Appendix 13.2

Population Biology of the Hong Kong/Pearl River Estuary Population of the Chinese White Dolphin (*Sousa chinensis*): Literature Review

1. INTRODUCTION

1.1. There are sixteen confirmed cetacean species in Hong Kong waters (Jefferson & Hung, 2007) and in March 2009, a Humpback whale was also reported in Hong Kong, which increased the number of recorded species to 17. There have also been two unconfirmed additional species, both baleen whales, in Hong Kong waters.

1.2. Although other cetaceans, including the Bottlenose Dolphin and False Killer Whale, have been previously noted in Hong Kong waters, these sightings are likely to be transient or extralimital records and only two species of cetaceans, the Chinese White Dolphin (CWD) or Indo-Pacific Humpback Dolphin (*Sousa chinensis*) and the Indo-Pacific Finless Porpoise (*Neophocaena phocaenoides*) are resident.

1.3. There appears to be only a limited overlap in the distribution of the CWD and Finless Porpoise in local Hong Kong waters, as the CWD tends to be predominantly distributed in the western waters, whereas the Finless Porpoise is usually recorded in areas further to the south and east of Hong Kong. The southwestern coast of Lantau around Fan Lau and the Soko Islands represent the only areas in Hong Kong where both species are commonly seen (Parsons *et al*., 1995; Jefferson, 2000; Jefferson *et al*., 2002).

1.4. As such, only the CWD has been consistently reported within the proposed study area of the extension of the existing Hong Kong International Airport (HKIA) and the third runway (3RS Project), comprising the area from Tuen Mun to the southwest of the existing airport platform. The Indo-Pacific Finless Porpoise habitat is located predominatly in the southern and eastern waters of Hong Kong and these animals do not occur along the west or north coasts of Lantau Island (Jefferson, *et al.*, 2002). As the proposed 3RS land platform will be formed by deep cement mixing and other non-dredging ground improvement methods, any marine excavation will be limited to the open trench and field joint works for the 11kv electicity cable diversion and bore piling for the approach lights and marker beacons. Thus, dredging and mud disposal will be minimal and the dispersion of suspended solids during the project works will be limited and confined. In additon, marine fill for the reclamation will also be brought in from outside Hong Kong which will negate the need for source material dredging in Hong Kong waters. Based on this, it is considered that the habitat of the Indo-Pacific Finless Porpoise would not be directly or indirectly affected by the project and this is confirmed by the water quality modelling in **Chapter 8,** which demonstrates that there will be no impact from the Project's construction or operation on the waters to the south of Lantau Island frequented by the Finless Porpoise. As such, it is considered that this resident marine mammal will not be impacted by the project and is not considered further, with this literature review focussing on the CWD only.

1.5. The largest known population of CWDs is located within the Pearl River Estuary (PRE), occurring in Hong Kong, Macau and the Guangdong Province waters. The total size of the Pearl River breeding population is difficult to determine accurately, although it has been estimated to comprise over 2,500 individuals, with about 103-193 inhabiting Hong Kong's waters at various times of the year, as of the late 2000s (Jefferson, 2007; Chen *et al.,*, 2010c). Numbers in Hong Kong have declined significantly in recent years (Hung, 2013), as further discussed below.

1.6. The presence of the CWDs in Hong Kong waters and the adjacent PRE of China's Guangdong Province was essentially unknown until relatively recently. The first mention of these animals appeared in Carnac-Temple's (1634-1637) log, in which he reported that white 'porpoises' were observed while lying at anchor off of Macau. The species was unknown to science at the time. In 1751, Osbeck (1771) reported live sightings of these animals from the Canton (Pearl) River and his observations formed the basis of the type description for the species (at the time, *Delphinus chinensis*). However, the first-ever scientific paper on the cetaceans of Hong Kong, Romer (1955), made no mention of the species. It was not until Melville's (1976) note reported several sightings of the species in Hong Kong in 1976 that this population of the species appeared in scientific literature. Soon after, Abel and Leatherwood (1985) reported several sightings of humpback dolphins in Hong Kong, together with a stranding in 1978.

1.7. The construction of the HKIA at Chek Lap Kok also highlighted the presence of the CWDs. It should be noted that no reliable survey data were available for the period prior to the construction of the HKIA and the hypothesis that the population was larger in the past was only an assumption. Since the mid 1990s, intensive research into the distribution, status and conservation requirements of this species have been on-going (see Jefferson, 2000, 2005 & 2007; Hung, 2008& 2013).

1.8. In 2008, the International Union for the Conservation of Nature and Natural Resources (IUCN) evaluated the status of the species *Sousa chinensis* throughout its range. The species was classified as Near Threatened (NT), although individual populations of the species may have a different status (Reeves *et al.,* 2008a). For instance, the Eastern Taiwan Strait population was classified as Critically Endangered, due to its very small population size and inference that a significant population decline has occurrred in the past (Wang *et al.,* 2007; Reeves *et al*., 2008b).

1.9. A workshop was conducted in 2008, which formed an an 'external review', mostly by experts from outside of Hong Kong, to evaluate the overall conservation status of the Hong Kong and PRE CWD population based on the IUCN criteria (Wilson *et al.*,, 2008). The extensive research conducted on this population since the early 1990s has made it clear that this is the best-understood population of CWDs (*Sousa chinensis)*. While the workshop participants were not able to clearly define the status of the population, they felt that there is the potential for a large number of human activities currently occurring in Hong Kong to have impacts on the population that are not sustainable.

2. SURVEY DATA SOURCES

2.1. As noted above, the main source of data on the CWD is obtained from the Hong Kong Agriculture, Fisheries and Conservation Department's (AFCD) long term CWD monitoring programme (AFCD, unpublished, 2013). However, besides these data, other studies and Environmental Impact Assessments (EIAs) have gathered additonal survey data relevant to to the proposed 3RS Project. A summary of the survey data used in this review is detailed in the sections below.

2.2. The AFCD long term monioring programme has been conducted by various consultants for AFCD from 1995 to the present, and is still on-going. Since 1995, this longitudinal research programme has been conducted on CWDs, together with the Indo-Pacific Finless Porpoises, in Hong Kong and with some additional study in the Pearl River Delta region. The annual marine mammal monitoring project in Hong Kong represents the continuation and extension of this programme. The territory-wide AFCD small cetacean monitoring programme covers nine zones within Hong Kong waters, including western and north Lantau waters, with vessel survey transects within each zone (AFCD, 2013). The nine monitoring zones and vessel transects are shown in **Figure 1.** These surveys provide the main data for examining abundance and trends in numbers of both CWDs and the Indo-Pacific Finless Porpoises in different areas of Hong Kong. In addition, the AFCD dataset has also included helicopter surveys (primarily of eastern waters of Hong Kong), and contains information on photographic records of individual dolphins, as well as detailed stranding records of all cetaceans in Hong Kong.

2.3. The AFCD dataset currently includes 18 years of data from vessel-based line transects, photo-identification surveys, periodic helicopter aerial surveys, investigation into CWD strandings, with later additional biopsy sampling of live dolphins, land-based surveys and acoustic studies using passive acoustic monitoring. There have been numerous published reports, theses and unpublished contract reports that have summarised the results of analyses of these data with respect to the CWD distribution, abundance, habitat use, ranging patterns, demography, life history, feeding habits, mortality and behavioral ecology for various time periods. These are summarised in **Table 1** below, with Hung (2013) providing the most recent comprehensive analysis.

Table 1. Summary of Literature Conducting Analyses of the AFCD Long-Term Monitoring Dataset

Reference	Data Period (Years)	Type of Data Analysed
Jefferson, 2000	1995-1998	Comprehensive
Hung and Jefferson, 2004	1995-2002	Ranging patterns
Jefferson *et al.* 2006	1995-2004	Strandings/mortality
Jefferson, 2007	1995-2007	Comprehensive
Hung, 2008	1996-2005	Comprehensive
Jefferson *et al.* 2012	1995-2009	Life history/growth
Hung, 2012	2002-2012	Comprehensive
Hung, 2013	2003-2013	Comprehensive

2.4. The field work on and major analyses of the data collected by the AFCD long term small cetaceans monitoring programme (**Table 1**) has been conducted primarily by T. A. Jefferson and S. K. Hung through the Ocean Park Conservation Foundation and later the Hong Kong Cetacean Research Project. One unique aspect of this work is that the large majority of all Hong Kong's Environmental Impact Assessments (EIAs) involving dolphin field work since 1995 have used data collection methods consistent with the AFCD monitoring and data from these studies have been incorporated into the AFCD long-term database. The following recent studies have produced CWD data that has subsequently been incorporated into the AFCD database:

- The EIA study on the Liquefied Natural Gas Receiving Terminal in northwest Lantau waters and Deep Bay conducted CWD surveys between July 2005 and May 2006. In total, 109 sightings of CWD were recorded in west Lantau waters, 79 in southwest Lantau waters, 62 in northwest Lantau waters, while only 25 sightings were made in Deep Bay.

