

**Marine Ecology Enhancement Fund (MEEF)**  
**Declaration**

To: The Secretariat of the MEEF

**Reference No.:** MEEF2017015

**Project Title:** Conservation Ecology of Chinese White Dolphins across the Pearl River Estuary Phase 2: Population Parameters, Socio-Demographic Structure and Habitat Requirements

**Name of Project**

**Leader:** Dr Leszek Karczmarski

I hereby irrevocably declare to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that all the dataset and information included in the completion report has been properly referenced, and necessary authorisation has been obtained in respect of information owned by third parties.

Signature: 

Project Leader, Dr Leszek Karczmarski

Date: 15 FEB 2019

Marine Ecology Enhancement Fund (MEEF)

**Conservation Ecology of Chinese White Dolphins across the Pearl River Estuary  
Phase 2: Population Parameters, Socio-Demographic Structure and Habitat  
Requirements**

**MEEF2017015 – Completion Report**

*31 Oct 2018*

## Executive summary

This project reported here represents an initial stage (half-a-year only) of Phase 2 of a multi-year undertaking, initiated with a pilot project in 2015. The multi-year undertaking aims at developing a sound ecological framework for the conservation of Chinese White Dolphins (CWD) across the greater Pearl River Estuary (PRE) region. The western reaches of the PRE appear to harbor substantial numbers of CWD, seemingly larger than those in Eastern PRE. The dolphins in Western PRE may in fact be critically important to the continuous long-term survival of CWD in the PRE. However, with no in-depth research ever done in Western PRE (other than our pilot Phase 1 of this multi-year project), literally nothing is known about these dolphins.

All work intended in the project reported here progressed as planned, timely and on schedule, and along the envisioned framework of the project. The photo-ID data collected across the PRE region contributed meaningfully to the long-term mark-recapture database that is the backbone for the entire multi-year project. Even though the short time-duration of this current Project have restricted the amount of data that was possible to collect, in conjunction with the ongoing MEEF-funded work, it represents an important building block within the framework of the larger multi-year undertaking. A total of 56 surveys were conducted during the project period reported here, which resulted with 245 encounters of dolphin groups and a cumulative number of 1168 dolphin sighting-records.

Our current analyses, albeit still preliminary in the context of the multi-year project, delivered indicative estimates of population parameters, mapped the pattern of habitat use, and assessed the health conditions of CWD in the eastern part of the PRE. Mark-recapture analyses indicate that 899 dolphins inhabit coastal waters across the Eastern PRE (including Hong Kong waters), suggesting that the number of dolphins in this area is lower than previously thought. Furthermore, at least 40% of the Eastern PRE dolphins rely on the western Hong Kong waters as their habitats, which highlights the importance of Hong Kong territorial waters, despite its relatively small size, to the daily needs of the CWD population. Moreover, the overall survival rate estimate of CWD across the Eastern PRE waters, albeit still preliminary, is likely below 0.955, which is the threshold of long-term biological persistence of CWD in the PRE. As such, the population trajectory of the CWD in Eastern PRE is likely on a downward slope.

The pattern of habitat use of CWD in the Eastern PRE, their home range and core areas, which indicate the areas and habitat of critical importance to the dolphins' daily lives, were identified (albeit again, only preliminarily at this stage). Evidently

though, dolphin core areas are restricted to inshore waters close to natural shorelines. The foraging core areas closely resemble the overall pattern of area utilization, which reaffirms our earlier observations that the dolphins' need of food and foraging locations governs their habitat use pattern. Moreover, the current evidence suggests that Hong Kong waters, particularly off west and southwest Lantau Island, represent amongst the most favorable option of dolphin habitat throughout the Eastern PRE.

Using the individual photo-ID data, we assessed the health conditions of free-ranging CWDs. Cutaneous lesions and abnormal skin conditions on the dolphin body are usually the first indicators of compromised immune system that are often related to habitat degradation, pollution and eutrophication from anthropogenic sources. Visual assessment of skin lesions therefore provides valuable proxy indicators of the health conditions and the intensity of human-related pressures. Seven categories of skin lesions were identified and approximately half (50.6%) of dolphins in the area suffer from at least one type of skin lesion. Among the affected dolphins, nearly 60% were observed with multiple types of lesions. Although these epidermal lesions may be non-lethal, the high rate of occurrence indicates the impaired immune system of the dolphins, which is likely related to the quality (or rather the lack of it) of their habitats, particularly when such a large proportion of individuals are affected. Our assessment of skin lesions is therefore very timely and serves as important indicator of the environmental burden and stressors acting on the dolphins.

