mangrove stands in Hong Kong.

Mangroves at Tai O

Mangroves occur in various locations at Tai O, including the marshes to the north of Tai O Creek, abandoned fish ponds, the salt pans and the tidal riparian zone of Tai O Creek. Locations of mangroves at Tai O are shown in **Figure 6.1** and in **Appendix 5**, **Figures A5.2** and **A5.3**. A variety of mangrove and mangrove associated species, including *Acanthus ilicifolius*, *Acrostichum aureum*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Clerodendrum inerme*, *Excoecaria agallocha*, *Hibiscus tiliaceus* and *Kandelia candel* have been recorded in the intertidal zone. Typical backshore species such as *Derris trifoliata*, *Ipomoea brasiliensis*, *Suaeda australis* and *Sesuvium portulacastrum* have also been recorded (see **Appendix 5**, Section A5.2.6, **Table A5.11**).

In light of the limited survey work that has previously been carried out on mangroves at Tai O, mangrove areas of Tai O, including those in the salt pans, were mapped under this Study to allow better assessment of project impacts. Survey methods and detailed results are reported in **Appendix 5** (Sections A5.1.6/A5.1.7 and A5.2.6/A5.2.7 respectively).

The mangroves in the salt pans are fragmented or scattered, occupying a total area of 0.3ha as measured through field surveys. The substrate varies from sandy mud to muddy surfaces with stones and accumulated refuse. Most of the mangrove trees are small (average height about 0.5m, see **Appendix 5**, Section A5.2.6, **Table A5.13**), probably indicating that they have become established only in recent years, following cessation of fish pond operation in the salt pans. Mature trees within the salt pans produce numerous seedlings (see **Appendix 5**, Section A5.2.6, **Table A5.12**). These individuals are irregularly spaced around the edge of the salt pans.

Mangroves in the intertidal zone outside the salt pans occupy a larger area and are taller, with some *K. candel* trees reaching a height of 4m (e.g. at tidal lagoon behind Po Chue Tam). The total area coverage of these mangroves outside the salt pans was found through field studies to be 4ha.

Surveys showed that of 8 true mangroves and 5 mangrove associates recorded in Hong Kong, 6 and 2 species respectively are recorded at Tai O (**Appendix 5**, Section 5.2.6, **Table A5.11**). *Kandelia candel, Avicennia marina, Hibiscus tiliaceus*, and *Clerodendrum inerme* are common. *Aegiceras corniculatum* and *Acanthus ilicifolius* are also present, while *Bruguiera gymnorhiza* and *Excoecaria agallocha* are poorly represented and are only recorded in the salt pans (Site A). Mangroves and mangrove associates mainly establish along pond bunds or margins of water bodies. The densest and most homogeneous patch of mangroves at Tai O was recorded at Site F, an abandoned field west of where Tai O Road crosses Tai O Creek (see **Appendix 5**, **Figure A5.2**). This mangrove had a height of 1-2 m, a density of 1.32 individuals/m^2 and an average basal diameter of 4.5cm.

Dominance of pioneer mangrove species (*K. candel, A. marina*) and backshore mangrove associate species (*H. tiliaceus, C. inerme*) and absence of a "middle" zone of back mangrove species (*B. gymnorhiza, E. agallocha*) is probably due to the absence of a real intertidal zone with continuous elevation gradient. This is rather typical at Tai O, where the estuary area has been urbanised or converted to salt pans. The bunds of salt pans and fish ponds and the stream banks are steep and offer limited areas for mangrove establishment, while most ponds are too deep for mangrove growth. Another reason for poor development of back mangrove species may be lack of seed source. Few adult trees of *B. gymnorhiza* and *E. agallocha* were found in the Study Area. Some major seed sources in the vicinity (Chek Lap Kok, part of Tung Chung) have been destroyed due to construction of the airport and new town development.

Water pollution appears to be most serious near Tai O village, where discharge of domestic sewage and wastewater is concentrated, and dumped or washed-up refuse has accumulated around the mangroves. Construction associated with sewage works near the salt pans have caused some blockage of tidal flow. This may have caused the symptoms of morbidity observed among scattered mangroves in the reclamation area on the north side of Tai O Bay.

6.3.5 Streams and Stream Fauna

Tai O Creek runs to the east and north of the anchorage site and proposed salt pan planting area. The main Tai O Creek channel in the middle and upper reaches is relatively unaltered by human activity, while the lower end of the estuarine zone appears to be heavily affected by pollution, probably long-term discharge of untreated domestic sewage. This pollution may affect the abundance and diversity of stream fauna.

The main Tai O Creek and its tributaries were surveyed between 1980–91 as part of a territorial survey of freshwater fish in rivers and streams by Chong and Dudgeon (1992) - no species of rarity or conservation importance were reported. Reaches of the stream above the intertidal zone will not be affected by the sheltered boat anchorage project, and field surveys were therefore not conducted here. Intertidal reaches of the stream are discussed in Section 6.3.4.

6.3.6 Terrestrial Habitats and Vegetation

Habitat Mapping

A 1:5,000 habitat map of the salt pans and terrestrial habitats within a 1km radius of the Study Area was prepared based on 1997 government aerial photography, the Hong Kong Vegetation Map (WWF-HK 1993), and site visits. The habitat map is shown in **Figure 6.1**.

Upland Habitats and Vegetation

A review of literature revealed no information on the upland habitats of Tai O. Site visits showed that upland habitats near the site were dominated by grassland and shrubland frequently disturbed by hill fires. Several hill fires affected the Tai O catchment during the field survey period, associated with grave visitation at the Ching Ming festival in April 1999. Some woodland patches were observed in the foothills, behind villages and in ravines where they were protected from fires. These were mainly open pine woodlands and orchards.

Reedbeds, Agriculture, Ponds, and Marshes

A large reedbed, identified as the Tai O reedbed in Dudgeon and Chan (1996), lies immediately to the east of the salt pans (**Figure 6.1**). This is one of the largest *Phragmites australis* reedbeds in the Hong Kong SAR (*ibid.*). It was not studied in detail by Dudgeon and Chan's freshwater wetland study due to its high salinity (25 ppt). The study did, however, describe a freshwater marsh, identified as Leung Uk marsh, to the south of the Tai O reedbed. This marsh was reported to be dominated by grasses and low lying emergent vegetation. No plant species list was provided for this marsh, which was described as “unexceptional” in terms of plant diversity (*ibid*.). Both the Tai O reedbed and Leung Uk marsh are physically and hydrologically separated from the old salt pans by the elevated concrete roadway to Leung Uk Tsuen and Nam Chung Tsuen, but are subject to tidal influence through Tai O Creek. Reedbeds are also established along with mangroves which have developed from abandoned salt pans, ponds and agricultural areas in the marshes to the north of Tai O Creek.

Baseline fauna surveys of the freshwater and brackish marshes immediately east of the salt pans (including the Tai O reedbed and Leung Uk marsh, **Figure 6.1**) were conducted to allow the assessment of project impacts. Survey methods and results are reported in **Appendix 5** (Sections A5.1.8 and A5.2.8 respectively). Surveys of aquatic fauna in these wetlands recorded juvenile Tilapia *Tilapia mossambica*, and spawning size female mud crabs (*Scylla serrata*) were also caught. Net surveys and visual observations noted numerous juvenile and subadult fish in the marsh, indicating that it may provide nursery functions for various species.

AFD (1995) identified 2ha of actively cultivated land, 8ha of fish ponds and 16ha of fallow land/ponds at Tai O. AFD classified these lands as "Grade C" (A being the highest and D the lowest grade) in agricultural terms, probably based on their small size, remoteness and limited road access. The area described by AFD (1995) includes the salt pans, the wetlands immediately east of them and abandoned fields to the north-east across the Tai O Creek. Agriculture and aquaculture appear to have been abandoned at most of these areas for at least 10 years, with the possible exception of a few large fish ponds north of Tai O Creek. Orchards near Po Chue Tam are actively operated, as pesticide application was observed during field surveys.

