

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

To: The Secretariat of the MEEF

**Reference No.:** MEEF2017007

**Project Title:** Monitoring of population dynamics of Indo-Pacific humpback dolphins (*Sousa chinensis*) in Lingding Bay of the Pearl River Delta region

**Name of Project Leader:** Chen Tao

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, Chen Tao

Date: 2018-12-26

MEEF2017007

# Monitoring of population dynamics of Indo-Pacific humpback dolphins (*Sousa chinensis*) in Lingding Bay of the Pearl River Delta region: Final Report

Submitted to

Marine Ecology & Fisheries Enhancement Funds Trustee Limited



Prepared by

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Supported by

Hong Kong Cetacean Research Project (HKCRP)



December 18, 2018

Project Leader: Chen Tao

A handwritten signature in black ink, appearing to be '陈涛' (Chen Tao), written over a horizontal line.

## **Executive summary**

A one-year study was conducted to investigate the latest situation of the Chinese White Dolphins (*Sousa chinensis*) in Lingding Bay of the Pearl River Delta region, as well as their fine-scale habitat use and individual ranging patterns. A total of ten sets of dolphin line-transect surveys with 4,852 km of survey effort were conducted among six survey areas in Lingding Bay during August 2017 to April 2018. During these surveys, a total of 238 groups of 1,152 Chinese White Dolphins and five groups of 11 finless porpoises were sighted. Dolphins were commonly sighted throughout the study area, but were mostly absent from the northernmost and the southeastern portion of Lingding Bay. The porpoises were all observed in the southernmost portion of Lingding Bay, where no dolphin was sighted.

The combined estimate of dolphin abundance in Lingding Bay was 945 individuals during the 2017-18 monitoring period, including 83 in North Lingding Bay (NLDB), 315 in Central Lingding Bay (CLDB), 301 in South Lingding Bay (SLDB), 238 in Macau (MA) and 8 in Southwest Macau (SWMA) for each of the survey areas (Aizhou area was excluded for estimation due to the insufficient sightings). Dolphin densities varied noticeably among different survey areas in Lingding Bay. MA and SWMA areas recorded the highest (89 individuals per 100 km<sup>2</sup>) and lowest (6 individuals per 100 km<sup>2</sup>) dolphin densities respectively.

Noticeable decline in dolphin abundance of Lingding Bay was detected in the past decade. The dolphin abundance estimate in the dry season during 2017-18 (990 individuals) was approximately 78% of the estimates in the dry season during 2005-06 (1,273 individuals) with a 22% decline, or an average rate of decline at 2.07% per annum. However, the overall dolphin abundance of Lingding Bay in 2017-18 was fairly similar with the one in 2015-16. Continuous monitoring on population dynamics are needed to figure out the temporal trend in dolphin abundance in Lingding Bay.

In 2017-18, the important dolphin habitats were mostly located in waters around the Datouzhou-Sanjiaoshan-Qingzhou islands (where the Guishan offshore wind farm is located), between Neilingding Island and Lung Kwu Chau, to the southwest of Lantau Island, and some areas within the Guangdong Pearl River Estuary Chinese White Dolphin National Nature Reserve including waters along the Hong Kong-Zhuhai-Macao Bridge. It appeared that the impacts of the main infrastructure projects in Lingding Bay such as the HZMB and Guishan offshore wind farm on habitat usage of the Chinese White Dolphins have lessened in recent years and the

dolphins have not avoided these areas in the past year.

The mean group size ( $4.86 \pm 4.59$ ) of dolphins in Lingding Bay in 2017-18 was very similar with the results from the previous surveys of 2005-06 ( $4.80 \pm 4.91$ ). The proportion of young dolphin calves was on the decline from 12.36 % in 2005-06 to 8.16 % in 2017-18. The overall reduction of young calves in the past decade could indicate a very low level of recruitment and is of grave concern as it is closely related to the future survival of the PRE dolphin population.

A high percentage sightings associated with feeding activities in Lingding Bay was recorded in 2017-18 (74.4%), which may imply that there is a lack of food resources for the dolphins in Lingding Bay and they are forced to spend more time looking for food. Fewer groups engaged in socializing activities to the north and west of Neilingding Island, where large-scale sand mining activities had been operating, which may signal the deterioration in habitat quality of this area.