The findings summarized in this report, although preliminary, are all first of its kind, indicating how little knowledge of the CWD population we had even after decades of former research effort in the region. Our current findings affirmed the direction of this multi-year project, which if continued, will deliver results of very considerable scientific value and major management implications. Further flow of incoming data is therefore much needed and it is currently underway (and intended to continue in the upcoming follow-up projects). Once our findings and analyses are based on sufficiently robust dataset (as intended by the end of this multi-year project), the results will carry important implications not only on our understanding of the well-being of the CWD in the PRE region, but also in advising local authorities on management recommendations based on empirical scientific evidence. As our current findings affirmed the direction of this multi-year undertaking, the only way forward is to continue this work in the coming years, as per our original proposal.

## **Brief description of the Project**

This project represents an initial stage (half-a-year only) of Phase 2 of a multi-year undertaking, initiated with a pilot project (Phase 1) and supported with the Airport Authority Hong Kong (AAHK) funding in 2015. The multi-year undertaking aims at developing a sound ecological framework for the conservation of Chinese White Dolphins (CWD) across the Pearl River Estuary (PRE) region, from Hong Kong in the east to the western reaches of the PRE. Recent findings of Phase 1 of this project indicate that the western reaches of the PRE appear to harbor substantial numbers of CWD; probably larger than those in Eastern PRE. The dolphins in Western PRE may be critically important to the continuous long-term survival of CWD in the PRE, possibly representing the main 'source' of individuals in a complex metapopulation system, while the dolphins in Eastern PRE may likely be merely a 'sink' that on its own might not be biologically viable without an influx from Western PRE.

With no in-depth research ever done in Western PRE, other than the Phase 1 of our multi-year project, literally nothing is known about these dolphins. However, if the Western PRE population is of the type, size and status as our current data suggest, this could re-shape the fundamental concept of CWD conservation; the management strategies might need to be revised and probably substantially refocused. The work summarized in this report have investigated CWD in the Middle and Western reaches of the PRE, and, along with continuous surveys in Eastern PRE, it assembles and compare the findings across the region to determine what constitutes the CWD population in the complex coastal habitats of the PRE and neighboring waters.

In a larger-scale of a multi-year project, this study will (i) quantify population parameters, size and socio-demographic structure; (ii) identify spatiotemporal patterns of movement, range use and habitat utilization; (iii) determine the population connectivity and identify meaningful demographic units (management stocks; if any) for conservation; (iv) will generate spatiobehavioral models of the population responses to anthropogenic change (e.g. habitat loss) and (v) demographic models of the processes that determine the population long term viability. This work, as part of a multi-year research framework, carries an immense potential for contributing to conservation management of CWD across the PRE and future assessments of anthropogenic impacts.

## Completed activities against the proposed work schedule

All work progressed as intended, timely and on schedule, and along the envisioned framework of the project. Sea-based fieldwork was performed over the budgeted 6-month period of this Project to collect data, and – as the original completion date coincided with the busiest time of the year (middle of field season with peak survey-effort) the project period was extended to complete initial analyses and to prepare this completion report.

Boat-based photo-ID surveys were carried out in Hong Kong (HK) waters and Pearl River Estuary (PRE) whenever the sea conditions allowed. The research team conducted a total of 56 surveys during the project period, and encountered 245 groups with a cumulative number of 1168 dolphin sighting-records. The monthly survey efforts and sighting rates are shown in Table 1. As pointed out in the original proposal and in the Interim Report, the intensity of field surveys is weather dependent, with a peak field-season in summer months and low-intensity period during winter.

**Table 1.** Summary of survey effort, number of groups and dolphin sightings

Area	Month	Number of surveys	Number of groups encountered	Cumulative number of dolphin sightings
HK	Jan	1	0	0
	Feb	1	3	8
	Mar	4	12	34
	Apr	5	14	46
	May	5	22	68
	June	2	7	16
	July	3	15	73
	Total	21	73	245
PRE	Jan	0	0	0
	Feb	3	7	15
	Mar	8	32	194
	Apr	8	49	299
	May	10	59	279
	June	6	25	136
	Total	35	172	923
Overall		56	245	1168

The short time-duration of this Project, which did not cover even one annual season, have restricted the amount of data that was possible to collect. Nevertheless, it facilitated the continuity of data gathering and as such, in conjunction with the prior and, especially, the ongoing MEEF-funded work, it represents an important building block within the framework of the larger multi-year undertaking.