The only other terrestrial lowland habitats found within 1km of the boat anchorage site and salt pans are urbanised areas (Tai O village, roads and other paved areas) of no ecological interest.

6.3.7 Terrestrial Fauna

Terrestrial Invertebrates

The protected Birdwing butterfly *Troides helena* was recorded at Leung Uk marsh during field surveys. As this species is primarily an inhabitant of woodland, its primary habitat within the study area was concluded to be the open woodlands fringing Leung Uk marsh to the south and west, e.g. behind San Tsuen village. Dudgeon and Chan (1996) recorded a rare culicid fly *Culex* sp. in the Leung Uk marsh. No other rare or noteworthy terrestrial invertebrates have been recorded from Tai O.

Avifauna

A total of 54 bird species have been recorded in intertidal and terrestrial habitats at Tai O by local birdwatchers between 1992 and 1996 and during the Hong Kong Bird Watching Society Breeding Bird Survey in 1993 and 1994 (Carey 1995, 1996, 1997; M. Chalmers pers. comm.). Bird species reported from Tai O include locally uncommon and rare species such as Pheasant-tailed Jacana (*Hydrophasianus chirurgus*) and Schrenck's Bittern (*Ixobrychus eurhythmus*), and the very rare Greater Crested Tern *Sterna bergii*. Locally, regionally and globally endangered species have also been reported. Some species recorded are protected by law in Mainland China (e.g. Reef Egret) or are CITES listed species (e.g. raptors); all wild birds are protected by law in the SAR.

The Tai O area is reported to be one of the most important bird breeding areas on Lantau in terms of bird species numbers (GLA 1998). This is most likely due to the high diversity of habitats available in a relatively confined area. Tai O was a breeding site of the Grey-headed Woodpecker *Picus canus* in 1971 and 1972 (Viney *et al*. 1994). This species was considered locally extinct from 1977 through 1996, until it was sighted again in the northern New Territories in winter 1996 and summer 1997 (Dahmer *et al*. 1997).

Bird Use of Salt Pans

The salt pans, as an area of potential avian interest which are due to be affected by the project, were made the subject of bird surveys. Survey methods and detailed results are reported in **Appendix 5** (Sections A5.1.9 and A5.2.9 respectively). The salt pans were found to be used by mostly common and widespread species. A minority of the species using the site were wetland-dependent. The salt pans showed low density of bird use, probably due to the relatively deep water which precludes use of most of the salt pans by all but a few species. Little Egret *Egretta garzetta* was the dominant species using the salt pans, accounting for about 31% of all observations.

Tai O Egretry

The Tai O Egretry is located on a wooded hillside on the north-east slope of Fu Shan, about 800m north of the proposed sheltered boat anchorage and the salt pans (**Figure 6.1**). It is the only egretry (breeding site for herons and egrets) on Lantau Island, and its presence is one justification put forward by the Green Lantau Association in favour of designating wetlands at Tai O as a Site of Special Scientific Interest (SSSI) (GLA 1998). Villagers report that this egretry has existed since 1988. Thirty-three nests belonging to 3 species of ardeids (herons and egrets) were recorded here in 1995 (**Table 6.1**). No counts were made in 1996, 1997, or 1998, though the egretry remained active during this period (Young pers. comm.). The egretry was surveyed in April 1999 during this Assignment to update the 1995 records. Survey methods and detailed results are reported in **Appendix 5** (Sections A5.1.9 and A5.2.9 respectively). Eight pairs of Little Egret and 13 pairs of Night Heron were recorded nesting in the Tai O egretry on 14 April 1999, and 1 Chinese Pond Heron nest was found on 30 April 1999 (**Table 6.1**). Numbers of nests represent minimum counts, as not all nests are visible due to dense foliage.

Table 6.1: Numbers of Nests in the Tai O Egretry in 1995 (data from Young and Cha 1995) and 1999 (data from this Study).

Species	1995 Nest Count	14/4/1999 Nest Count	29/4/1999 Nest Count
Chinese Pond Heron	10	0	1
Night Heron	3	13	4
Little Egret	20	8	7
Total	**33**	**21**	**12**

Based on data through the end of April 1999, a 33.3% decline in number of breeding pairs in the Tai O Egretry took place between 1995 and 1999. The breeding species have not changed, but dominance has shifted from Little Egret to Night Heron. The 1999 high nest counts represent 4% of the average local breeding Little Egret population, 5% for Night Heron and <1% for Chinese Pond Heron (Young and Cha 1995).

The feeding ecology of ardeids breeding at the Tai O Egretry has not been studied previously. To address this data gap, and particularly to establish whether the salt pans are an important feeding site for birds of the egretry during the breeding season, a flight line study was conducted to examine the use of nearby habitats by Little Egrets breeding at the egretry. Survey methods and detailed results are reported in **Appendix 5** (Sections A5.1.9 and A5.2.9 respectively). Fish ponds were found to be by far the most important foraging habitats for Little Egrets. Habitats of lower importance included channels, mangroves and marshes. The salt pans were found to be markedly the least important foraging habitat for breeding Little Egrets in the area.

Reptiles, Amphibians and Mammals

The Common Rat Snake *Ptyas mucosus* has been reported at Tai O (Ades 1995). Although this species occurs in many habitats in Hong Kong (Karsen *et al*. 1986), it is a CITES Appendix II listed species. Mangroves at Tai O are reported to provide a habitat for the Mangrove Water Snake *Enhydris bennetti*. Tai O is one of the two sites outside Inner Deep Bay where this species has been recorded in Hong Kong (GLA 1998); the other site, Tung Chung, has now being affected by New Town development. This species has a narrow global distribution, being found only along the coast of southern China between Hainan and Fujian Province (Zhao and Adler 1993).

Dudgeon and Chan (1996) recorded 4 frog species in Leung Uk Marsh, east of the salt pans: Rough-skinned Floating Frog *Occidozyga lima*, Paddy Frog *Rana limnocharis*, Three-striped Grass Frog *Rana macrodactyla* and Brown Tree Frog *Polypedates megacephalus*. Two additional species were heard calling at Leung Uk marsh during field surveys in April 1999: Asian Common Toad *Bufo melanostictus* and Gunther's Frog *Rana guentheri*. Dudgeon and Chan (ibid.) recorded salinity of 0.0ppt in Leung Uk Marsh, which accounts for the presence of amphibians that are normally restricted to freshwater habitats.

Rough-skinned Floating Frog is an inhabitant of cultivated lands and slow streams and is restricted to lowlands; this species is quite uncommon in Hong Kong and was restricted to the central New Territories and Lantau Island in the early 1980s (*ibid*.). Prior to its rediscovery, the species was thought to be extinct in Hong Kong (Dudgeon and Corlett 1994). Tai O wetlands are the only known remaining habitat for this species in Hong Kong. Tai O wetlands including the Leung Uk marsh have been recommended by the Green Lantau Association for designation as an SSSI for conservation reasons including the presence of the Rough-skinned Floating Frog (GLA 1998). Progressive filling on the south side of the marsh near Leung Uk village is encroaching on the marsh habitat and probably reducing the habitat available to the Rough-skinned Floating Frog.

Barking Deer *Muntiacus reevesi* has been recorded near Tai O (Reels 1996). This is the only large mammal recorded on Lantau. Barking Deer is protected by law in Hong Kong.