- A systematic CWD line-transect survey in the PRE and Hong Kong waters (covering all of Hong Kong's waters and PRE from Hu Men in the north to Aizhou Dao in the southeast and Sanzao Dao in the southwest) was conducted between February 2006 to January 2007 for the "Proposed Port Development at northwest Lantau". The survey covered the entire known range of the CWD population in the Pearl River Estuary, and the waters at the exit of Modaomen, in order to calculate abundance and density in a 12-month period. In Hong Kong waters, individuals of CWD were frequently sighted along the narrow strip of coastal waters west of Lantau Island. Most sightings were made near the Tai O Peninsula, Kai Kung Shan, Peaked Hill and Fan Lau. The frequency of dolphin occurrence was slightly higher along the inshore transect lines than the offshore ones. The dense distribution of dolphin sightings throughout west Lantau was in accordance with results from AFCD's long-term monitoring studies.

- Eighteen systematic CWD line-transect vessel surveys were conducted between July 2008 to March 2009 for Hong Kong Boundary Crossing Facility (HKBCF), Hong Kong Link road (HKLR) and Tuen Mun – Chek Lap Kok Link (TM-CLKL) EIA studies. The survey area covered the central portion of north Lantau waters between Pillar Point and Brothers Islands. In total, 30 groups of CWD numbering 100 individuals were sighted, with most sightings (22 in number) being made in the western section of the northeast Lantau survey area (the transect covering the Brothers Islands), while another eight sightings were made in the eastern section of northwest Lantau survey area.

3. SCOPE OF LITERATURE REVIEW

3.1. In addition to the survey data from the sources noted above, references have also been obtained from other research and scientific papers as detailed at the end of this Appendix. The literature review presents discussion of the ecological baseline of the CWD based upon the following main categories:

- Occurrence;
- Distribution;
- Abundance;
- Detected declining trends in abdundance.
- Habitat use and behaviour and fine-scale habitat use;
- Social structure and geographical clustering;
- Individual movement and range (including travel corridors); and

- Residency patterns.

3.2. In addition, further discussion have been provided on:

- Life history and reproduction;
- Acoustics; and
- Threats and Human Impacts.

4. OCCURRENCE / DISTRIBUTION

Regional Occurrence and Distribution

4.1. Globally, populations of CWDs are present in the coastal and in-shore waters throughout the Indo-Pacific region, from Australia and China in the east to South Africa in the west (Jefferson and Karczmarski, 2001). It appears that the Chinese populations of the CWD have a relatively recent origin. Lin *et al*. (2010) suggested that *Sousa chinensis* originated in Southeastern Australia, and spread northward into Southeast Asia and China during the past 0.5-1.5 million years, as a result of sea-level changes that at various times expanded available habitat for these shallow-water animals. The recent origins of Chinese humpback dolphins may explain the relatively low levels of genetic diversity found in Chinese waters (Chen *et al*. 2010a).

4.2. The Hong Kong CWDs were once suggested by local green groups to be a unique population, separated from other such populations of the species. However, this was based on conjecture, with no valid scientific basis. Early studies into the stock structure of the Hong Kong animals suggested that there was exchange of genetic information between Hong Kong CWDs and those just west of Hong Kong in the PRE of China and Macau, and that a single population was found in this area (Jefferson, 2000). However, the possibility of links with other groups of CWDs along the mainland Chinese coast has been controversial. Interview surveys with Chinese fishermen suggested that 20-30 years ago dolphins were continuously distributed along the coast in such places as Dongshan, Gulf of Tonkin, Shantou, Jiazi, Shanwei and Magong. However, the CWDs were absent or rare in most of these areas and are patchily distributed along the Chinese coast (Wang *et al*., 2010). Although survey effort is minimal in most of these areas, and almost non-existent between them, this may suggest that the discrete areas of CWD occurrence that apparently occur today may not all be natural and may result in part from human-caused impacts over the past several decades.

4.3. Based on the current understanding of the distribution and discreteness of CWDs along the Chinese coasts, there are currently considered to be five known populations (Chen *et al*., 2009):

- Eastern Taiwan Strait,
- Xiamen/Jiulong River Estuary,
- Hong Kong/Pearl River Estuary,
- Leizhou Peninsula, and
- Beibu Gulf.

4.4. In addition, humpback dolphin records are known from a few other locations along the Chinese coast, as far north as the mouth of the Yangtze River (Wang and Han, 1996; Zhou *et al.,* 1997), and there may be additional populations in at least three other areas (Chen *et al.,* 2009; Chen *et al.,* 2010b; Wang *et al*., 2010):

- Ningde (north of Xiamen),
- Shantou (northeast of Hong Kong), and
- Dongshan.

4.5. It has been clearly established that the CWDs in Hong Kong and the PRE and those off the west coast of Taiwan (the Eastern Taiwan Strait population) are completely separate, with distinct colouration differences (Wang *et al*., 2008). Possible connections with dolphins that inhabit the Xiamen area have been more difficult to establish. Past studies, although suggesting that Xiamen dolphins formed a separate population, were not able to provide conclusive evidence of such population separation (Jefferson, 2000; Wang *et al*., 2008). A mtDNA study conducted by Chen *et al*. (2008) found several shared haplotypes between HK/PRE and Xiamen, and based on this, suggested that there was gene flow between these two areas. However, as pointed out by Wang *et al*. (2008), such shared haplotypes do not necessarily mean that there is contemporary gene flow, but in some cases may be an artifact of recent separation not allowing enough time for fixed differences to become established. More recently, Chen *et al*. (2010a) found highly-significant levels of mtDNA differentiation between specimens from HK/PRE and Xiamen, again suggesting (and this time with more solid evidence) that they are indeed separate populations.

4.6. Recent surveys in the western PRE indicated that CWDs have occurred in moderately-high densities in that area, far from the Hong Kong/mainland China boundary and that significant densities of CWDs have occurred west of Macau, as far west as Xiachuan and Hailing Islands. Photo-identification data have demonstrated matches between the eastern Pearl PRE and western PRE (Chen *et al.*, 2010c, 2011; SCSFRI and HKCRP, 2012), which provide solid evidence that the CWD inhabiting this area do not represent a separate population, but that the Hong Kong and PRE populations of CWDs extend to this area. Therefore, the balance of evidence strongly suggests that there is a single population of CWDs that inhabits the PRE, including Hong Kong's western waters.

Hong Kong Occurrence/Distribution

4.7. CWDs used to occur as far east as the eastern shores of Lantau Island, but are now very rarely spotted in this location and within Hong Kong waters. CWDs only regularly occur in the western waters influenced by the freshwater input from the PRE (Jefferson and Leatherwood, 1997; Jefferson, 2000; Parsons, 1997). **Figure 2** shows the CWD distributions around Lantau Island for six years periods, from 2007-2008 to 2012-2013. **Figure 2**, together with the graph in **Figure 3,** show that the most important areas of distribution in Hong Kong's western waters (with the highest sighting rates and densities) are west Lantau, northwest Lantau, northeast Lantau and southwest Lantau (see **Figure 3**).