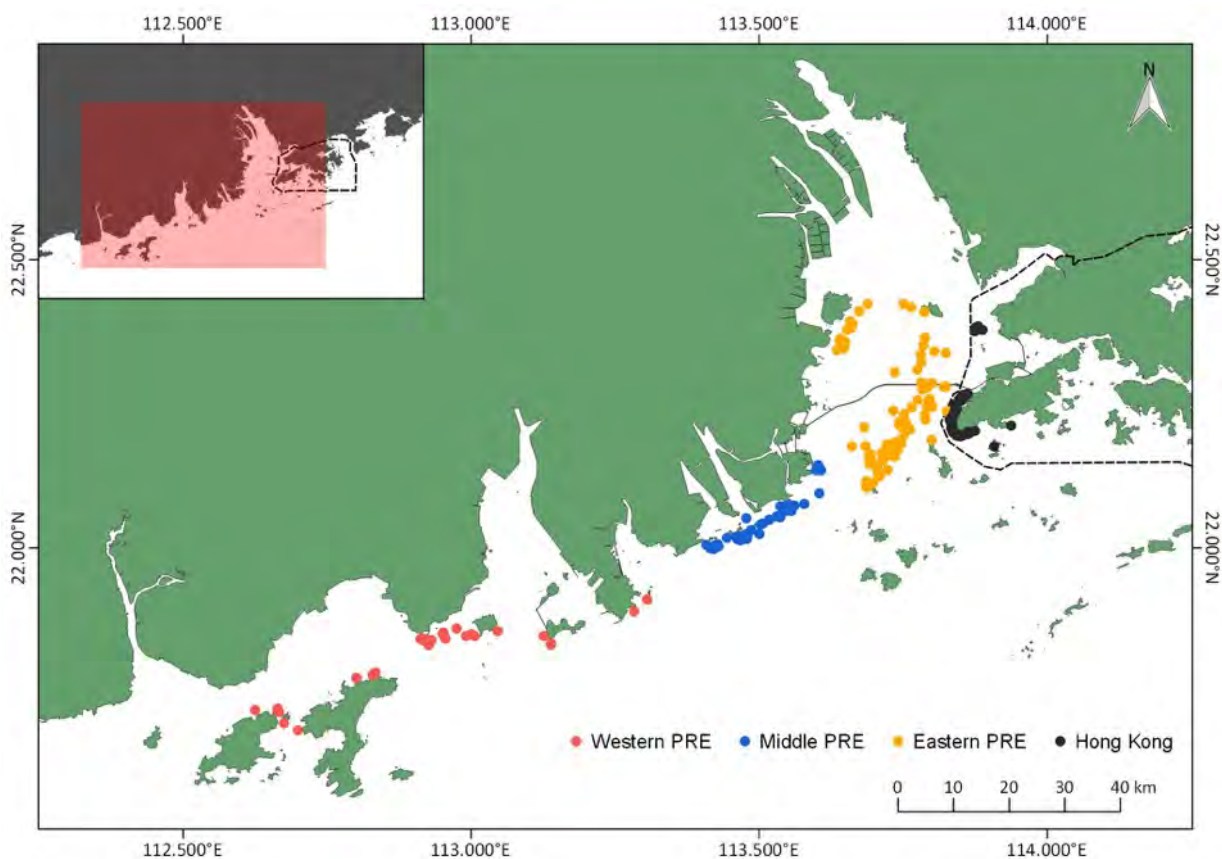
**Summary table of completed activities:**

Categories of activities*	Key-points
Field Surveys	<ul style="list-style-type: none"> <li>• Sea-based fieldwork was performed in Hong Kong waters and Pearl River Estuary whenever the sea conditions allowed</li> <li>• A total of 56 boat-based photo-ID surveys were carried out with 245 groups encountered</li> <li>• Intensity of field surveys is weather dependent – peak field-season is in summer months and low-intensity period during winter – as indicated in the proposal</li> </ul>
Data Analyses <i>(see further in Results section)</i>	<ul style="list-style-type: none"> <li>• Preliminary analyses were carried out to indicate the progress of the project. However, the dataset from the current phase of the Project alone is far from sufficient to deliver comprehensive analyses, particularly as it pertains to Western and Middle PRE</li> <li>• As this multi-year project started in Hong Kong and shortly after extended to Eastern PRE, we have accumulated reasonably-sized dataset to perform preliminary analyses in the eastern reaches of the PRE region</li> <li>• Mark-recapture analyses were performed to provide early assessments of the population numbers of CWD in the Eastern PRE</li> <li>• The pattern of habitat use of CWD in the Eastern PRE was constructed using kernel density estimation (KDE)</li> <li>• Further to the work expected to be completed in this phase of the project, we utilized the high-quality images collected in our photo-ID surveys to assess the health conditions of CWDs in Eastern PRE</li> <li>• The estimates presented in this report are <u>not</u> yet conclusive and should not, at this stage, be referenced to avoid misinterpretation and to not cause misunderstanding</li> </ul>

\* Note that the timetable listed in the original application referred to a 12-month project. As subsequently the project had to be truncated to 6-month only, at this current stage the completed activities, which have progressed flawlessly throughout, represent approximately half of what the timetable in the original application indicated.

## Results

During the time-period budgeted for in this Project, the sighting records of Chinese white dolphins obtained during the 56 surveys cover the entire range of the Pearl River Estuary (PRE) coastal waters (also referred to as the Pearl River Delta region, PRD), with Hong Kong at the easternmost flank of the range. The geographic distribution of dolphin encounters (and our photo-ID records) is displayed in Fig. 1.