6.3.8 Summary

The relative ecological values of the habitats surveyed at Tai O (shown in **Figure 6.1**) are summarised in **Table 6.2**. Criteria used in this table are adapted from Annex 8, Table 2 of the EIA TM with amendments as required. It should be noted that the ecological surveys performed for this study did not take a habitat approach, but were designed to focus on species of conservation interest. Therefore, not all the habitats were surveyed in detail. **Table 6.2** should be used as a reference only and should be interpreted as a subjective evaluation.

Table 6.2: Summary of Ecological Values of Habitats Surveyed at Tai O.

Habitat	Stream (estuary)	Marshes and Reedbed	Agriculture (including fish ponds)	Intertidal (including mangroves)	Saltpans	Marine
Naturalness	+ +	+ +	+	+ + +	+	+ +
Size	+	+ +	+	+ +	+ +	+ + +
Diversity	+	+ +	+	+ +	+	+
Rarity	+ +	+ +	+ +	+	+	+
Irreplaceability	+ + +	+ + +	+ +	+ + +	+	+ + +
Lack of fragmentation	+ + +	+ + +	+ +	+ +	+ +	+ + +
Ecological Linkage	+ +	+ +	+	+ +	+ +	+
Potential Value	+ +	+ +	+	+ +	+	+ +
Nursery/Breeding Ground	+ +	+ + +	+	+ +	+ +	+ +
Age	+ +	+ +	+	+ +	+	+ + +
Abundance/ Richness of Wildlife	+	+ + +	+ +	+	+	+

+ + + to + are relative scales given for the habitats, with + + + representing relatively high conservation value (e.g. large size, high diversity, old age) and + representing relatively low conservation value (e.g. small size, low diversity, young age).

Tai O harbours a number of species of conservation interest. Intertidal habitats support mangroves, which are a local and regional conservation priority. In particular, the *Avicennia marina* trees at Tai O are of conservation importance because they represent one of the few locations in the SAR where the species is successfully reproducing. Tai O mangroves are also reported to support the Mangrove Water Snake, a regionally rare species known in Hong Kong only from Mai Po, Tung Chung and Tai O.

Freshwater to brackish habitats at Tai O include Leung Uk marsh, which supports a rare invertebrate species, the rare Rough-skinned Floating Frog, and two species of rare waterbirds, Pheasant-tailed Jacana and Schrenck's Bittern.

Shallow marine habitats off Tai O support horseshoe crabs. On a global scale, horseshoe crabs are of importance in medical and pharmaceutical research and testing, in addition to being members of an ancient and taxonomically isolated group. Indo-Pacific Hump-backed Dolphins occur in Tai O Bay, and the rare Greater Crested Tern has also been recorded here. Tai O woodlands support the protected Birdwing butterfly, and an egretry which provides a nesting habitat for 3 ardeid species of local and regional conservation importance. These species of highest conservation interest at Tai O are listed in **Table 6.3**. The column indicating "Locations found at Tai O" must not be assumed to represent all habitats or sites where these species occur at Tai O; it only shows those sites where the species have been recorded by observers to date, in this or other studies. Of the 11 taxa listed in **Table 6.3**, only 5 taxa could be affected by construction and operation of the anchorage. Those 5 taxa are Black Mangrove, horseshoe crab, Greater Crested Tern, Mangrove Water Snake, and Indo-Pacific Hump-backed Dolphin. Impacts to those taxa are discussed in following sections.

Table 6.3: Rare Species Recorded from Tai O. (Taxa which could be affected by construction or operation of the anchorage are indicated by a double asterisk under the category Habitat Association).

Rare/Uncommon Biota	Reason for Rarity	Conservation Importance	Habitat Association	Locations Recorded at Tai O
Black Mangrove *Avicennia marina*	Herbivory by moths	Declining throughout HKSAR and region	Intertidal zone **	throughout the intertidal zone (this study)
Birdwing	Over-collected, restricted habitat preference	Uncommon, WAPO	Open woodland	Leung Uk marsh (this study)
Culicid fly	Unknown	Rare	Marsh	Leung Uk marsh (Dudgeon and Chan 1996)
Horseshoe crabs	Habitat loss, overexploitation	Rare, declining	Seabed **	Tai O Bay, Yi O (Huang *et al.* 1998)
Greater Crested Tern	Unknown	Very rare, WAPO	Coastal marine **	unknown (Hong Kong Bird Report)
Schrenck's Bittern	Habitat loss, restricted habitat preference	Rare, WAPO	Marsh	unknown (Hong Kong Bird Report)
Pheasant-tailed Jacana	Habitat loss, restricted habitat preference	Rare, WAPO	Marsh	Leung Uk marsh (this study)
Rough-skinned Floating Frog	Habitat loss, restricted habitat preference	Very rare; Tai O is sole known site in HKSAR	Marsh	Leung Uk marsh (Dudgeon and Chan 1996)
Mangrove Water Snake	Habitat loss, restricted habitat preference	Rare	Mangrove **	Unknown (GLA 1998)
Barking Deer	Unknown; possibly over-hunting	Rare, WAPO	Uplands	unknown (Reels 1996)
Indo-Pacific Hump-backed Dolphin	May include bycatch, overfishing, habitat loss, marine pollution	"Rare" status not fully confirmed, but total Pearl River Delta population estimated at only slightly over 1,000. WAPO	Estuarine and coastal waters **	Tai O Bay, offshore waters to west of Tai O (Jefferson 1998, Scott Wilson 1998c, this study)

Notes:
WAPO - Wild Animals Protection Ordinance (Cap. 170)

6.4 Construction Phase Impacts

6.4.1 Assessment Methods and Sources of Impact

The significance of ecological impacts has been evaluated based primarily on the criteria set forth in Table 1, Annex 8 of the EIA TM:

- habitat quality;
- species affected;
- size of habitats/numbers of organisms affected;
- duration of impacts;
- reversibility of impacts; and
- magnitude of environmental changes.

Impacts are generally ranked as "minor", "moderate" or "severe". The ranking assigned varies based on the criteria listed above. For example, an impact may be ranked as "minor" if it affects only common species or habitats, small numbers of individuals or small areas, whereas it may be ranked as "severe" if it affects rare species or habitats, large numbers of individuals or large areas. The major factors giving rise to a given ranking are noted in the text. As noted in Annex 16 of the EIA TM, a degree of professional judgement is involved in the evaluation of impacts.

The following construction activities are potential sources of ecological impact:

- dredging of the sheltered boat anchorage, approach channels and breakwater site;
- off-site disposal of dredged material;
- reworking of the outer seawall;
- modification of bunds within the salt pans;
- placement of dredged material into salt pans and salt pan area reworking;
- breakwater construction; and
- reclamation of sites within the salt pans.

The project design has been developed to minimise negative impacts to ecology, e.g. by minimising the extent of dredging, but some negative impacts are still predicted to result from project construction. These are identified and evaluated below. Positive impacts are also identified and evaluated, where relevant.

6.4.2 Dredging of Sheltered Boat Anchorage, Approach Channels and Breakwater Site

The sheltered boat anchorage site, breakwater site and approach channels will be dredged as part of project construction. Predicted duration of dredging is broken down by task in **Table 2.2**. The total time required for dredging would be 106.65 weeks, although this would be shortened by dredging simultaneously at multiple sites. Whilst a small proportion of the dredged sediment will be placed in the salt pans (i.e. approximately 20,000m^3), most will be disposed of at an approved off-site marine borrow area. Impacts of disposal are addressed in Section 6.4.3.

Dredging of the sheltered boat anchorage will result in the temporary loss of benthic habitat over 10ha (13%) of Tai O Bay (total area 75ha). Dredging of the approach channels will result in the temporary loss of benthic habitat over 13.5ha (6.5ha on the south channel; 7.0ha on the north channel), or 18% of the bay. Dredging at the breakwater will be followed by breakwater construction, eliminating the soft bottom at this site and resulting in a permanent change of 1.3 ha of muddy bottom benthic habitat to an unspecified area of hard subtidal seawall.