4.8. There is a distinct seasonal component to dolphin distribution in Hong Kong. Although these are not technically migrations, as CWDs do not generally vacate particular areas at different times of the year, these seasonal shifts in density are prominent and predictable (Hung, 2008). In most areas of Hong Kong (which is along the eastern periphery of the population's known range), lowest densities occur from March to June, with highest ones from August to November (Hung, 2008). The peak in CWDs in Hong Kong in the wet seasons is influenced by water temperature, clarity and salinity in additon to prey abundance. However, in their main areas of distribution to the north and west of Lantau Island, they are found in moderate to high densities year-round (**Figure 2**). CWD "hot spots" occur along the west coast of Lantau Island from Fan Lau to Tai O, near the Sha Chau and Lung Kwu Chau Marine Park and in the general vicinity around the Brothers Islands, including south of the Brothers along the shore of Lantau Island at Siu Ho Wan (Dungan *et al.*, 2012, Hung, 2013). These patterns have been consistent over at least the last 17 years, as indicated by comparisons of distribution patterns from early work by Jefferson and Leatherwood (1997) and Jefferson (2000) with more recent maps of CWD sightings in Hong Kong (**Figure 2**). While lower densities occur during some seasons (more so in the wet season) in the region south and east of Lantau Island and also in Deep Bay to the northwest, the CWDs have nearly dissappeared from east Lantau waters in recent years (Jefferson, 2007; S. K. Hung, pers. comm.). The only Hong Kong region where they overlap in range with Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) is to the south of Lantau Island, in particular near the Soko Islands, but porpoises appear to avoid this area during the times of year when CWDs are there in larger numbers (Jefferson, 2002; Jefferson *et al*., 2002; Hung, 2008).

4.9. CWDs in Hong Kong prefer estuarine waters, with waters that are either too saline or too fresh not being a good habitat for this species and dolphins would occur in such waters only in low densities, if at all. While the species generally occurs only in shallow waters, usually less than about 20-40 m deep, Hong Kong's CWDs prefer the deeper range of waters, with steeper benthic slopes, often around islands and corners of land masses (Hung, 2008). CWDs appear to avoid shallow, flat-bottomed regions, areas with anchorage activities and fishing ports and piers, although such areas may be used as travel corridors and may still be important (Hung, 2008). There have been no specific studies of whether the recent trawling ban (effective on 31 December 2012) has affected CWD distribution.

4.10. Several species of fish that are known to be preyed upon by CWDs in Hong Kong have been identified among the species collected in trawl, purse seine, gillnet and handline sampling as part of the current EIA study. The CWD prey distribution is shown in **Drawing No MCL/P132/EIA/14-010** in **Chapter 14**, Fisheries). This figure shows that fish species preferred as prey by the CWD are distributed throughout the study area, to the north, east and west of the existing HKIA island, although the present key CWD feeding areas are known to be around Lung Kwu Chau and near the Tai O Peninsula (Hung, 2013) and around the Brothers Island/Siu Ho Wan.

4.11. As discussed above, while the larger-scale patterns of distribution of CWDs in Hong Kong's western waters are well-known based on the broad dataset collected by AFCD's long term monitoring programme, specific patterns of occurrence and distribution relevant to the 3RS Project works area are not known due to the restricted access to areas adjacent to the exisitng airport island and, therefore, specific surveys will be needed to fill this data gap.

5. ABUNDANCE / POPULATION SIZE

5.1. The key data for estimating abundance in Hong Kong waters have been collected by AFCD-funded monitoring efforts since 1996, or were collected by EIA projects and incorported into the AFCD long-term database, as noted above.

5.2. In the early years of the HKIA construction, the Hong Kong CWD population was believed by some to have only about 85 individuals (Smith, 1995). However, the first systematic surveys designed to estimate abundance quickly showed that there were many more individuals in the population (Jefferson and Leatherwood, 1997). Once initial surveys in all of Hong Kong's waters had been completed in the late 1990s, together with a large portion of the adjacent waters of the eastern Pearl River Estuary, it was demonstrated that CWD numbers in Hong Kong ranged from about 100 to 200 seasonally (Jefferson, 2000). The most recent data available (from 2012), shows the total abundance of CWDs in the three main habitat areas of Hong Kong (west Lantau, northwest Lantau and northeast Lantau) to be approximately 61 individuals in number (Hung, 2013). **Figure 4** depicts the abundance of CWDs for these three main survey areas between 2003 and 2012 and shows an overall decreasing level of abundance over time. The latest abundance levels can be compared to total population size numbering well over 2,500 individuals, as was established from the preliminary surveys in mainland waters of the PRE in the late 1990s (Jefferson 2000). At that time, it was speculated that dolphins from this population ranged further west still and might be found in large numbers in the western PRE. Until recently, this was unproven, but recent surveys in the far western Pearl River Estuary confirmed that the distribution extends as far west as Hailing Island (SCSFRI and HKCRP, 2012).

5.3. In recent years, surveys following the Hong Kong model have been conducted in the Chinese waters of both the eastern and western PRE, as far west as Xiachuan Island (Chen *et al*., 2010c, 2011). Seasonal differences were found in the distribution and density of CWDs, but in general densities were fairly high. Based on line-transect analysis of the data from these surveys, it was estimated that the Hong Kong and PRE CWD population numbered approximately 2,555 individuals in the wet season and 2,517 individuals in the dry season (Chen *et al*., 2010c). Further surveys in the far western PRE and Moyang River Estuary have found CWDs (with no apparent distributional gaps) as far west as Hailing Island, suggesting that total PRE population size may be larger still (SCSFRI and HKCRP, 2012). This makes it by-far the largest known population anywhere in the range of the species, although in most areas outside of China no information on population structure or abundance is available.

5.4. The overall abundance of the CWD at several survey areas has been estimated by Jefferson (2007) using line-transect analysis from vessel survey data collected during 2004 - 2006 (in part, using data from AFCD long-term monitoring). It was found that the area with the highest CWD densities occurred in the west Lantau waters, with exceptionally high densities in all four seasons of 159-219 individuals/100 km^2. The recorded CWD densities at northwest Lantau were quite high with 52-107 individuals/100 km^{2,} but relatively low for the northeast Lantau area with 6-34 individuals/100 km^2 (Jefferson, 2007). Since CWD densities are much higher in West and northwest Lantau than in northeast Lantau among all four seasons, it appears that CWD usage to the west of the Airport is much higher than to the east.

5.5. Overall patterns of density and abundance in Hong Kong's waters are well established and smaller scale patterns of density in 1 x 1 km grids have been evaluated by Hung (2008, 2013), as shown in **Figure 6.** However, more recent data on densities specific to the 3RS Project works area, specifically the area of restricted access, are needed and specific surveys to fill these data gaps will be required.

6. DECLINING TRENDS IN ABUNDANCE

6.1. There has been an observed decline in CWD encounter rates in most survey areas between 1996 to 2008 (Hung, 2009; Kallamaa, 2010), and recently more detailed work has shown an apparent declining trend in all three of the major habitat areas of Hong Kong (west, northwest, and northeast Lantau) from between 2001 to 2011 (Hung, 2013). An independent analysis by Jefferson of the AFCD long-term data on Hong Kong CWD abundance using line transect methods (**Figure 5**) also shows declining trends for these same areas, plus for southwest Lantau (**Figure 4)**. Group sizes have also declined between 2002 and 2011 (Hung, 2012). There has been no indication of an arrest or reversal of the decline from recent monitoring surveys of that part of the population that frequents Hong Kong waters (S. K. Hung, pers. comm.). A total of 345 groups of 1,097 CWDs were sighted during the recent vessel and helicopter surveys between April 2012 to March 2013 (Hung, 2013). Most CWD sightings were made in the west Lantau and northwest Lantau survey areas. The combined estimate of CWD abundance in west Lantau, northwest Lantau and northeast Lantau survey areas in 2012 was 61 CWDs, down from 78 in 2011 (**Figure 4**). This is the lowest number recorded during the past decade of monitoring.

6.2. A case study on the impact of high-speed ferries (HSFs) on local CWDs and finless porpoises (Hung, 2012, 2013) revealed that the total number of HSF trips to and from Macau and Mainland ports increased by 48% during 1999-2010 and this increase was dominated by the vessel traffic between Hong Kong and Macau. An examination of temporal changes in CWD usage at several sites at or near two major vessel fairways in North and South Lantau indicated that the notable decline in CWD densities at Fan Lau, around Soko Islands and the northeast corner of the airport in the past decade correlated closely with the increase in traffic volume of HSFs during the same period.

6.3. Collisions with marine vessels have recently been identified as a significant cause of injury and death for many species of small cetaceans worldwide (Van Waerebeek et al. 2007). The AFCD stranding programme has been running for well over 18 years and provides notable information on the cause of death for CWDs in Hong Kong. Of the 179 CWD strandings documented in Hong Kong, the cause of death (COD) could only be identified in 10% of cases due to decompostion. Where COD could be determined, 8 (4.5%) were from vessel collision, 7 (3.9%) were from fisheries activities, 2 (1.0%) were disease related and 1 (0.6%) was from another cause (net ingestion). These figures represent absolute minimum numbers and it is reasonable to assume that a notable proportion of the other 90% of strandings that did not have COD identified could have been as a result of vessel collision, as it is identified as the most frequent cause of death in the CWDs and from international evidence (Wells and Scott 1997; Honma et al. 2001; Van Waerebeek et al. 2007; Ritter 2010; Carillo and Ritter 2010). This would make vessel collision the most common cause of death for CWDs in the AFCD stranding database, and it indicates that vessel collisions would appear to be a potential factor in the cause of death for Hong Kong CWDs (see Jefferson et al. 2006, Van Waerebeek et al. 2007).