**Figure 1.** The location of sighting records of Chinese white dolphins across the PRD region where individual ID-data were collected. Different sectors of the deltaic system (e.g. Western, Middle, Eastern PRE) are indicated by different colors.

As stated previously, the dataset from the current Project (and any individual sub-components of the multi-year undertaking) alone is far from sufficient to perform comprehensive analyses. When combined with our earlier obtained data, it still remains weak at present (particularly as it pertains to Western and Middle PRE) to investigate the socio-demographic structure and connectivity across the entire PRE region. On the other hand, as this multi-year project started in Hong Kong and



shortly after extended to Eastern PRE, we have accumulated reasonably-sized dataset to perform preliminary analyses on the population numbers and habitat use pattern of CWD in this eastern flank of the PRE region. Here we present our early-findings which will be strengthened and refined at a later stage (as per the original proposal). It has to be highlighted, however, that the estimates presented here are not yet conclusive and should not be referenced to avoid misinterpretation and to not cause misunderstanding.

Mark-recapture analyses were performed to provide early assessments of the population figures of CWD in the Eastern PRE. The data treatment and analytical protocols were adopted from recently published work by Chan and Karczmarski (2017)<sup>1</sup>, with only the high-quality images of highly distinctive adult individuals used for analyses. The mark-ID ratio – the proportion of individuals that are highly marked – was estimated to be 91.2%, which is similar to the ratio estimated in Hong Kong waters (see Chan and Karczmarski 2017). Multiple mark-recapture models, including Cormack-Jolly-Seber (CJS) and POPAN models, were used to estimate population parameters. Our analyses indicate that 899 dolphins inhabit coastal waters across the Eastern PRE (including Hong Kong waters), suggesting that the number of dolphins in this area is lower than previously thought. Also, based on this early assessment and compared with the figure in Chan and Karczmarski (2017), at least 40% of the Eastern PRE dolphins rely on the western Hong Kong waters as their habitats. This highlights the critical importance of Hong Kong territorial waters, despite its small size as compared to the remaining part of the estuary on the other side of the administrative border, to the CWD's survival.

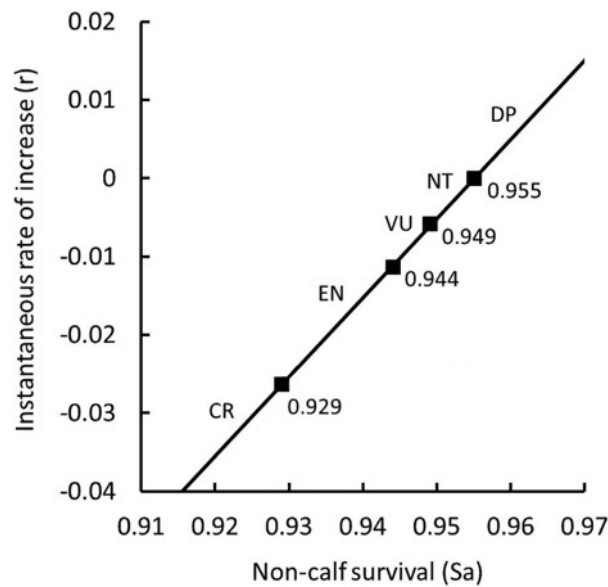
Moreover, the overall survival rate of CWD across the Eastern PRE waters, albeit preliminary, is likely below 0.955, which is the threshold of long-term biological persistence of CWD in the PRE (Fig. 2, reproduced from Karczmarski et al. 2017<sup>2</sup>). As such, contrary to the statements in articles publicized by local media, the population trajectory of the CWD in Eastern PRE is likely on a downward slope. These findings, which effectively quantify population parameters, once refined, will have profound implications not only on our understanding of the well-being of the CWD in the

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<sup>1</sup> Chan S.C.Y. & Karczmarski L. (2017). Indo-Pacific humpback dolphins (*Sousa chinensis*) in Hong Kong: Modelling demographic parameters with mark-recapture techniques. *PLOS ONE*, 12(3): e0174029. DOI: 10.1371/journal.pone.0174029.