Benthos will be affected at dredging sites through direct mortality and loss of habitat. Dredging impacts to the benthic fauna community from the Tonggu Waterway project (dredging volume some 20 times larger than the current project) were predicted to be defaunation of the dredged area, followed by rapid re-colonisation over a period of several months to several years (Scott Wilson 1998c). A similar scenario is predicted for Tai O Bay. Impacts should be self-correcting through benthic recolonisation at all areas of temporary habitat loss, and the area of permanent loss is small.

Benthos in Tai O Bay will be affected in areas adjacent to the dredging sites through short-term local increases in sedimentation, possibly affecting individual survival and short-term community structure. Greiner Maunsell (1991) predicted similar impacts due to construction of the new airport (also of much larger scale than the current project). That study concluded that the benthic communities off north Lantau are acclimated to irregular sediment deposition and high levels of suspended solids due to the influence of the Pearl River estuary, and therefore able to persist in the face of sporadic heavy sedimentation events. Benthos of Tai O Bay, also subject to Pearl River influence, will be similarly adapted.

During dredging, the mean suspended solid concentration outside Tai O Bay has been predicted to be less than 4.6mg/L and sedimentation rates are likely to be $< 3.5 g/m^2$ (refer to Chapter 5). Sedimentation effects would, therefore, be short-term and limited in extent. Re-suspension of contaminants bound to sediments is not a concern because Tai O Bay sediments are generally classified as class A (least contaminated), as documented in Chapter 4.

Based on the mostly widespread/common status, low density, low numbers of species and low diversity of the benthic fauna found at the dredging sites, and the time period over which dredging will take place each day, impacts of dredging upon benthic ecology are predicted to be minor.

One group of benthic species has, however, been identified as of concern: horseshoe crabs. Tai O Bay provides a habitat for horseshoe crabs, although there is no recorded use of the area as a breeding site. Dredging will result in some temporary (anchorage and approach channel) and some permanent (breakwater site) loss of habitat for horseshoe crabs. The permanent habitat loss would amount to 1.3ha, or approximately 2% of the bay. Because the habitat loss would be subtidal, it would not affect horseshoe crab egg deposition or larvae development sites, which are in the intertidal zone. Based on the small percentage of the bay to be affected and the absence of impact on egg laying and larvae development habitats, the impact of loss of 1.3ha of subtidal habitat on horseshoe crabs is predicted to be minor. Mitigation measures are proposed to minimise mortality during dredging.

Water quality change would result primarily from increased sediment loads, as discussed in Section 5.8.2. Under each of the three modelled scenarios the WQO specifications would be met outside Tai O Bay, and in most locations inside the bay. Only in the immediate vicinity of the operating dredgers would exceedances occur. This could cause mobile organisms to flee the vicinity of dredging for a short time period, causing a short-term reduction in habitat area for affected species. Because the areas affected by excessive sediment loads would be confined to small areas where dredgers are operating such impacts are predicted to be minor.

No impacts are predicted to dolphins *S. chinensis* outside Tai O Bay because of the minimal increase in sediment loads and sedimentation in that area, and because dredging will be confined to within the Bay. Sediment loads within Tai O Bay would exceed WQO limits only in the immediate vicinity of operating dredgers, and dolphins would be expected to avoid those areas due to general disturbance caused by noise and equipment activity. Noise, disturbance, and sedimentation caused by grab dredgers will be substantially lower than that caused if hydraulic dredgers were used. On completion of dredging there would be no residual impacts on dolphins from noise, disturbance, or sedimentation. Because excessive sediment loads would be confined to the vicinity of dredger activity and because sediment loading would only occur during the course of dredging, impacts of sedimentation on dolphins would be expected to be minor.

Impacts on dolphins from vessel traffic inside Tai O Bay during dredging are predicted to be minor due to the slow speeds of dredging vessels and the tendency of dolphins to avoid areas of construction activity. However, mitigation measures are proposed to minimise potential collisions.

Based on the water quality modelling results (refer to Chapter 5), sedimentation from dredging could affect some intertidal areas of ecological interest, including the salt pans and the lower parts of Tai O Creek. Tai O reedbed and Leung Uk marsh would not be affected. Sedimentation in the salt pans is not an issue because the salt pans would be filled for mangrove restoration. Sedimentation could affect flora and fauna in lower Tai O Creek through reduced light penetration or degraded water quality (increased nitrogen concentration or BOD). Water quality modelling results showed that total organic nitrogen and BOD concentrations would not exceed the WQO criterion in the Bay or the Creek. Given the short-term nature of the increased sediment loads and the modelling results, it is unlikely that flora or fauna of lower Tai O Creek would be affected by sedimentation to a detectable extent; impacts are therefore predicted to be insignificant.

6.4.3 Off-site Disposal of Dredged Material

Off-site marine disposal of dredged material has been assessed as part of separate EIAs undertaken for the various marine disposal grounds in the SAR, and the ecological impacts of it have been found to be acceptable. It is therefore not necessary as part of this EIA to investigate ecological impacts resulting from sediment disposal at these designated sediment disposal sites.

6.4.4 Site Formation for the Mangrove Planting Area

Reworking of the Outer Seawall

The existing outer seawall fronting the salt pans will require more complete breaching to facilitate tidal exchange in the salt pans (related to mangrove plantation at this site). This would involve limited removal of the boulders making up the outer seawall, and could be accomplished by moving boulders landward into the salt pan area. Negative impacts of outer seawall re-working upon salt pan flora and fauna could include small-scale loss of existing mangroves and intertidal areas. Such impacts would be minor due to the limited areas affected. Ecological benefits are possible from this exercise through (a) increasing tidal exchange in the salt pans and (b) provision of boulders as substrates for sessile epifauna colonisation in the salt pans. Damage to the seawall, identified as a feature of historical/heritage value, is to be avoided as far as possible. In fact, however, the seawall has already been breached in several places, probably by storms and wave/tide action over time. In its current state, it is subject to further degradation from these sources. The breaching required to ensure adequate tidal flushing of the mangrove planting site will be accomplished by making narrow breakages in sites where the seawall is already breached and badly degraded. Thus only widening of existing breaches will be required. The seawall will not be touched in areas where it is in a better state of preservation, for example at the south end of the salt pans facing Fan Kwai Tong village.

Modification of Bunds Within Salt Pans

Breakdown of the old salt pan bunds at selected points as currently proposed and would potentially cause the loss and disturbance of vegetation established on the bunds and intertidal areas that is dominated by mangroves and *Suaeda australis*. Loss of reproductive mangrove trees would reduce availability of droppers for colonisation of the salt pan area following filling. The extent of disturbance and loss of mangroves depends upon the salt pan layout plan selected (Scott Wilson 1999); under the proposed layout (refer to **Figure 2.2**), bund modification would minimise the loss of existing mangroves and other vegetation. While the potential areas of mangrove lost would total less than 0.1ha, reproducing *Avicennia marina* trees could be affected, which would increase the degree of short-term impact.

Breaching of salt pan bunds will lower the gradient of bund slopes, thereby creating greater areas of suitable substrate for establishment of mangrove seedlings. Approximately 11ha of filled saltpans will be available for the creation of the mangrove planting area on completion of the project, as compared to the 0.3ha of mangroves which occurred there during the study period (see Section 6.3.4). The planted seedlings will replace those trees lost during construction in addition to providing adequate mitigation for the mangrove losses due to construction of the Port and Airport Development Strategy (PADS) projects.