6.4. However, while it is understood that the decline in CWD numbers would be a result of a mix of causes including the fact that the CWDs are shifting to waters outside of Hong Kong, the analysis of the standing data indicates that death/injury from vessel collision may be a notable factor.

6.5. In 2012 and early 2013, some identified CWD individuals appeared less frequently near the Brothers Islands than in earlier years which coincided with the overall general abundance decline in northeast Lantau waters (Hung, 2013). It is possible that this decrease is in part due to the recent construction activities associated with the Hong Kong-Zhuhai-Macao Bridge construction and recently with the HKBCF and HKLR northeast of the HKIA (Hung, 2013).

6.6. It is important to note that these studies have only evaluated trends within Hong Kong, which is a small part of the population's range. On the Chinese side of the border (the largest portion of the population), there have not been adequate time-series of surveys to properly evaluate trends in abundance, although Xu *et al.* (2010) reported an increasing trend in the number of strandings and the number of newborns (especially in 2009). However, it is not clear if this takes into account increased survey effort. Past studies have shown that numbers of CWDs within Hong Kong fluctuate up and down in ways that are more consistent with shifts into and out of the survey areas rather than population size changes (Jefferson, 2000; Jefferson, 2007). The trends in the numbers of CWDs within the Hong Kong survey areas are not, therefore, accurate indicators of the size of the overall CWD population both in Hong Kong and the wider PRE. Thus, while there is evidence of declines in specific areas of Hong Kong, no statistically-defensible trend has yet been established for size of the overall Hong Kong / PRE population from survey data.

6.7. Based on computer modelling from stranding data and estimated life history parameters (not on actual time-series of surveys), Huang *et al.* (2012) estimated an annual 2.46% decline in abundance of the Hong Kong / PRE CWD population. This corresponds to a projected 74% reduction in population size after three generations. The authors used this information to suggest that the population faces a major risk of local extinction (extirpation) in the near future. However, the data were from strandings, and there are known to be strong biases in the occurrence, sex/age composition and health status of stranded CWD individuals (see Reddy *et al.,*. 2001; Peltier *et al.* 2012). Also, this study failed to properly address the very large amount of uncertainty in many of the model inputs, as well as the vast uncertainty in future events in the CWD's habitat and, therefore, the study may have little relevance to the actual risks and management of this population.

7. HABITAT USE AND BEHAVIOUR

7.1. As with the topics described above, virtually all of the data for examining habitat use of HK CWDs has come from the AFCD long-term database (see above). It has long been recognized that Hong Kong CWDs prefer brackish, estuarine waters as their habitat, as shown by the fact that the CWDs occur rarely in Hong Kong's eastern waters which have very little freshwater input and where instead the finless porpoises are more common (Jefferson, 2000; Jefferson *et al*., 2002). In many areas, there are higher CWD densities during the wet season, possibly related to prey abundance. CWDs tend to aggregate around islands, headlands and areas with steep bottom slopes (Hung, 2008).

7.2. Habitat use patterns of CWDs between 2008-2012 (Hung, 2013) revealed that the highest densities were recorded near the west Lantau shoreline, in the Lung Kwu Chau area in North Lantau, near the northeast corner of the airport platform, off Kau Ling Chung and Yam O, similar to previous years. Moreover, the grids with higher occurrence of feeding and socialising activities during 2003-12 have been located as in previous analyses, around Lung Kwu Chau and near the Tai O Peninsula (Hung, 2013). The west coast of Lantau and Lung Kwu Chau also appeared to be the most important CWD areas for nursing activities with higher densities of mother-calf pairs. All these areas can be viewed as priority habitats for the CWD.

7.3. The quantitative grid analysis by Hung (2008) has provided empirical data to support these observation findings. Although there are higher density grids scattered throughout Hong Kong, regions consisting of multiple high-density grids only occurred in three parts of Hong Kong's waters (**Figure 6**):

- The entire west coast of Lantau Island,
- The region around (and especially east of) Lung Kwu Chau, and
- The region around the Brothers Islands and Siu Ho Wan.

7.4. These are clearly the preferred areas for CWD feeding and socialising activities, and for females to rear their young calves, there has been long-term stability in the use of these high-density areas (Hung, 2008). Water temperature, clarity and salinity were all found to be correlated with dolphin occurrence, but these factors were thought to be secondary to dolphin prey abundance. Densities were also higher along natural, rocky coastlines, than along human-modified shorelines (Hung, 2008). These preferred habitats for CWD occurrence have been recognized since the early years of the CWD assessment work in Hong Kong (see Jefferson, 2000), but it was only after the quantitative assessment by Hung (2008) that these regions could be confirmed statistically.

7.5. As noted above under “Hong Kong Occurrence/Distribution”, the CWDs are to be found in and near estuaries of larger rivers, in shallow depths (but often in and near deeper channels, Hung, 2008), and turbid waters (Saayman and Tayler 1979, Ross *et al*., 1994, Jefferson 2000. A common characteristic is association with rocky substrates and near rocky, natural, shorelines (Karczmarski *et al*., 2000, Hung, 2008) and it is generally surmised that these animals, which feed on a wide variety of prey (Parsons, 1997, Barros *et al*., 2004), occur opportunistically where prey are most abundant. Parra and Ross (2009) call them “opportunistic-generalist” feeders, almost exclusively on midwater and demersal fishes, but also occasionaly on cephalopods and crustaceans.

7.6. It is difficult to assign general behavior to CWDs viewed only from the surface, especially in turbid waters in Hong Kong. Nevertheless, foraging appears to be the predominant activity of the CWDs, with about 23% (or higher) designated from the Hung (2008) study, and up to 55% as seen from shore by Parsons (1997) at Castle Peak. Travelling for foraging tends to be less frequent for the CWDs in Hong Kong than in areas where dolphins travel between river mouths (Karczmarski and Cockcroft 1999 as an example from Algoa Bay), and it is surmised by Hung (2008) that this is due to the general estuarine nature of the habitat, with prey not abundantly, but sufficiently, distributed throughout much of the area. Resting and socialising activities also occur for small proportions of time in Hong Kong waters (Hung, 2008).

7.7. Specific patterns of habitat usage are well known in the broader Hong Kong waters, specifically the western waters, from the grid analyses conducted by Hung (2008, 2012, 2013), and there is no need for further specific surveys to provide additional data on this issue.

7.8. Thus, overall sighting densities have been highest in north Lantau waters in 2011/early 2012 (Hung 2012, 2013) especially immediately north and east of Lung Kwu Chau, while the Brothers Island habitat to the east of the airport has declined in use since the early 2000’s (Hung 2008, 2012, 2013, see especially Fig. 34 of Hung, 2012)). The areas directly north and west of the airport, within about 2-3 km, have been considered to be used relatively sparsely as recorded by Hung (2012, 2013). While there has been little knowledge of CWD occurrence patterns at night, recent deployment of a click-detecting Cetacean Pods (C-Pods) off the east of Lung Kwu Chau indicates that CWDs used the area both day and night, with more click events recorded at night than in the daytime, but it is not known whether dolphins might be more vocally active at night (Hung, 2013).

7.9. Details on fine scale habitat are presented in the 1 X 1 km grid analyses conducted by Hung (2008, 2013) (**Figure 6**). However, further fine scale habitat use of the HKIAAA immediately north of the exisitng airrport island is needed to fully assess the impacts of the 3RS Project and further surveys would be required to fill this data gap.