During the study period, 162 individual dolphins with 279 re-sightings were identified altogether. Among these individuals, 43 of them have never occurred in Hong Kong waters before in the past two decades of dolphin monitoring works, while the other 119 individuals have been regularly sighted in different survey areas around Lantau Island. Most dolphins have strong site fidelity which occurred primarily in Hong Kong waters or have some preference of range use in different parts of Lingding Bay. Meanwhile many of them also ranged extensively across the border, with some utilizing the entire Lingding Bay as part of their ranges. A number of frequently sighted individuals in Hong Kong have disappeared from there, and some of them have re-appeared in Lingding Bay in the past few years, implying that they may have moved permanently away from Hong Kong waters. Therefore, it is crucial to continue the long-term monitoring surveys throughout Lingding Bay to confirm the presence or absence of these individuals that were known to occur regularly in Hong Kong waters in the past.

All of the changes in dolphin abundance, activities and individual range in Lingding Bay waters in the past decade are the consequences stemmed from the combination of existing threats. It needs to be quite cautious to conduct any new offshore projects in the whole Lingding Bay and the existing constructions should be stringently monitored. Moreover, the large-scale sand mining activities near Neilingding Island in the north part of Lingding Bay should be strictly controlled and a better management with stringent control over fishing activities is also urgently needed.

## 1 Introduction

The Pearl River Estuary (PRE) population of Chinese White Dolphins (*Sousa chinensis*) is the largest known population throughout this species' range, and the Lingding Bay (including Hong Kong and Macau SAR waters) comprises the major distribution range of this population with significant conservation importance. At the same time, the coastal region of Lingding Bay has one of the highest densities of human population in the world, and therefore the dolphins are inevitably affected by immense human activities within their coastal habitat. Their future survival is seriously threatened as their living habitat has continued to deteriorate with constant conflicts from various anthropogenic threats, especially the various coastal reclamation projects within Lingding Bay which leads to direct and permanent habitat loss for the dolphins. Such intense coastal development also affects the availability of prey resources and suitable habitat for the dolphins, which in turns, affecting their individual range use and movements as well as long-term survival. Therefore, it is critical to conduct long-term monitoring on the Chinese White Dolphins in the Pearl River Delta, to track any temporal changes in their population dynamics. In fact, such long-term monitoring of Chinese White Dolphins in the wider PRE is aligned with the objective of the establishment of Marine Ecology Enhancement Fund (MEEF).

As a continuation of previous dolphin monitoring works conducted by the South China Sea Fisheries Research Institute (SCSFRI) in the wider PRE region, the present study aims to conduct a year-long vessel-based monitoring programme in Lingding Bay, with the aims to collect systematic line-transect survey data and photo-identification data of Chinese White Dolphins, which can be integrated with the monitoring data collected by SCSFRI in the past decade to assess the trends in abundance and other parameters such as overall habitat use and individual range use. With the cross-examination of data collected from the on-going long-term dolphin monitoring program in Hong Kong SAR waters conducted by the Hong Kong Cetacean Research Project (HKCRP), the present study will greatly enhance the overall understanding on the cross-boundary movements of individual dolphins between Guangdong and Hong Kong waters.

Several objectives are set for the present project as follow:

- 1) To examine the latest situation of the Chinese White Dolphins in Lingding Bay of the Pearl River Delta region, including their abundance estimates and distribution patterns. Results from the present project will be compared with past monitoring results collected by SCSFRI in the past decade, to examine

- their long-term temporal trend in population dynamics in Lingding Bay;
- 2) To examine the individual ranging patterns, especially any cross-boundary movements, through photo-identification of Chinese White Dolphins in Lingding Bay by matching individual dolphins with the photo-ID catalogue from Hong Kong waters;
  - 3) To assess the fine-scale habitat use of Chinese White Dolphins in Lingding Bay and associated temporal trend, for a better understanding of where important habitats are utilized by the dolphins; and
  - 4) To make recommendations on management and conservation strategies based on the latest monitoring results from this study for better implementation of conservation measures for the PRE Chinese White Dolphin population.