Placement of Dredged Material into Salt Pans and Area Reworking

The salt pan area will be reworked in order to raise bottom levels to a level suitable for mangrove colonisation or plantation over some ±11ha. This will involve the placement of approximately 20,000m^3 of dredged sediment. Final mudflat levels will be set in the range +1.0

to 2.5 mPD. This will minimise the risk of overfilling which could adversely affect existing mangroves, including some reproducing *Avicennia marina* which are of conservation interest. Whilst considered limited, the degree of impact to existing vegetation will depend upon the future design of the mangrove planting area as developed from the mangrove layout plan (Scott Wilson 1999); impacts to existing vegetation are, therefore, considered to be minor.

Mortality of some benthic and intertidal fauna in the salt pans is likely as a result of filling/reworking. Fauna such as polychaetes and crustaceans might overcome this impact by burying themselves deeper for an extended period of time, while gastropods and mudskippers would most likely evacuate the areas being filled, or perish due to smothering. During previous studies at Ha Pak Nai, Deep Bay, a mudflat sampling station was affected by deposition of coarse sediment following heavy rain. Crabs began to recolonise the mudflat some 6 months later (Ecosystems Ltd. unpubl. data). Tests conducted as part of the Shenzhen River Regulation Project showed that instantaneous deposition of 5 cm of sediment on the mudflat resulted in a 31.2% reduction in benthos abundance and a 73.9% reduction in benthos biomass after 10 days, no rates of recolonisation were reported. Benthic fauna was completely eliminated by instantaneous deposition of sediments 20-30 cm in depth (Peking University 1995), and again, no recolonisation rates were reported. Practical difficulties associated with reworking of dredged muds in intertidal conditions result in the need for the deposition of muds in a single lift, rather than application of shallow layers. Therefore, the opportunity for migration and survival of organisms is likely to be greatest in areas requiring shallower depths of mud to achieve the desired formation level. Following filling, flora and fauna will begin to colonise the filled area from the less disturbed portions of the saltpans or from surrounding intertidal habitats. As compaction advances, crabs and mudskippers will begin to recolonise the area, excavating burrows and mixing sediments, meaning that in the long-term, impacts will be self-correcting. Given the anticipated short-term nature of impacts together with the common nature of benthic and intertidal species identified in the salt pans, impacts upon benthic and intertidal fauna are ranked as insignificant regardless of the mangrove layout design. No mitigation measures are proposed.

Reworking of the salt pans may cause birds to temporarily abandon the salt pans and possibly the adjacent freshwater or brackish marshes, leading to a temporary and short-term loss of foraging and roosting habitat for some species. Given the low diversity of species and numbers of birds using the salt pans, and their low importance to breeding ardeids, such impacts are ranked as insignificant.

6.4.5 Breakwater Construction

Construction of the breakwater will require approximately 12 months. Impacts during construction will include disturbance from vessel traffic, and increased sedimentation from seabed disturbance. The latter impact will be confined to the immediate vicinity of the breakwater, and will only occur during placement of the initial layer of fill. The impact will be limited to the duration of fill placement, and sedimentation will cease immediately upon completion of filling. Sedimentation would be minimal following initial fill placement because successive layers of fill would not be placed on the mud substrate but on previously placed fill material. Due to the previous disturbance and loss of habitat resulting from dredging, little additional impact is expected to arise from fill placement. This impact is identified as minor for all ecological receivers, including benthos and dolphins.

Increased vessel traffic during breakwater construction could cause a temporary impact on dolphin distribution or behaviour. However, all vessels would be capable of travel only at very slow speeds, therefore would not increase the risk of dolphin mortality due to collisions. Any impact on dolphin distribution or behaviour would be temporary, and would terminate on completion of breakwater construction. Mitigation measures are proposed to avoid collisions between dolphins and dredging vessels.

Construction of the breakwater will provide an opportunity to create a rocky intertidal habitat which would simulate natural boulder shorelines, and would have ecological benefits, including colonisation sites for sessile organisms and refuge areas for mobile organisms (refer to Section 6.6.5).

6.4.6 Reclamations within the Salt Pans

The reclamation areas in the northern end of the salt pans would cause a loss of 1ha of salt pan area and a few mangroves (*Avicennia marina, Kandelia candel*) established along a bund. This impact is considered to be minor based on the small areas affected.

During reclamation, erosion and sedimentation around the reclamation sites could have negative effects on nearby habitats within the salt pans by burying mudflat fauna or reducing water quality. Such impacts would be limited through the adoption of specific mitigation measures as detailed in Section 5.10.2, and as such these impacts are ranked as minor.

6.4.7 Project Interface with the Future PADS Mangrove Replanting Project

Discounting the 1ha area allocated for the reclamation, there will be an areal coverage of approximately 11ha of salt pan available for the future development of the mangrove planting area. Reworking the salt pans will provide a mudflat substrate at the proper level for colonisation by mangroves. The final levels of the filled area will range from +1.0 to +2.5 mPD intersected by drainage channels which are necessary to allow seawater ingress and flushing of the mangroves. This will enable creation of an area of mangrove habitat, to provide off-site compensation for some 7ha of mangrove lost due to the Port and Airport Development Strategy (PADS) projects. Restoration of mangroves is typically considered to be a major ecological benefit given the numerous ecological functions served by the mangrove habitat, including water purification, provision of a fish nursery habitat, provision of an invertebrate habitat, recycling of nutrients, storage of carbon and coastal protection (Tomlinson 1986). As identified above, the placement of fill necessary for the formation of the mangrove planting area and the 1 ha area allocated for the reclamations has been identified as resulting in a minor net loss of habitat. However, the future mangrove replanting project would be expected to result in an overall conservation benefit to the Tai O area as a whole.

6.4.8 Summary of Construction Phase Impacts

Predicted ecological impacts due to project construction are summarised in **Table 6.4**.

Table 6.4: Construction Phase Impacts.

Activity	Receiver	Potential Impact	Severity	Requirement for Mitigation
Dredging of anchorage, approach channels and breakwater site	Benthic fauna (including horseshoe crabs) and subtidal habitats at and near dredging site	± 1.3 ha of permanent habitat loss and ±22 ha of temporary degradation. Mortality of benthos and temporary reduction in habitat area for dolphins due to sedimentation	Minor	Yes
	Dolphins in and around Tai O Bay		Minor	Yes
	Intertidal habitats and biota, including salt pans and Tai O Creek	Habitat degradation	Insignificant	No
	Dolphins	Vessel collisions	Minor	Yes
Off-site disposal of dredged material	marine fauna	Habitat degradation	Assessed by other studies	n/a
Reworking of the seawall	Salt pan flora and fauna	Minor mortality or habitat loss along seawall area < 1 ha	Insignificant	No
Modification of bunds within salt pans	Mangroves	Mortality and short-term habitat loss of ±0.1 ha	Minor	Yes
Placement of dredged material into salt pans	Salt pan flora		Minor	Yes
	Intertidal and benthic fauna of salt pans	Mortality of some benthos and short-term feeding habitat loss to birds of ±11 ha	Insignificant	No
	Birds using salt pans		Insignificant	No
Breakwater construction	Benthic organisms and dolphins in Tai O Bay	Sedimentation, noise and disturbance	Minor	Yes
	Hard-substrate colonising fauna	Simulation of natural boulder shore on ±0.75 ha	Positive	N/A
Reclamation of sites within the salt pans	Flora and fauna on reclamation sites	Mortality and 1 ha of habitat loss	Minor	Yes
	Salt pan biota near reclamation sites	Mortality/injury, habitat degradation	Minor	Yes

6.5 Operational Phase Impacts

6.5.1 Assessment Methods and Sources of Impact

The significance of operational phase ecological impacts has been determined using the methodology described for construction phase ecological impact assessment (refer to Section 6.4). The following discussion focuses on marine and intertidal ecology, because no impacts to terrestrial ecology are predicted from operation of the anchorage.