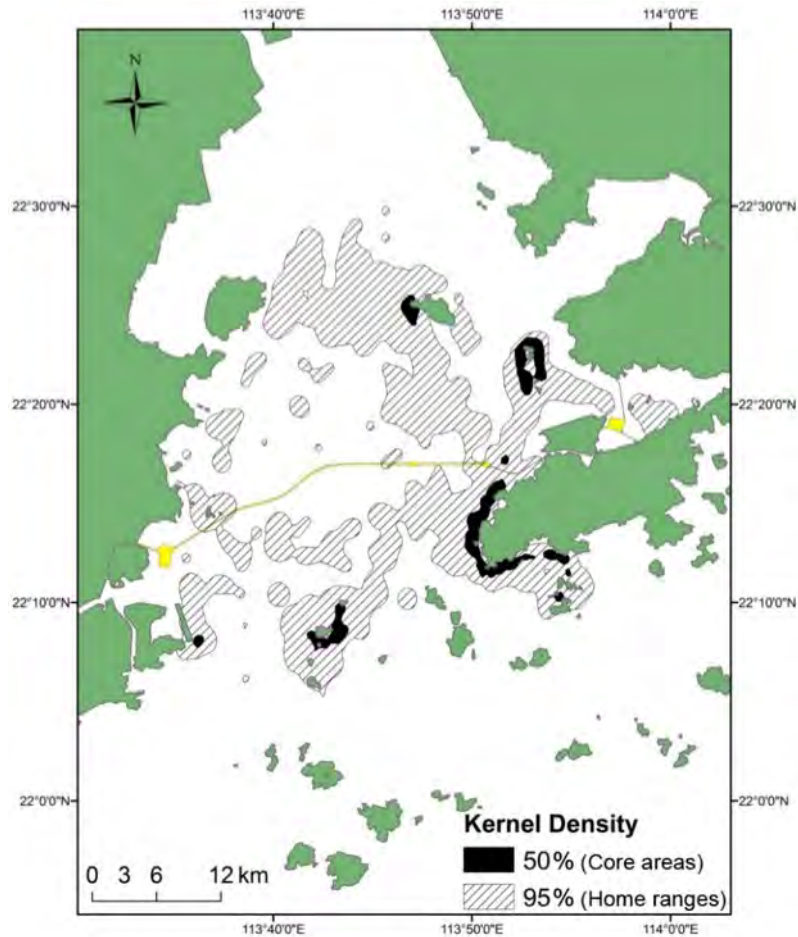
<sup>2</sup> Karczmarski, L., Huang, S-L. & Chan, S.C.Y. (2017). Threshold of long-term survival of a coastal delphinid in anthropogenically degraded environment: Indo-Pacific humpback dolphins in Pearl River Delta. *Scientific Reports*, 7, 42900. DOI: 10.1038/srep42900.

region, but also on our directions of conservation management. Further flow of incoming data is therefore much needed, and this will be followed up in the upcoming phases of this multi-year project.



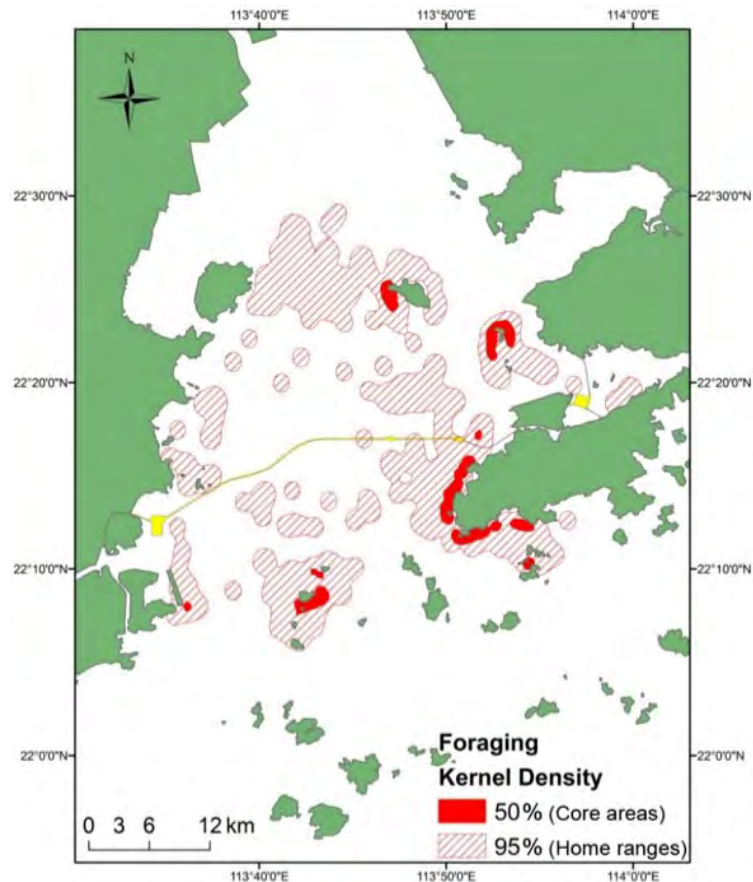
**Figure 2.** The relation between instantaneous rate of increase ( $r$ ) and non-calf survival rate ( $S_a$ ) for Chinese white dolphins in the Pearl River Estuary. At survival rates ( $S_a$ ) below the threshold value of 0.955, negative rates of population change ( $r$ ) indicates the trajectory of decreasing population size (Figure reproduced from Karczmarski et al. 2017).