## 2 Work schedule

The project generally progressed well according to the proposed schedule, with an approved extension for fifteen days for the final report submission, and some necessary adjustments for the field surveys.

Time	Proposed activities	Completed activities
July 2017	Preparation for line-transect vessel surveys.	Done accordingly
August 2017	The 1 <sup>st</sup> line-transect vessel survey	Done accordingly
September 2017	The 2 <sup>nd</sup> line-transect vessel survey	Done accordingly
October 2017	The 3 <sup>rd</sup> line-transect vessel survey	Done accordingly
November 2017	The 4 <sup>th</sup> line-transect vessel survey	Done accordingly, submitted the progress report
December 2017	The 5 <sup>th</sup> line-transect vessel survey, conduct analysis on individual identification.	Done accordingly
January 2018	The 6 <sup>th</sup> line-transect vessel survey, submit interim report.	Done accordingly, interim report (progress report) was submitted in November 2017

February 2018	The 7 <sup>th</sup> line-transect vessel survey,	Done accordingly
March 2018	The 8 <sup>th</sup> line-transect vessel survey,	Conducted the 8 <sup>th</sup> and 9 <sup>th</sup> line-transect vessel survey (the annual fishing moratorium from May 1 <sup>st</sup> to August 15 <sup>th</sup> and survey was not able to conducted in May)
April 2018	The 9 <sup>th</sup> line-transect vessel survey.	Conducted the 10 <sup>th</sup> line-transect vessel survey
May 2018	The 10 <sup>th</sup> line-transect vessel survey, conduct analyses on individual identification and movement pattern.	Conducted analyses on individual identification and movement pattern.
June 2018	Conduct analyses on estimates of density/abundance, fine-scale habitat use, submit final report.	Conducted analyses on estimates of density/abundance, fine-scale habitat use, individual movement pattern
July 2018		Final report submission

### 3 Methodology

#### 3.1 General approach

The systematic line-transect survey data were utilized to calculate the latest abundance estimates and densities of Chinese White Dolphins in Lingding Bay, which were then compared to the past monitoring results collected by SCSFRI, to examine any temporal changes in population dynamics.

Photo-identification of individual dolphins was conducted during the line-transect vessel surveys, and the acquired data were used to track individual movement and their ranging pattern in Lingding Bay. Photo-identification data collected from the present study were compared to those from the concurrent long-term marine mammal monitoring program in Hong Kong conducted by HKCRP, in order to examine the extent of cross-boundary movements by individual dolphins, in light of the coastal development on both sides of the border, such as the construction of the airport's third runway system expansion project.

Using the analytical method of fine-scale grid analysis, the habitat use of Chinese White Dolphins was examined in details, which could establish the importance of

dolphin habitats at various locations of Lingding Bay, and identify the critical dolphin habitats with conservation importance.

### **3.2 Study areas**

The Lingding Bay of the Pearl River Estuary is divided into six survey areas (Figure 1), including North Lingding Bay (NLDB), Central Lingding Bay (CLDB), South Lingding Bay (SLDB), Macau (MA), Southwest Macau (SWMA) and Aizhou (AZ). The survey areas covered the entire known range of the Chinese White Dolphin population in Lingding Bay, with ten sets of systematic line-transect vessel surveys conducted along the transect lines (Figure 1) previously established in past dolphin monitoring projects in this area.

### **3.3 Line-transect vessel surveys**

A series of parallel transect lines, perpendicular to the major coastlines in the study area, are placed every ~3 km apart in each survey area. These transect lines are designed to cover the survey area evenly and to provide representative coverage throughout different sections of Lingding Bay. A total of 10 sets of line-transect surveys were completed during the 12-month study period, with one set per month from August 2017 to April 2018 (note: the study period cannot cover the period of annual fishing moratorium from May 1<sup>st</sup> to August 15<sup>th</sup>, due to the strict regulation on fishing boat activity in Lingding Bay).

A shrimp trawler (*Yuedongguan 00589*) which has an open upper deck with relatively unrestricted visibility was used to conduct all line-transect vessel surveys for the present study. The survey vessel transited through different transect lines at a constant speed of 13–15 km/h. Observations were made from the flying bridge area, which is 4–5 m above sea level, and in acceptable weather condition (Beaufort 0-5, no heavy rain, and visibility >1,200 m). However, only the monitoring data collected in calm conditions of Beaufort 0-3 were included in the line-transect analysis for calculating estimates of dolphin density and abundance as well as examining dolphin encounter rates.