The following operation phase activities are potential sources of ecological impact:

- discharge of sewage, bilge and other wastes from boats;
- increased vessel activity within the anchorage and approach channels;
- maintenance dredging of approach channels;
- restriction of tidal exchange in the salt pans; and
- process wastewaters generated from the reclamation areas.

6.5.2 Discharge of Sewage, Bilge and Other Wastes from Boats

Most of the vessels expected to use the anchorage currently moor at Cheung Chau, Tuen Mun, Aberdeen and Tai O village. Provision of the anchorage will increase the number of boats and the likelihood of vessel pollution in Tai O Bay (refer to Section 5.9). It has been predicted that up to 32m^3 of sewage a day may be discharged into the anchorage from vessels – this is equivalent to approximately 10% of the amount of sewage discharged directly into the marine environment from Tai O villages. The BOD load of such vessel discharges could be in the order of 7.16kg/day (refer to **Table 5.15**).

Water quality degradation resulting from leakage, bilge pumps, discharge of untreated sewage and spills may cause physiological stress to marine and intertidal fauna. Benthic fauna may be most affected due to their relatively sessile nature and consequent greater risk of long-term exposure to pollutants (see McChesney 1997). Impacts would be concentrated in the sheltered boat anchorage area due to the presence of the breakwater, which can reduce mixing of anchorage waters with the rest of Tai O Bay. The salt pans could also be prone to impacts from this pollution source, but to a lesser degree due to their physical separation from the source and the presence of mangrove vegetation, which will process nutrients and other contaminants.

The typical response of marine or estuarine benthic communities to increased pollution (nutrient) loads is a decline in species richness, and an increase in abundance of pollution-tolerant species such as polychaete and oligochaete worms. The benthic community beneath the anchorage is predicted to follow that pattern, and the degree of impact would be directly related to the volume of pollution discharged.

The impact of this change would be long-term, and would only be reversible on abandonment of the anchorage. Based on the containment of most impacts from sewage discharge within the anchorage area and the absence of benthic fauna of particular conservation concern recorded in the anchorage site and salt pans, the impact is ranked as minor. This ranking is supported by the finding that neither the saltpans nor the anchorage site was preferred habitat of horseshoe crabs.

Mangroves and other vegetation will naturally colonise and/or be planted in the salt pans. Mangroves in Hong Kong and elsewhere have a proven resistance to impacts of pollution from domestic, agricultural and industrial sources. In Hong Kong, mangroves thrive in heavily polluted areas such as the Shenzhen River channel, Inner Deep Bay, and near boat operation and maintenance sites such as the marinas at Pak Sha Wan, Port Shelter. As noted by Miao *et al*. (1994), and Tam and Wong (1996), mangrove soils are effective at removing nitrogen, phosphorous, and heavy metals from wastewater. Miao *et al*. (1994) documented removal of over 60% of total nitrogen and 88% of total phosphorous by a simulated *Kandelia candel* mangal. Removal of cadmium, nickel, lead, and zinc exceeded 70% in all cases. Although rates of contaminant removal in the published literature are typically not quantified on a unit-area basis, the mangrove plantation in the salt pans would be expected to contribute to a water quality improvement in the Tai O estuary, and would not be expected to suffer adverse impacts from exposure to contaminants introduced from residential wastewater discharges. Therefore, impacts from this source upon mangroves establishing in the salt pans are predicted to be insignificant.

Oil spills, however, can adversely affect mangrove ecosystems. Oil soaks into sediments and/or coats exposed trunks, prop roots and pneumatophores, and can cause extensive mortality of mangroves, decline in productivity or growth irregularities. If the amount of oil spilled is small, it is possible for mangroves to recover from the damage. The degree of damage and recovery is dependent on the type of oil spilled, the amount reaching the mangroves, the type of mangrove affected and other environmental conditions. For this development the impacts of oil spills would be expected to be minor and short-term, as all vessels using the anchorage would be commercial fishing boats or pleasure craft which would not carry bulk fuels or oils. Any spills would likely be of diesel fuel or engine lubricants, which would be expected to be of very small volume, and would readily disperse. It is noted that Marine Department (1999 pers. comm.) records show that P4's use highly volatile gasoline and that the potential for oil pollution from such vessels is very low. In addition, given that the discharge of oil/oily mixtures is illegal under the Shipping and Port Control Ordinance and that the pumping of boat bilge in confined waters is easy to spot by Marine Department patrols, such activities rarely occur in inland areas. Nevertheless, Section 5.9 considers a range of measures which may be able to reduce the occurrence of oil spillages within the anchorage and therefore, minimise the potential for impacts upon the mangrove habitat.

Based on the water quality modelling results (refer to Chapter 5), operational impacts on water quality are restricted to within Tai O Bay. Water quality of upper Tai O Creek, the marsh, reedbed and areas outside Tai O Bay will not be significantly affected. Therefore, operational impacts on the flora and fauna in these habitats are predicted to be minimal.

6.5.3 Increased Vessel Activity in Anchorage and Approach Channels

Increased vessel traffic in Tai O Bay will increase the level of noise disturbance to dolphins. Since dolphins navigate and locate prey using sound, this could affect their behaviour and foraging efficiency. Given that small numbers of dolphins enter the Bay, such impacts are considered insignificant. Increased vessel traffic will also increase the chance of collisions with dolphins, known to be an agent of dolphin injury and mortality (Jefferson 1998, Parsons 1997). However, given the slow speeds at which boats would travel within the bay, such impacts are considered to be insignificant.

Boat movements and human noise and activity in and around the anchorage will be a source of disturbance to sensitive wildlife. The key concerns are birds that use the salt pans. Considering the relatively low bird use of the salt pans at present, and the fact that disturbance would be concentrated along one or two sides of the salt pans which occupy a large area, this impact is ranked as insignificant. In the long term, the establishment of a large, contiguous mangrove area in the salt pans should provide adequate hiding places and buffers against human disturbance for sensitive wildlife.

6.5.4 Maintenance Dredging of Approach Channels

Maintenance dredging may be required every 5 years and involve removal of 120,000m^3 of sediment. Impacts of maintenance dredging would include short-term increases in sedimentation and deposition on the surrounding seabed which could cause smothering of benthic fauna. Impacts would be substantially less than during the construction phase, which will require removal of some 2.045Mm^3 of sediments. Due to the infrequent and short-term requirements for maintenance dredging, and to the relatively small volumes of material to be dredged, impacts are ranked as minor.

Maintenance dredging of the approach channels and boat shelter area may cause sediments to be deposited on the surface of the filled salt pans. This is predicted to have an insignificant impact on colonising or recently planted vegetation due to the infrequency and small scale of the dredging operations and the barrier effect of the outer seawall, which would impede movement of sediments onto the new mudflats. Furthermore, maintenance dredging would not be required during the first 5 years after planting, during which time the mangrove seedlings would become established and insensitive to sedimentation.

6.5.5 Restriction of Tidal Exchange in the Salt Pans

The presence of the breakwater and the boats in the anchorage may reduce tidal exchange within the salt pan area. The extent of reduction would be expected to be slight. The mangroves growing in the reedbed immediately east of the salt pans provide a useful index of the extent to which mangroves can tolerate reduction in tidal flow. Tidal flows must back 700m up Tai O Creek, flow 300m upstream through a constructed channel, flow through a concrete culvert into the pond surrounding the sports field, flow through the pond a distance of 150m, and then pass through a second culvert beneath the footpath before reaching the reedbed. Because any reduction in tidal flow to the created mudflat would be insignificant compared to that experienced by the established mangroves in the reedbed east of the salt pans, the impact on mangrove colonisation, growth, and survival on the created mudflat from reduced tidal exchange is predicted to be undetectable.