8. SOCIAL STRUCURE AND GEOGRAPHICAL CLUSTERING

Social Structure

8.1. Although CWDs can occur in groups of up to several dozens (Jefferson, 2000), the CWDs in Hong Kong tend to associate in small groups of less than five individuals and with a high proportion of solitary or paired individuals. This social relationship was suggested (Hung, 2008) to be related to feeding on generally dispersed prey, with smaller groups of nearshore dolphins, compared to the larger group tendencies of species that live in more open ocean waters (Wells *et al*., 1980 and Balance, 2009). However, larger groups have been noted to occur with fishing trawlers, probably related to the stirring up of the seabed bottom, potential concentration of prey and fish dropouts making this a particularly useful resource (Jefferson, 2000), Hung and Jefferson (2004) details that the individual dolphins that more often follow behind fishing trawlers also tend to have larger home ranges. Interestingly, there has been a decrease in fishing activities in the 2000s compared to the 1990s, a concommitant shift in frequency of dolphins feeding behind only a few large fishing trawlers, and a shift in dolphin group sizes and overall ranging patterns, likely as a result of this decrease in fishing activity in Hong Kong waters (Hung, 2008). Similar details are not known for the PRE. It is also presently unknown what effects the Hong Kong wide trawling ban may have on CWD distribution and foraging patterns.

8.2. Hung (2013) recently updated group sizes and compositions for April 2012-March 2013, with CWD groups ranging from single individuals to 18 CWDs, with a mean of 3.2 + 2.7 S.D., the lowest in the past decade (Hung, 2013). The mean group size was slightly higher in northeast Lantau, than the average overall, at 3.6 dolphins. Mean group sizes in northwest Lantau, west Lantau and Deep Bay were similar to the average. Young unspotted calves (UC) and unspotted juveniles (UJ) accounted for 4.2% of the overall total of CWDs encountered during the Hung (2013) surveys of 2012-2013. **Figure 7** shows the proportion of groups made up by calves and juveniles and their changes in recent years. The UCs were sighted largely around the Sha Chau and Lung Kwu Chau Marine Park and also near the Brothers Islands and the UJs were evenly sighted throughout the northeast, northwest, and west Lantau waters. Overall, the occurrence of young calves was considerably lower in the past two years than during earlier surveys (**Figure 7**) and Hung (2013) states that this lowered percentage could be related to the general decrease in CWD abundance especially in west Lantau, which used to be identified as an important area for nursing activities (Hung, 2008, 2012).

8.3. Group sizes also appear to have been declining in recent years (**Figure 8**). The long-term AFCD data, including the most recent work summarised above, provide a sufficent background database for determining the CWD social structure and no further surveys are required.

Geographical Clustering

8.4. While Hung (2008) presented general core areas of known individuals in western Hong Kong, these data were recently further analysed and refined by Dungan *et al*. (2012), from a data set of 88 known individuals with resightings over ten years. Core ranges of individuals varied from only several square kilometers to throughout much of the western and northwestern Hong Kong area, but overall, two distinct social communities became apparent (**Figure 9**). Within the western waters, a larger Northern Community, centered around the general Sha Chau and Lung Kwu Chau Marine Park, as well as in the Brothers Island area, had higher numbers of associates than the smaller Western Lantau community, off west Lantau approximately from the village of Tai O and to the south. The Northern Community showed greater fission-fusion (fission/fusion is a type of society in which individuals associate for short periods of time, with few long-term associations), with short-term individual associates and the Western Community had more long-term associations among individuals. However, associations between the communities occurred commonly as well, with inter-community associations tending to have more calves present. Dungan *et al*. (2012) surmised that such mixtures may be biased towards females (and their calves), with common habitat use of these animals, especially in overlap areas between the Northern and Western Communities. The overlap area is marked by more calves than in either individual community area (Dungan *et al*., 2012), although note that recent studies have shown a decrease in young calf occurrence overall (Hung 2012, 2013).

8.5. In the past several years, a general trend was noticed of Northern Community members moving more often towards the west, and Dungan *et al*. (2012) suggested that human habitat alteration in the north could be responsible for this trend. It is important that these two social clusters, and the special value of the area of overlap between the two along the west coast of Lantau Island, be recognised and protected (**Figure 9**).

9. INDIVIDUAL MOVEMENT AND RANGE

9.1. As noted above, Dungan *et al*. (2012) further described two general overlapping social communities, with data derived from Hung (2008). However, it is emphasised that these basic social communities blend into each other and are not geographically islolated. They may also be changing, either due to natural or anthropogenic influences, or both. Thus, some members from the Northern Community are more often found westward recently than ten years ago (Dungan *et al*., 2012, Hung 2012, 2013) and at the same time, there has been a decrease in habitat use by CWDs east of the airport, off the Brothers Island and to the south of there (Hung, 2013).

9.2. Examination of individual range use through photo-ID techniques, using data from the early 2000s, revealed that most CWDs had very specific preferences for sites within their home ranges, which act as core area(s) receiving greater intensity of use (Hung, 2008). During the study period between April 2011 to March 2012, 192 individuals were identified with 635 re-sightings and a total of 52 being new individuals that were added to the photo-identification catalogue. The majority of re-sightings were made in west Lantau and northwest Lantau, and a number of new individuals from the previous monitoring period were also sighted repeatedly in this study period, showing their increased reliance on Hong Kong's waters (AFCD 2013). This overall trend continued for the rest of 2012 to March 2013 (AFCD 2013), with a total of 177 individuals identified, again with most being recorded in the west Lantau (45.8% of all the research effort) and northwest Lantau (30.5% of all research effort) and with a total of 77 of the 2012-2013 sightings being new individuals.

9.3. In 2012-2013, Hung (2013) began an exploratory set of six CWD individual focal follows from the observation vessel. These lasted between 0.70 and 2.97 hours and the CWDs were tracked for between 2.0km to 11.3km. This allowed for swim speeds and other basic parameters to be calculated. The swimming speeds of dolphins from those six tracks ranged from 2.22 to 4.83 km/hr, with a mean of 3.4 $\pm$ 0.9 km/hr. Swim speeds appreared highest when CWDs were travelling and lowest when engaged in feeding and milling (Hung, 2013). Six CWDs tracked provide too few data for meaningful conclusions relative to potential differences in behaviours in different areas north of Lantau (in and near the area of the proposed 3RS project).

9.4. During the past two years of published AFCD CWD data (Hung, 2012, 2013), between April 2011 to March 2013, seventy-nine sessions with nearly 326 hours of theodolite-tracking were conducted from Tai O, Sham Wat and Fan Lau shore-based stations, with the aim of determining if dolphin movement patterns and other behaviours changed in relation to vessel types and speeds. From these observations, 400 sightings of dolphin groups with 8,305 fixes of their positions were collected.

Analysis of the data indicated that CWD leg speed increased in the presence of commercial trawlers, and their reorientation rate also increased slightly in the presence of small tour boats originating from Tai O (Hung, 2012). Leg speed refers to the speed (in km/hr) of travel between two consecutive points obtained by theodolite (distance divided by time). This is the terminology defined in the Pythagoras software specifically created for marine mammal theodolite tracking. Reorientation rate refers to the amount an individual or group changes course over time (degrees/min) and is calculated by dividing the sum of all bearing changes by track duration. Increased leg speed indicates that CWDs may have been increasing their avoidance in the presence of generally straight-moving trawlers and displays of increased reorientations indicates manoeuvering reactions, also related to avoidance, by vessels orienting towards the CWDs. Analysis of the most recent AFCD data (Hung 2013) concentrated on the variables of swimming speeds, reorientation rates and linearity as related to vessel traffic off Fan Lau, of the souhtwestern tip of Lantau Island. Overall, swimming speeds and reorientations increased with an increase in the total number of vessels to use the area, but linearity decreased. There was thus an indication of more and more rapid “zig-zag” swimming as related to numerous vessels, a clear disturbance effect.

9.5. It was mentioned by Hung (2008) that travel and travel/foraging can occur anywhere, but particular areas have been more recently singled out as having a certain general behaviour (in daytime) more than another. Thus, sighting density of CWDs with corrected survey effort per km^2 is especially high for feeding directly to the east and west of Lung Kwu Chau, and of slightly less density but still high further towards the east into Urmston Road, and to the north of Lung Kwu Chau (Hung, 2012, Fig. 35) Social activity is also high around Lung Kwu Chau, especially directly east and north of the island (Hung, 2012, Fig. 35). At the same time, this Lung Kwu Chau “hotspot” of activity is also where many newborn and older calves are sighted (Hung, 2012, Fig. 36), making the area an indisputably important one for CWD in the north Lantau waters. Hung also began vessel based focal follows in 2012-early 2013 and concluded (based on only few data, however) that the area north of the airport, essentially between the airport and the Sha Chau and Lung Kwu Chau Park/Tuen Mun coastline, was an important one for CWD transiting between northwest Lantau and northeast (east and north of the airport) waters (Hung, 2013).