The pattern of habitat use of CWD in the Eastern PRE (inclusive of Hong Kong) was constructed using kernel density estimation (KDE). With the application of this technique, the core areas of the dolphins (the areas depicted by 50% KDE isopleth) and their home ranges (areas within 95% KDE isopleth) were identified, which indicate the areas and habitat of critical importance to the dolphins' biological needs and daily behaviors. Based on the dataset currently in our possession, this analysis indicated four primary core areas, all of which were restricted to inshore waters close to natural shorelines and were spatially connected by narrow strips of home range (Fig. 3). Two substantially larger core areas were identified in Hong Kong, around Lung Kwu Chau and off west-to-southwest coast of Lantau Island; while the other two core areas, comparatively smaller, are situated in mainland China waters at western Neilingding Island and around Sanjiao Island.



**Figure 3.** The pattern of area use of Chinese white dolphins modelled with 50% (core areas) and 95% (home range) isopleths of Kernel Density estimation (KDE) in the Eastern Pearl River Estuary (Eastern PRE). Note that core areas are larger and the home range area is better inter-connected in Hong Kong as compared to those in the mainland China waters. However, as the survey effort is still insufficient in mainland China waters, especially in Middle and Western PRE, it is likely that this current pattern is biased towards Hong Kong waters and it may change to some degree (perhaps substantially) once the dataset is sufficiently robust (once more spatial data from Middle and Western PRE is included). Therefore, although the pattern displayed above is indicative of the core areas of primary importance, it may not be sufficiently accurate in the proportionality of display across the considerable spatial gradient of the Eastern PRE. Consequently, although it is the best spatial projection possible at present (with the current dataset), it carries considerable uncertainty and likely bias that cannot yet be sufficiently accounted for, and therefore should be treated cautiously (*i.e.* it is not yet suitable for making management recommendations). We estimate that a minimum of at least another 2+ years of spatial sighting records from Western PRE is needed before the spatial dataset will be sufficiently robust for reliable and conclusive analyses.

The prime habitats for dolphin foraging are of particular importance in conservation, as these areas harbor the resources that secure the daily nutritional needs and thus the survival of CWD. Area utilization analyses were therefore also performed to estimate the habitat use patterns specifically for foraging of CWD in the Eastern PRE (Fig. 4).



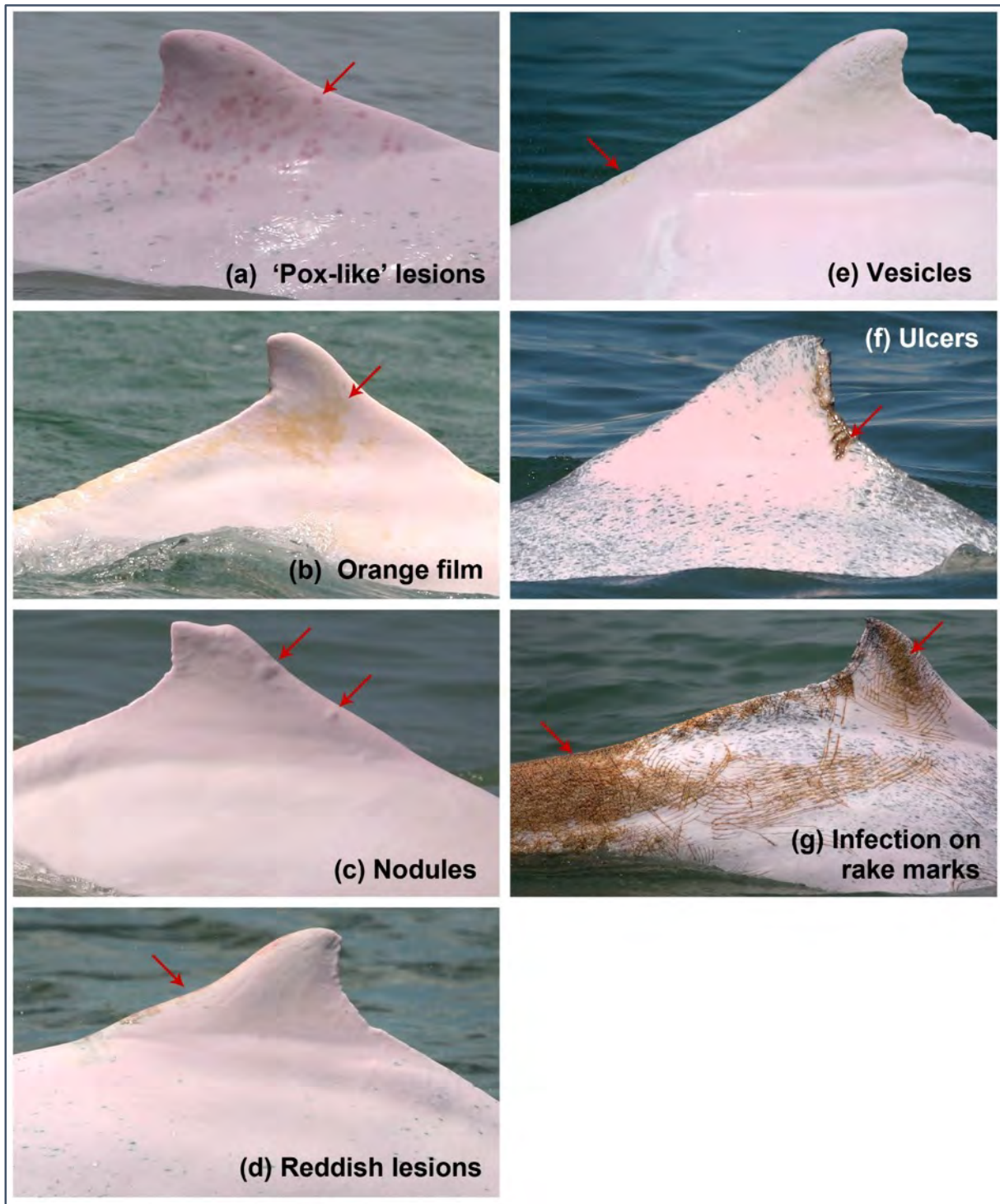
**Figure 4.** Area utilization pattern for foraging behavior of Chinese white dolphins modelled with 50% (core areas) and 95% (home ranges) isopleths of Kernel Density estimation (KDE) in the Eastern Pearl River Estuary (Eastern PRE). Note that the pattern of habitat use for foraging resembles the overall range use pattern (shown in Fig. 3), where the core areas are larger and the ranges are better connected in Hong Kong as compared to those in the mainland China waters. Note also that although the figure above is indicative of the core areas and the overall pattern, it is still preliminary and should therefore be treated cautiously (*i.e.* it is not yet suitable for making management recommendations).