6.5.6 Process Wastewaters from the Reclamation Areas

The western reclamation may be used for boat maintenance and thus generate process wastewaters as identified in Section 5.9.2. Discharge of such wastewaters in the marine environment or the mangrove habitat could affect subtidal fauna. Section 5.11.5 specifies that treatment of process waters will be required before discharge to the marine environment. This will minimise impacts of effluent discharge because treatment will bring effluent quality up to levels required by HKSAR standards. No detectable adverse impacts are predicted from such discharges.

6.5.7 Summary of Operation Phase Impacts

Predicted impacts to ecology due to project operation are summarised in **Table 6.5**.

Table 6.5: Operation Phase Impacts.

Activity	Receiver	Potential Impact	Severity	Requirement for Mitigation
Discharge of sewage, bilge and other wastes from boats	Subtidal and intertidal fauna of Tai O Bay and its shores, including the salt pans	Degradation of water quality, physiological stress on biota	Minor	Yes
	Mangroves establishing in salt pans	Degradation of water/substrate quality	Insignificant	No
	Upper Tai O Creek, reedbed and marsh	Degradation of water quality, physiological stress on biota	Insignificant	No
Increased vessel activity within the anchorage and approach channels	Dolphins	Noise disturbance leading to reduced foraging efficiency; risk of collision	Insignificant	No
	Birds using salt pans	Noise disturbance leading to reduced foraging efficiency	Insignificant	No
Maintenance dredging of approach channels	Benthic fauna along channels	Smothering	Minor	Yes
	Salt pan ecology	Sedimentation	Insignificant	No
Restriction of tidal exchange in the salt pans	Mangroves establishing in the salt pans	Reduced dispersal, effects on growth	Insignificant	No
Operation of boat maintenance facilities on new reclamations	Subtidal fauna of Tai O Bay	Pollution, leading to reduced reproduction or survivorship	Would depend on type/scale of activities	Yes

6.6 Mitigation of Construction Phase Impacts

The EIA TM directs that mitigation of significant negative ecological impacts should be sought through avoidance, minimisation, and compensation, in that sequence. Total avoidance of ecological impacts from construction of the sheltered boat anchorage could only be achieved by not building the project (the “no-build” scenario); this would achieve preservation of the existing ecological environment, but would preclude realisation of the significant benefits of mangrove restoration.

Avoidance of certain impacts, or minimisation of unavoidable impacts, can be achieved by careful engineering design, choice of construction methods, scheduling of works, and elimination of unnecessary project components. Such methods are discussed below. Compensation measures are also considered where appropriate to mitigate project impacts.

6.6.1 Dredging of Anchorage, Approach Channels and Breakwater Site

It stressed that a key aim of the anchorage design has been to minimise dredging requirements and thus minimise the potential for adverse knock-on environmental impacts. In this regard it is noted that prior to the initiation of this Study, CED anticipated that the development of the anchorage would require dredging of 5.5Mm^3 of sediment. Through the adoption of innovative design techniques (e.g. the use of a partially dredged foundation) for the breakwater, the volume of dredging required to form the anchorage has been reduced by 63% to 2.045Mm^3, thereby minimising the potential impacts to marine ecology.

Potential impacts to dolphins, although ranked as minor, can be minimised through good site practice. Dredging crew supervisors will be notified of the potential for dolphin occurrence in Tai O Bay, and the need to avoid dolphins when operating vessels. Notification will also be made regarding the legal vessel operation speed in Tai O Bay.

Reduction of the volume of material to be dredged will minimise potential impacts to horseshoe crabs. During the dredging operation contractors will be notified of the possible presence of horseshoe crabs, and will be directed to return to the sea any found during dredging. The release site should be distant from the dredging operation, but in Tai O Bay.

Sedimentation during dredging and salt pan reworking will be controlled by various measures to minimise loss of sediments to surrounding waters. Measures to be applied include grab dredging as opposed to hydraulic dredging, and the dredging best practices as detailed in Section 5.10.1. These measures will minimise or eliminate impacts of sedimentation to marine benthos and dolphins. As specified in Section 5.10.1, if the need for additional protection is identified during environmental monitoring of the construction phase, silt curtains may be deployed.

After implementation of the above measures residual impacts will include defaunation of the dredged areas for a period of several months to several years, following which benthic fauna will have successfully recolonised the dredged areas. Residual impacts will affect the two approach channels (13.5ha) plus the anchorage site (10ha), or a total of 23.5ha. The breakwater site (1.3ha) would be converted from a soft bottom to a hard seawall substrate following dredging and thus will not be available for recolonisation by soft-bottom benthos. Residual impacts are predicted to be insignificant and acceptable.

6.6.2 Reworking of the Existing Outer Seawall

No mitigation measures are required.

6.6.3 Modification of Bunds Within Salt Pans

To minimise the potential loss of ecological value due to bund modification, retention of existing mangroves has been made a priority in the development of a mangrove habitat layout plan (Scott Wilson 1999). The layout proposed in **Figure 2.2** aims to minimise the loss of mangroves associated with the internal bund structures.

6.6.4 Placement of Dredged Material into Salt Pans and Area Reworking

Sediments will be placed in the salt pans mechanically, using a grab dredger. Mechanical placement of sediments will introduce less water to the salt pans than hydraulic dredging. This will eliminate the need to completely embay the salt pans during filling and will enable fish in the ponds to escape, thereby minimising fish mortality during the works.

Sediments placed in the salt pans will be distributed to the required levels using low-ground-pressure track equipment, which will result in rapid compaction of sediments, minimising subsequent erosion while enabling mangrove planting immediately on completion of filling.

The proposed afteruse of the reworked salt pans is a mangrove plantation. As noted in Section 6.6.3, the proposed mangrove layout aims to minimise the loss of existing mangroves, particularly *Avicennia marina* which are successfully reproducing. Retention of the existing mangroves will ensure future provision of propagules which are adapted to the site and which reflect the mangrove biodiversity of Lantau Island.

Construction equipment operators must be informed by the Environmental Team Leader (ETL) of the need to preserve existing mangroves. Mangroves which are to be avoided must be flagged to provide a visual reminder to construction workers. The Environmental Team (ET) must monitor worker activity on the site to ensure that mangroves marked for preservation are not damaged.

Whilst no mitigation is deemed necessary to mitigate the impacts associated with the temporary loss of foraging habitat within the salt pans, as a measure of good practice, salt pan reworking should, as far as possible, be undertaken outside the ardeid breeding season. While only limited information is available about the timing and duration of breeding at the Tai O egretry, it began in April in 1999, while breeding at local egretries usually occurs between April and July. Therefore, construction works in the salt pans should aim to be carried out between August and March.

As filling has been predicted to cause insignificant, temporary impacts to some benthic and intertidal species, direct mitigation is not deemed necessary as these organisms are not considered to be of high conservation value and have been shown to recolonise such sites after filling.

Whilst not a mitigation measure for the direct impacts caused by filling of the salt pans, the mangrove planting scheme on the formed salt pans will result in a long-term benefit by supporting a more plentiful and diverse biota than do the salt pans as they now exist.

6.6.5 Breakwater Construction

To mitigate impacts of habitat loss due to breakwater construction, the facing of the breakwater should be built of rock rip-rap. The rip-rap or rock armouring should be designed and constructed such that it simulates a natural boulder or rock shore. Quarry rock could be used, of good quality and with minimal fines content. AFD specifications for quarry rock to be used in artifical reefs, which require that 90% of the material be over 70kg and maximum weight not over 325kg, could be applied to the material used in seawall facing. This will provide a replacement habitat which will be of value to colonising biota.

Potential impacts to dolphins, although ranked as minor, can be minimised through good construction site practice. Crew supervisors will be notified of the potential for dolphin occurrence in Tai O Bay, and the need to avoid dolphins when operating vessels. Notification will also be made regarding the legal vessel operation speed in Tai O Bay.