9.6. While notable data are available for the broader Study Area, additional surveys are required to focus on the 3RS works area and the aiport resticted zone to fill this data gap by assessing overall behaviour of the CWD to the north and west of the airport.

10. RESIDENCY PATTERNS

10.1. While quite a few studies on *Sousa* behavioral ecology have occurred elsewhere, most notaby off South Africa (Saayman and Tayler, 1979, Karczmarski *et al.*, 1999) and Moreton Bay, east-central Australia (Corkeron, 1990), it was Parsons (1997) who first investigated behavioral descriptions and behavioral ecology for the CWDs in Hong Kong, using shore vantage points mainly off Castle Peak and south of Lantau Island. Parsons found that these areas were utilized quite differently, with, for example, a general tendency for more near-shore CWDs to be off Castle Peak in the morning than in the afternoon, and this situation reversed south of Lantau Island. In additon, a weak relationship of most sightings in both areas during ebb tide was shown and it was assumed (however with no solid data) that both characteristics may be related to food availablity patterns. Overall, there was more time spent by CWDs feeding near Castle Peak than to the south of Lantau Island, showing association with fishing trawlers in the Castle Peak area, and the CWDs were in larger groups (at about 6-7 dolphins per group) in this area than those otherwise engaged in milling, travelling or socialising, where there were about 2-3 individuals per group.

10.2. More recent data on residency are likely to be especially relevant to the habitat use patterns of CWDs in the general north Lantau area. It is important to note that during AFCD-sponsored research, most of the 203 CWD sighted between April 2012 and March 2013 moved widely across different areas around much of Lantau Island. A total of 60 individuals were re-sighted in both northwest Lantau and west Lantau survey areas, another 40 individuals travelled between northwest Lantau and northeast Lantau, while only 31 CWDs occurred exclusively in northwest Lantau while they were sighted (but it is of course unknown where they moved at non-sighted times). A total of 8 individuals ranged as far as southwest Lantau to northwest Lantau, indicating that while there are certainly core areas of habitat use per many individuals (Hung, 2008, Dunghan *et al.*, 2012), many individuals also range widely (Hung, 2013).

11. LIFE HISTORY AND REPRODUCTION

11.1. Early attempts to study the reproduction and life history characteristics of Hong Kong/PRE CWDs were limited by the lack of fresh specimens and only very crude and preliminary estimates of most life history parameters could be made (see Jefferson, 2000). In recent years, however, data from photo-ID studies and biopsy sampling of live animals, as well as the steady accumulation of samples from several decades of dedicated stranding recovery work, have made it possible to examine in detail many aspects of the growth, reproduction, and life history of this population of dolphins (Jefferson *et al.*, 2006, 2012).

11.2. In summary, Hong Kong and PRE CWDs are born at an average length of about 101 cm, and growth is very rapid during their first several years (**Figure 10**). Near the age of attainment of sexual maturity (about 9-10 years in females and 3-4 years later in males), growth rate decreases and then increases again after they become sexually mature. Growth levels out soon afterwards, and the asymptotic length is about 249 cm for both sexes (physical maturity based on skeletal growth is reached at about 14-17 years of age). There appears to be little sexual dimorphism in growth patterns of this population, with males and females about the same size. Dolphins live to at least 38 years of age and perhaps longer. Maximum lengths and weights of about 268 cm and 240 kg are achieved. However, there is significant sexual dimorphism in the development of color patterns. Both sexes are born unspotted (dark gray on the back, and lighter on the belly). Most adult females are lightly spotted or virtually unspotted, but most adult males appear to retain some spotting into old age, while females tend to lose their generally-sparse spots earlier than do males. Reproduction has a seasonal component and although some calves are born throughout all months of the year, there is a strong peak in calving from March through June, which is at the beginning of the wet season (**Figure 11**). The months showing the highest number of births in the current dataset (Jefferson *et al*., 2012) are May and June and these should be considered the apex peak of the calving season, a time period when females and their newborn calves would be most vulnerable to disturbance by human activities. The general peak in calving from late spring to early summer months is supported by both the work using strandings, as well as data from sightings of young calves at sea (see Jefferson *et al*., 2012).

11.3. Overall, compared to other related species, calf production appears to be rather low and there is a long intercalf interval of about 5 years and many calves appear to die within their first few weeks to months of life. This is thought to be related to the very high contaminant loads (especially high DDTs) that CWDs carry in their tissues (Jefferson *et al*., 2012). This may limit the population's ability to adapt to, and recover from, human impacts of various sorts. The most important areas for mother/calf pairs are the regions of west Lantau and the area around Lung Kwu Chau (Hung, 2012). From sightings data, Hung (2012) found that production of young calves had overall declined in recent years, but also noted that in 2011-12 there appeared to be a rebound in the proportion of newborns.

12. ACOUSTICS

12.1. Vocalisations of CWDs were partially described by Zbinden *et al*. (1977) and Pilleri *et al*. (1982) and more thoroughly for Moreton Bay, Australia, by Van Parijs and Corkeron (2001). Overall, CWD sounds possess similarities with those of other dolphins, especially with those of common bottlenose dolphins (*Tursiops truncatus*). Both produce: 1) broadband clicks, probably for echolocation; 2) burst pulses; and 3) narrowband frequency-modulated sounds such as whistles, with the latter two likely to be for communication purposes (Van Parijs and Corkeron, 2001).

12.2. The first descriptions of the sounds produced by the Hong Kong CWDs were made by Goold and Jefferson (2004). They described clicks typical of those of other delphinid species, extending up to at least 200 kHz, and with pulse durations of a few tens of microseconds. Sims *et al.* (2011) published more detailed (though still preliminary) descriptions from AFCD-derived data from only 12 recordings of CWD sounds gathered in the waters off the north and west of Lantau Island. Moreton Bay dolphins and Hong Kong's CWDs make broadly similar sounds, except that two marked low frequency "quacks" and "grunts", both social sounds <3.7kHz in frequency, described by Van Parijs and Corkeron (2001), were not recorded in the recent Hong Kong study. These were either absent or of low occurrence and, therefore, not present during the few recordings made, or masked by loud low-frequency anthropogenic sounds in Hong Kong waters (see Würsig and Greene 2002). Whistles were present and numerous, and while none had the same frequency-sweep shape as those of Moreton Bay, whistles had similar overall frequencies with major harmonics at about 4 to 7kHz.

12.3. Humpback dolphins (including CWDs) produce whistles and frequency modulated click trains for communication, as well as echolocation clicks. Whistles are produced largely within frequencies from about 3 to 8 kHz, although can be higher, and clicks tend to be much higher, with echolocation clicks for fine-scale close-up discrimination going beyond 100kHz (Sims *et al.*, 2011, Hung, 2013).

12.4. Echolocation-type click sounds ranged below and above the usable frequency response of equipment available to Sims *et al.* (2011), at approximately 68kHz, so it was not possible to ascertain the highest click frequencies obtained. There were two types of inter-click intervals (ICIs) of the click trains, those with constant intervals and those with variably fluctuating intervals, as recorded for other echolocating dolphins and bats (see summary by Au 1993). These types of click trains are very likely related to whether a dolphin is simply scanning the environment (constant ICIs) or echolocating while ranging onto a target, such as a prey item or another dolphin (variable ICIs, which would be increasing while approaching the target). Recently, Hung (2012, 2013) expanded noise studies during AFCD surveys. He also described many whistle types that matched those of other studies (Van Parijs and Corkeron 2011 and others), and concluded that Hong Kong CWDs often have complex whistle contours with a high degree of frequency modulation in multiple whistle types.

12.5. Until very recently, there were no audiograms (characterizations of hearing sensitivity by frequency) available for *Sousa chinensis*, as this species has only rarely been held in captivity, where such measurements are usually made. However, Li *et al.* (2012) very recently provided the first audiogram of a captive CWD, based on measurements taken from a 2.25-m male specimen, which was live-stranded in southern China. The CWD was estimated to be about 13 years old. It showed high sensitivity in the range of about 11 - 128 kHz, with the highest sensitivity of hearing being at 45kHz (Li *et al*., 2012). Unfortunately, no useful data on the low-frequency hearing range of these animals were obtained, as the lowest sounds played to the CWD were only at about 5.5 kHz, well above much of the noise from shipping and other industrial activities that occurs in Hong Kong (Würsig and Greene, 2002, Sims *et al*., 2012) and elsewhere.