Our current early-stage findings indicate that the distribution pattern of the range and core areas for foraging (Fig. 4) closely resembles the overall pattern of area utilization (see Fig. 3). The two core areas in Hong Kong, around Lung Kwu Chau and off west-to-southwest coast of Lantau Island, are notably larger and within a more frequently used range than the two core areas in mainland China waters at western Neilingding Island and around Sanjiao Island.

While these results of spatial analyses remain preliminary, our early findings reaffirm the reliance of CWD on coastal habitats for their daily needs and survival. The close spatial resemblance of foraging habitat distribution to the overall area utilization pattern suggested that the dolphins' need of food and foraging locations apparently govern their habitat use patterns. Moreover, the current evidence suggests that Hong Kong waters, particularly west and southwest Lantau Island, represent amongst the most favorable option of habitat throughout the Eastern PRE. Such finding corresponds with the high proportion of Eastern PRE dolphins relying on Hong Kong territorial waters as mentioned above. This is, however, likely indicative of the level of disturbance and habitat degradation only in comparative terms; in other words, the coastal habitats in Hong Kong waters may be less degraded than those across the administrative border, but the overall disturbance is still intense throughout the whole Eastern PRE region (see further for the indications of health conditions of CWD in Hong Kong). As stipulated in the original proposal, further analyses will be carried out over a wider geographical range and in more details when more data will become available in the upcoming phases of this multi-year project. The results will provide much needed insights into the spatial pattern of area/habitat use of the CWD in the PRE region, which will facilitate the evaluation of the existing and proposed marine protected areas (MPA) based on empirical scientific evidence.

Further to the work expected to be completed in this phase of the project, and benefiting from the high-quality images collected in our photo-ID surveys, we assessed the health conditions of free-ranging CWDs. Cutaneous lesions and abnormal skin conditions on the dolphin body, which can be observed in the field without physical contact with the animal, are often the first indicators of compromised immune system that are often related to habitat degradation, pollution and eutrophication from anthropogenic sources. Visual assessment of skin lesions therefore provides valuable proxy indicators of the health conditions and the intensity of human-related pressures on free-ranging dolphins. Here we present the early findings of the examination of the epidermal lesions and their prevalence on the CWD in Hong Kong waters.

Seven categories of skin lesions were identified, including 'pox-like' lesions, orange film, nodules, reddish lesion, vesicles, ulcers, and infection on rake marks. The example images of these lesions are shown in Fig. 5. The prevalence of 'pox-like' lesions, orange film, and nodules are the highest among the observed lesion types (Table 2). Approximately half (50.6%) of the identified individuals in the area suffered from at least one type of skin lesion (Table 2); and among the affected dolphins, nearly 60% were observed with multiple types of lesions (Table 3).