6.6.6 Reclamation of Sites Within the Salt Pans

Given that impacts caused by the removal of existing salt pan area and bund to accommodate the 1 ha reclamation are predicted to be low, direct mitigation is not considered necessary.

Control measures to minimise erosion and escape of sediments from the reclamation sites should be implemented during the reclamation phase (refer to Section 5.10.2 for details of control measures).

6.7 Mitigation of Operation Phase Impacts

6.7.1 Discharge of Sewage and Bilge from Boats

Discharge of waste from boats could be addressed through installation of quay-side facilities to pump waste from boats to the trunk sewer system for treatment. This would, however, have little benefit given that fishing boats do not have on-board sewage holding tanks. Section 5.11.1 specifies a range of measures through which the discharge of sewage effluents and bilge from boats can be controlled. The measures are based on reducing discharges through education of boat owners about proper vessel maintenance and operation.

Reduction of sewage discharge to Tai O Bay from land-based sources will occur as sewage connection programmes are completed in Tai O (including the potential clearance of the stilted village areas), this will offset increases in discharges from boats into the anchorage.

Existing ordinances prohibiting improper disposal or discharge of waste should be strictly enforced at the anchorage. This will help to control discharge of bilge contaminated with oils.

Residual impacts will consist of an unquantifiable increase in the discharge of bilge from boats using the anchorage. Given that the maximum predicted volume of effluent from boats at the anchorage approximates 10% of the existing village discharge to Tai O Bay and Tai O Creek, and that sewerage schemes currently planned or under construction are estimated to reduce untreated sewage discharges by approximately 48% (800/1667), the total untreated sewage effluent input after construction will be substantially below what it is currently experienced.

Therefore, the residual impact of increased boat discharge would be offset entirely by improvements in the village sewerage system.

6.7.2 Increased Vessel Activity in Anchorage and Approach Channels

No mitigation measures are required.

6.7.3 Maintenance Dredging of Approach Channels

Maintenance dredging should be carried out under the same set of mitigation measures as specified for construction dredging (refer to Section 5.10.1). This will minimise impacts from sedimentation on benthic fauna along the channels, and on the biota of the saltpans.

6.7.4 Restriction of Tidal Exchange in the Salt Pans

The proposed salt pan layout includes breaching of the outer seawall to facilitate tidal exchange and flushing. No additional measures are prescribed to mitigate potential impacts of changes in tidal flows.

6.7.5 Process Wastewaters from the Reclamation Areas

As indicated in Section 5.11.5, specific measures will need to be undertaken to protect the marine environment and the salt pan mangrove habitat from process wastewaters generated from any boat maintenance facilities on the western reclamation. No other mitigation measures are proposed.

6.8 Summary of Mitigation Measures

Mitigation measures proposed to minimise the potential for ecological impacts during project construction and operation are summarised in **Table 6.6**.

Table 6.6: Implementation Schedule of Mitigation Measures for Ecological Impacts.

Section ref.	Mitigation Measure
6.6.1	Dredging mitigation measures as detailed in Section 5.10.1
6.6.3	Design salt pan mangrove layout to retain existing mangroves as possible; fully consider desirability of retaining existing mangroves in selecting mangrove layout
6.6.4	Grab dredge placement of sediments in salt pans; do not completely embay salt pans during filling
6.6.4	Distribute sediments within salt pans using low-ground-pressure track equipment
6.6.4	Design mangrove layout to retain existing mangroves as possible
6.6.4	Inform equipment operators to protect mangroves on salt pans
6.6.4	Demarcate existing mangroves using flagging
6.6.4	Monitor equipment operators to ensure mangroves are protected
6.6.4	Rework salt pans principally between August and March
6.6.5	Advise dredging supervisors to avoid dolphins when operating dredging vessels
6.6.5	Design breakwater facing to function as natural boulder or rock shore
6.6.6	Implement control measures to minimise erosion and escape of sediments from the reclamation sites (refer to Section 5.10.2)

Section ref.	Mitigation Measure
6.7.1	Implement control measures specified in Section 5.11.1
6.7.3	Dredging mitigation measures as detailed in Section 5.10.1
6.7.5	Implement standard water quality controls in operation of boat maintenance facilities (refer to Section 5.11.5)

6.9 Ecological Monitoring and Audit

The purpose of ecological monitoring is to verify the predictions of the impact assessment, detect unpredicted ecological impacts, monitor the effectiveness of mitigation measures, and recommend action plans in response to unpredicted impacts and/or failed mitigation. A programme of ecological monitoring to achieve these objectives is outlined below and are detailed where relevant in the EM&A Manual.

6.9.1 Construction Phase

To monitor impacts to subtidal and intertidal benthos, marine organisms and mangroves, a construction phase water quality monitoring programme should be undertaken (refer to Section 5.12). The methodology and threshold levels established for water quality purposes should be adequate to protect ecological resources. Monitoring sites, monitoring parameters and appropriate threshold levels are specified in the EM&A Manual.

In addition, during the construction phase, monitoring should be carried out to ensure minimal destruction of existing mangroves during salt pan area reworking.

6.9.2 Operation Phase

It is considered that following mangrove planting in the salt pan area, the ecological use of the created habitat should be monitored. Whilst this monitoring is outside the scope of the present Assignment, ecological monitoring recommendations are provided below for reference:

Benthos Colonisation of Salt Pans: Following reworking, flora and fauna will begin to colonise the area. As compaction advances crabs and mudskippers will begin to recolonise the area, excavating burrows and mixing sediments. The rate of benthic taxon accretion and the numbers of individuals in/on the salt pans could be monitored to assess whether the mudflat serves as a useful ecological habitat. Sampling and analysis methodologies could match those used for baseline surveys.

Mangrove Colonisation of Salt Pans: The rate of mangrove colonisation of the salt pans could be monitored in conjunction with the proposed plantation programme. Permanent sampling plots could be established on the mudflat to quantify numbers of established mangroves by species. Some areas with permanent plots are recommended to be left unplanted to enable comparison of plantation with natural mangrove colonisation.

Bird Use of Salt Pans: Birds are likely to be a key beneficiary group of the creation of increased mudflat and eventual mangrove area in the salt pans. Transect surveys could be used to quantify bird use of the created mudflats on the salt pans, and compared to pre-filling conditions. This would provide a useful indicator of the ecological benefits of the mangrove creation for other species.

6.10 Conclusions

The proposed works have the potential to affect the ecology of Tai O in two areas, namely; the offshore area designated for the anchorage and the intertidal salt pans allocated for future mangrove planting.

A key aim of the anchorage design has been to minimise dredging requirements such that any adverse marine ecology impacts are minimised. Nevertheless, approximately 23.5ha of soft seabed would be temporarily disrupted by deepening of the anchorage area and access channels. No species of conservation interest would be significantly impacted and the residual impact associated with the loss of the 1.3ha strip of soft seabed for the breakwater is insignificant. In short, the residual ecological impacts of these activities are largely temporary and predicted to be minor if the specified mitigation measures are implemented.

The salt pan filling will inevitably impact upon the existing habitat, (in this case, 12ha of disused salt pan including the 1ha lost to the northern reclamation). Given the low ecological value of this habitat and the measures that will be taken to retain its scattered mangrove plants, the residual ecological impact is considered to be insignificant and acceptable. Whilst not a direct benefit of this project, the future creation of the mangrove planting area will result in an overall conservation benefit to the Tai O area as a whole.

During anchorage operation, ecological impacts may be caused by water pollution arising from boat activities as well as wastewater discharges from the reclamation area. Measures to control water quality in Tai O Bay, including the discharge of vessel sewage and bilge have been proposed. Fully implemented, these measures should ensure that the potential impact upon the existing ecology as well as the future mangrove planting project would be minor.