12.6. No calculations of sound pressure level have been made for CWDs, but data from bottlenose dolphins (*Tursiops sp*.), which are of a similar size to CWDs, can be used as a basis. For bottlenose dolphins, lower frequency whistles of 7-13kHz can have a source level (expressed as 1 m from the dolphin) of about 168 dB. These can be heard in shallow muddy-bottomed waters, similar to the Hong Kong environment, up to about 2 km distance without background noise, with some higher frequency whistles (13-19 kHz) detectable to an even greater distances (Quintana-Rizzo *et al*., 2006). Janik (2000) calculated similar source levels and estimated a potential communication distance of about 1.5-4 km at a Beaufort 4 sea state, stating that this long range distance makes it likely that dolphins are in contact with each other over much greater distances than a "group" of animals within a travelling and closely-spaced unit.

12.7. Underwater noises caused by human marine activities have the potential to cause disturbance of the CWDs normal activities and can mask important communication and ranging sounds. While such noise can occasionally be intense and loud enough to injure or kill CWDs (such as in the case of blasting or percussive piling operations), the impacts on dolphins are usually sub-lethal and affect behavioural patterns and activities. Anthropogenic noise is believed to be a source of stress for cetaceans (Wright *et al*., 2007a,b). There are limited data on how noise from vessels, dredging, reclamation and various marine construction activities influence CWD behavior and physiology, with the recent exception of AFCD studies and vessel noise, cited aboveas Hung (2012). There is concern that disturbing noise may cause the CWDs to abandon critical habitat areas and thereby reduce their survival and reproductive prospects. For instance, it has been demonstrated that CWDs avoided the area of the construction for the Aviation Fuel Receiving Facility, which used percussive piling that created intense underwater noise (Würsig *et al*., 2000). However, **Figure 12** demonstrates how a bubble curtain can be used to reduce underwater sounds levels for CWDs.

12.8. Acoustic disturbance can also occur from marine traffic. Recent dedicated studies have investigated this aspect on Hong Kong CWDs (Ng and Leung, 2003; Hung, 2012; Sims *et al*., 2012; Piwetz *et al*., 2012). Sims *et al*. (2012) and reported that vessel noise at >= 100m exceeded the levels of CWD sounds at closer distances and suggested that vessel noise may be causing masking effects on CWD vocalisations. While the seriousness of this threat and the particular ways that if affects the CWDs is not clear, it is apparent that acoustic disturbance from vessels is an issue for these animals (see further discussion in Individual Movement and Range).

13. THREATS AND HUMAN IMPACTS

13.1. There are a large number of potential human impacts on the Hong Kong and PRE CWD population, although it has been difficult in the past to clearly rank these in importance. Both entanglement in fishing gear and vessel collisions are clearly important, as stranding records of CWDs in Hong Kong based on the period 1996 - 2012 showed the number of annual strandings ranged from 5 (2006) to 17 (2007) and the stranded CWDs have shown evidence of mortality caused by one of these two factors (Parsons and Jefferson, 2000; Jefferson, 2000; Jefferson *et al.*, 2006). CWD stranding data has been collected over a period of over 18 years. During this period, 179 CWD strandings were documented in Hong Kong. The cause of death (COD) could only be identified in 10% of cases due to decompostion. Where COD could be determined, 8 (4.5%) were from vessel collision, 7 (3.9%) were from fisheries activities, 2 (1.0%) were disease related and 1 (0.6%) was from another cause (net ingestion). However, there has not been any apparent increase in CWD strandings in Hong Kong since the AFCD long-term study began in 1995/1996 (**Figure 13**), and this is suggestive that mortality might not be the only factor causing the decline in CWD numbers, including the fact that the CWDs are shifting to waters outside of Hong Kong as a result ofavoidance of certain areas and possibly lowered reproductive success caused by ingestion of environmental contaminants.

13.2. Hung (2008) showed with quantitative data that CWD use of the area where the contaminated mud pits are located north of the airport platform has declined from the late 1990s to the late 2000s. Similarly, Hung (2008) also provided evidence of a decline in the usage of the area at Tuen Mun Area 38.

<u>Vessel Collision</u>

13.3. Although there is no recorded instance in which a CWD has been directly observed as being hit by a vessel, evidence from injuries and scars on photo-identified CWDs, as well as records from the marine mammal stranding programme (Jefferson *et al.* 2006; AFCD unpublished data), indicate that it does happen (see Parsons and Jefferson, 2000). Although many CWDs apparently survive such encounters, there is a reason to believe that some incidences are fatal. There have been no indications as to how often such events occur or how many CWDs may die annually from this threat. However, between 1.2% and 1.8% of CWDs recorded in the in the photo-ID catalog bear clear-cut propeller scars (Jefferson *et al.*, 2006). CWDs have been found stranded in Hong Kong, apparently cut in half, presumably by fast ferries with sharp-edged hulls. Thus, this can be considered as a threat, with high-speed vessels (especially passenger ferries) being thought to be the major culprits.

13.4. As noted in Section 6.3 above, CWD strandings data in Hong Kong from the start of detailed records (1995) through August 2013 (a period of 18.5 years, AFCD unpublished data) detailed that 179 CWD strandings occurred in Hong Kong and, of the 10% where cause of death (COD) could be identified, 8 (4.5%) were from vessel collision. These figures represent absolute minimum numbers and it is reasonable to assume that a notable proportion of the other 90% of strandings that did not have COD identified could have been as a result of vessel collision, as it is identified as the most frequent cause of death in the CWDs and from international evidence (Wells and Scott 1997; Honma et al. 2001; Van Waerebeek et al. 2007; Ritter 2010; Carillo and Ritter 2010). Thus, while it is understood that the decline in CWD numbers would be a result of a mix of causes including the fact that the CWDs are shifting to waters outside of Hong Kong, the analysis of the standing data indicates that death/injury from vessel collision may be a notable factor.

Fishery Bycatch

13.5. Worldwide, bycatch in fishing gear occurs wherever cetaceans and fisheries overlap and it is thought to be the greatest threat to many dolphin populations (Read *et al.,* 2005). CWDs have been recorded to get caught in fishing nets and lines in Hong Kong (Parsons and Jefferson 2000; Jefferson *et al.,* 2006) and fatalities resulting from fishing gear entanglement have been well-documented in the stranding programme (Jefferson, 2000; Jefferson *et al.,* 2006; AFCD unpublished data). Most of these incidences appear to be related to trawl nets, with evidence that some CWDs spend significantly large amounts of time feeding in close proximity to active trawlers (see Jefferson, 2000). Some CWDs survive entanglements and collisions with fishing nets and lines, as evidenced by the 2.9% - 6.8% of CWDs in the photo-ID catalog that have scars from nets and ropes (Jefferson *et al.,* 2006). Taking into account the injuries from marine vessels, up to 8.6% of photo-identified CWDs in the PRE bear human-related scars. In contrast, 30% of a population of the same species of dolphin off the west coast of Taiwan is scarred in these ways (Wang *et al.,* 2007). Due to the absence of a fishery-observer programme in Hong Kong, there is no data on the number of CWD entanglement mortalities per year. However, bycatch is believed to be one of the major causes of human-related deaths for these animals.

Direct Capture

13.6. There is no evidence that direct killing has ever been a major factor for CWDs in Hong Kong, although there has been no research done on these animals until the early 1990s. There is no recordings of any direct capture taking place in the mainland waters of the western PRE either, but again, there has been little research on that segment of the population. It should be mentioned that live captures, athough they do not involve intentional killing of the individual, have the same result to wild populations, as CWDs are removed from the gene pool.

Loss and Degradation of Habitat

13.7. Hong Kong is developing extremely rapidly, and has been for many decades. The opening of the new airport in Hong Kong's western waters has resulted in increased development pressure on this part of Hong Kong and it has now become the focus of plans to create links with mainland cities to the west and north, and to develop tourism hubs for the surrounding Pearl River Estuary region. As a result, there is extensive development in the area north of Lantau Island, which has involved reclamation of shallow seabed areas to create useable land; dredging to create and maintain deep channels and basins and establish pits for dumping; building of structures such as cargo terminals, bridges, jetties, and piers; and other anthropogenic activities (see Jefferson *et al.,* 2009). All these result in a physical loss of habitat for CWDs and even when no net loss occurs, often there can be degradation of the quality of the marine habitat that provides critical resources for the CWDs.