**Figure 5.** Examples of skin lesions observed on Chinese white dolphins in Hong Kong, including (a) 'pox-like' lesion, (b) orange film, (c) nodules, (d) reddish lesions, (e) vesicles, (f) ulcers, and (g) infection on rake marks.

**Table 2.** Prevalence of the seven types of skin lesions observed on Chinese white dolphins in western Hong Kong waters.

<b>Skin lesions</b>	<b>No. (%) of affected individuals</b>
'Pox-like' lesions	151 (34.7%)
Orange film	110 (25.3%)
Nodules	134 (30.8%)
Reddish lesions	5 (1.1%)
Vesicles	4 (0.9%)
Ulcers	7 (1.6%)
Infection on rake marks	9 (2.1%)
<i>At least one type</i>	220 (50.6%)

**Table 3.** Proportions of single and multiple types of skin lesions observed on Chinese white dolphins in western Hong Kong waters.

<b>Number of types of skin lesions observed on the same individual</b>	<b>Number of affected individuals</b>	<b>Proportion to the total number of affected individuals</b>
1 type	90	40.9%
2 types	69	31.4%
3 types	52	23.6%
4 types	9	4.1%

The estimated prevalence of skin lesions represents only the minimum percentage of affected individuals. For most dolphins, only the upper bodies were photographed, while the potential lesions at the other parts of dolphin body remained underwater and unobserved. Also, the lesions assessment was likely obscured by the natural coloration of CWD which changes from dark grey in calves to pink in mature animals. The mottled and speckled pigmentations, especially on juveniles and young adults, might have masked some inconspicuous skin conditions that went unnoticed even on images of the highest quality. Therefore, the skin lesion prevalence, despite already being alarmingly high, was most likely still underrated. Although these epidermal lesions may be non-lethal, the high rate of occurrence unmistakably indicates the impaired immune system of the dolphins, which is likely related to the quality of

their habitats (or rather the lack of it) particularly when such a large proportion of individuals are affected. As such, the assessment of skin lesions not only provides timely insights into the health status of CWD in the PRE, but may also serve as important indicators of the environmental burden and stressors acting on the dolphins.

### **Evaluation of the project effectiveness**

Despite the short time-duration of the project which, unfortunately, had to be truncated to only six months, all intended activities of the Project have progressed effectively along the envisioned framework. The chances of field surveys were optimized to collect data under workable weather conditions. As stated previously (in the original proposal and in the interim report), survey intensity was unavoidably lower in winter months due to the highly unfavorable sea conditions in winter, but has gradually increased as summer approached, which represents the peak field season. All collected data contributed to a comprehensive photo-ID mark-recapture database of CWD across the PRE region, which is of major importance if any intended population analyses are to produce scientifically sound results.

As stated in the original proposal, comprehensive analyses on the population connectivity and socio-demographic structure of CWD will require further research effort for at least 3 more years (for the obvious reasons that the database across the greater PRE region – especially in Western and Middle PRE – is not yet sufficiently robust). Nevertheless, we have achieved in delivering indicative results, even if still preliminary, on demographic parameters, habitat use patterns and population health conditions; all of that despite the early stage of the project (we are not even half-way-through the multi-year undertaking) and very early stage of our analyses. Once these analyses are based on sufficiently robust dataset, as intended by the end of this multi-year project, the results will carry important implications in advising local authorities on management recommendations based on empirical scientific evidence. We expect that all the findings reported here and in the upcoming future reports will be published in respected peer-reviewed scientific journals.

As the time-period of this project was very short, the analyses reported here were only possible thanks to the incorporation of data obtained by our research team in our prior work in Hong Kong and Eastern PRE (as per the original proposal). Now, the very same process is underway for the remaining parts of the PRE region. As such,



the early findings presented in this report not only provide the first glimpse into the population and conservation ecology of CWD in the eastern flank of the estuary, but also showcase what may be achieved and learnt should a robust dataset be constructed across the greater PRE region, as intended for the multi-year project.

### **Summary and way forward**

In summary, both field data collection and analytical process, the two major tasks for this phase of the multi-year project, have proceeded in the pace as intended. Photo-ID data collected across the PRE region contributed to the long-term mark-recapture database which will be the backbone for all subsequent investigations. Preliminary analyses delivered early estimates of population parameters, mapped the habitat use pattern, and assessed the health conditions of CWD in the eastern part of the PRE region. These preliminary findings are all first of its kind, indicating how little knowledge of the CWD population we had even after decades of former research effort in the region. Current findings affirmed the direction of this multi-year project, which if continued, will deliver results of very considerable scientific value and major management implications, benefiting the conservation efforts of CWD across the entire PRE region. The only way forward is to continue with the work as intended and described in our original proposal.

**Financial position of the project**

**Project expenditure details are not disclosed due to confidentiality reason.**

# Appendix I

## Photos of field surveys