Harassment by Ecotourism Vessels

13.8. This is a relatively new issue, as CWD watching in Hong Kong has only been a major activity since about 1995. When conducted properly, with appropriate education, such ecotourism can have a positive outcome for dolphins. However, if not regulated thoroughly and education is poor or non-existent, then this can become yet another threat. Unfortunately, in Hong Kong, many operators conduct dolphinwatching as a way to make quick money off tourists with little to no value-added services. There is often little to no education, and although Hong Kong has a well-developed code of conduct, it is voluntary, and therefore non-enforceable. Evidence of harassment by CWD-watching boats (especially in the area of Tai O) has been obtained, clearly showing that this is an issue of concern (Hung, 2008, Piwetz *et al.,* 2012).

Distrurbance by Aircraft Noise

13.9. Although there have been no detailed studies examining this aspect for CWDs in Hong Kong, there is currently no evidence that dolphins are avoiding the area directly to the east or west of the existing HKIA, the major routes for departing and landing aircraft, due to the aircraft themselves. The area directly to the west of the airport platform traditionally has been considered a lower density area, but it is unknown whether CWD occurrence patterns have changed there since the airport opened in 1998.

13.10. Much has been written about the effects of aircraft noise on marine mammals (reviews by Richardson *et al.,* 1995, Würsig *et al.,* 1998 and Luksenburg and Parsons, 2009), but there has been little detailed work on effects of airports near dolphin habitats. In general, whales and dolphins tend to dive abruptly when airplanes fly directly overhead at less than about 250-460m altitude, but reactions are extremely variable, depending on species, general behaviour, sex-age composition, and other factors (Würsig *et al.,* 1998).

13.11. In reality, the strip of water in which significant noise from aircraft overhead enters the water is rather narrow, representing an approximate 26° cone around the location of the sound source at any one time – this is referred to as 'Snell's Cone' (as associated with Snell's Law of incidence of light or sound refraction). Outside of Snell's Cone and in the absence of large surface waves, the majority of the sound energy is reflected off the water's surface and little enters the water column. Therefore, the issue of aircraft noise disturbance to CWDs is considered to be a minor issue.

Contamination by Pollutants

13.12. There has been a substantial amount of work conducted on examining the concentrations of various environmental contaminants (heavy metals, organochlorines, organotins, PBDEs, and even sewage-borne bacteria) in Hong Kong CWD tissues since the mid-1990s (Parsons, 2004; Jefferson *et al.,* 2006). However, the understanding of how these compounds are affecting the CWDs and the overall population is still rudimentary.

13.13. Within Hong Kong waters, two groups of organochlorine (OC) compounds have been identified as potentially quite high and of possible health concern to dolphins: DDTs (Parsons and Chan, 1998; Minh *et al.,* 1999) and PCBs (Minh *et al.,* 1999). The organochlorine classes of DDTs and PCBs (often called Persistent Organic Pollutants, or POPs) have therefore been the focus of much of the work and recent studies have found compelling, although still largely-circumstantial, evidence that these contaminants are having a negative effect on CWD health, survival, and reproduction (Jefferson *et al.,* 2006). In particular, DDTs have been identified as the most serious concern, due to the very high levels in some specimens, and the fact that their input to the system has been deemed to be very recent, based on DDE/DDT ratios (Parsons and Chan, 1998). Using a toxic equivalent approach (TEQ), Minh *et al.,* (2000a) determined that PCBs (and their congeners) exceeded levels that have been associated with immunosuppression in harbor seals (*Phoca vitulina*). In fact, the TEQs for Hong Kong CWDs were found to be the highest among 14 areas/species compared (Minh *et al.,* 2000b). Finally, two newly-identified microcontaminants have been discovered in significant concentrations in tissues of CWDs from Hong Kong (Minh *et al.,* 2000c). Their specific effects are not yet known.

13.14. Little is known about newly-recognized chemicals, such as PFOA/PFOS, which are used in fire-fighting foams. However, these should not be assumed to be safe.

Other Threats

13.15. Other diagnosed causes of death for CWDs stranded in Chinese waters of the PRE from 2003-2009 (besides boat strike at 46% of diagnosed causes and fishery bycatch at 31%) were disease, blast injuries, and swallowing foreign objects, at 8% each (Xu *et al.,* 2010). It should be mentioned that the potential cumulative effects of these various threats on the CWDs have not been properly evaluated but it is generally perceived that cumulative impacts may be a key issue.

14. SUMMARY

14.1. After nearly 20 years of data collection, detailed scientific study has shown that the Hong Kong CWDs are part of a larger population in the PRE (of about 2,500 animals, the largest known of the species anywhere in its range), and that the CWDs are common in Hong Kong's western waters. The Sha Chau and Lung Kwu Chau Marine Park is thought to have been a successful management measure, with CWD densities in the park significantly higher than in most of the surrounding habitat more than a decade later (Hung, 2008).

14.2. However, coastal development in both Hong Kong and the surrounding areas of the Pearl River Estuary in China is on-going and CWDs continue to be affected by increased marine traffic and vessel collisions, noise from construciton activities and entanglements with fishing nets. Habitat loss continues through the on-going developments and tissue samples from live CWDs have shown that contaminant levels are high in these CWDs and could be associated with signs of reduced calf survival (Jefferson *et al.,* 2006). Evidence of a decline in densities in Hong Kong's waters over the past several years suggests that caution is justified in considering this population's conservation prospects.

14.3. Despite all this, the true status of the population and the importance of various potential threats as factors causing dolphin mortality are still not known with any certainty. With well over 2,500 individuals in the PRE as a whole and a lack of evidence for an overall long-term decline in the total population, the population does not appear to be in any immediate danger of extinction. However, modelling studies (Huang *et al.,* 2012) have suggested that within a few generations there is a real extinction risk. While the accuracy of such modeling exercises can be debated, CWDs habitats clearly remain under pressure from human activities. Analyses also suggest that, besides the CWD shifting out of Hong Kong into mainland waters, mortality from vessel collisions may also be a potential factor.

14.4. In terms of establishing an ecological baseline for the CWDs in the 3RS Project area, the extensive data from the AFCD long term monitoring programme and analysis of these data has provided notable details with respect to the CWD distribution, abundance, habitat use, ranging patterns, demography, life history, feeding habits, mortality and behavioral ecology for various time periods. Some of the details are summarised in **Table 2** below for the CWD main habitats in Hong Kong's western waters:

Table 2. Summary of CWD Ecological Baseline

CWD Parameter	NW Lantau	NE Lanatu	W Lantau	SW Lantau	PRE
Abundance	38	7	19	9	Approx. 2,500
Peak Season	Wet	Wet	Wet	Wet	n/a
Densities	High	Moderate	Very High	Moderate	Moderate to High
	44 individuals/ $100km^2$	12 individuals/ $100km^2$	67 individuals/ $100km^2$	14 individuals/ $100km^2$	Variable
Average group sizes	3.4	2.8	3.2	2.2	Variable
Preferred nursing area	√	-	√	-	Unknown
Preferred feeding/milling areas	√	√	√	-	Unknown

14.5. However, based on the above literature review, it is apparent that some additonal information, specifically for to identify how CWDs use the potential land formation area for the 3RS project, and how important this habitat is to them, needs to be obtained. Details of the data gaps and the surveys needed to fill them, are discussed in the section below.

15. IDENTIFICATION OF DATA GAPS

15.1. Based on the results of the above review, the following data gaps specific to the 3RS EIA were identified (with relevant reference to the EIA study brief requirements indicated):

1) Smaller-scale information on the distribution, density, habitat use and behavior of CWDs in the 3RS work area and west of the airport platform. This is important to understand how the CWDs are using the works area for the 3RS. This relates to Appendix F, Clause 3(iii)(a and b) of the EIA Study Brief.

2) The further evaluation of the acoustic habitat of the CWDs and the impacts of anthropogenic noise in the 3RS work area using passive acoustic monitoring. This relates to Appendix F, Clause 3(iii)(d) of the Study Brief.

3) Further work to elucidate individual movements and social structure in and around the 3RS study area. This relates to Appendix F, Clause 3(i) of the Study Brief.

4) Work to determine if portions of the 3RS study area are being used as travelling corridors by CWDs while moving between core habitat areas. This relates to Appendix F, Clause 3(v)(c) of the Study Brief.

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