The surveys were conducted by the same group of observers who are experienced in small cetacean survey techniques and identifying cetacean species occurred in the area in the past decade. HKCRP staffs were also on board regularly throughout the study period to audit the surveys, which would ensure the consistency in standardizing the survey methodology with the one used in Hong Kong waters, thereby allowing an opportunity to compare the monitoring results across the border.

On all surveys, two observers (a data recorder and a primary observer) made up the on-effort survey team. The primary observer searched for marine mammals [primarily Chinese White Dolphins but also Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) as well] continuously through  $7 \times 50$  marine binoculars, whereas the data recorder searched with unaided eye and was responsible to fill out the datasheets. Both observers searched ahead of the vessel between  $270^\circ$  and  $90^\circ$  (in relation to the bow, which is defined as  $0^\circ$ ). Two to three additional observers also were available on board to work in shifts. Observers rotated positions after approximately 30 minutes of effort, and were given a rest after each hour of search effort, thereby minimizing any observer fatigue.

Effort data collected during on-effort survey periods included time and position for the start and end of search effort, vessel speed, sea state (in Beaufort scale), visibility, and distance travelled in each series (a continuous period of search effort). When dolphins were sighted, the team went off-effort and the vessel was diverted from its course to approach the dolphin group for group size estimation, assessment of group composition, behavioural observations, and collection of identification photos. The data recorder filled out a sighting sheet, which includes information on time, initial sighting angle and distance, position of initial sighting, sea state, group size and composition, activities, and behaviour (e.g. response to the survey vessel, any associations with fishing vessels). Position, distance travelled, and vessel speed were obtained from a hand-held GPS.

### **3.4 Photo-identification and individual ranging patterns**

When a group of Chinese white dolphins were sighted during the line-transect survey, the team went off-effort and approached the dolphin group slowly to photograph and identify individuals. Two autofocus digital cameras (Canon 7D and Canon 1D), each equipped with long telephoto lens (100-400mm zoom) and digital data recorder to record date and time for each frame, were used by the survey team to take sharp, up-close photographs of dolphins as they surface in order to capture their natural markings. Every attempt was made to photograph each dolphin in the group, even those that appeared to have no unique markings. Both the left and right sides of the dolphins were photographed if possible, since the natural markings of the two sides are not symmetrical.

All images containing potentially identifiable individuals were sorted out for photo-identification. Dolphins were identified by their natural markings, such as nicks, cuts, scars, and deformities on their dorsal fin and body (Jefferson and Leatherwood 1997; Jefferson 2000). Their unique spotting patterns were also used as a secondary

identifying feature. All photographs of each individual were compiled and arranged in chronological order in a database, with data including the date and location of the initial sighting of the dolphin, re-sightings, associated dolphins, distinctive features, and age classes. Any new individuals were given a new identification number, and their data was also added to the photo-identification catalogue curated by Hong Kong Cetacean Research Project for the PRE Chinese White Dolphin population.

Location data of each individual dolphin identified in the Lingding Bay (including both Guangdong and Hong Kong waters) were obtained from the dolphin sighting database and photo-identification catalogue to examine individual movements and range use. Individual ranges and movement patterns were examined by plotting all sighting locations of each cataloged individual (including the ones identified in the past surveys) on a desktop GIS (ArcView<sup>®</sup> 3.1), to determine whether any individuals have been found across different survey areas, and to examine individual movements within the entire study area as well as any cross-boundary movements across the territorial border of Hong Kong SAR and Guangdong waters.

### **3.5 Dolphin distribution pattern**

The line-transect survey data were integrated with Geographic Information System (GIS) in order to visualize and interpret different spatial and temporal patterns of dolphin distribution using their sighting positions collected under the present study period. Location data of dolphin group were plotted on map layers of Lingding Bay using a desktop GIS (ArcView<sup>®</sup> 3.1) to examine their distribution patterns during the entire study period.

### **3.6 Encounter rate analysis**

The encounter rates of Chinese White Dolphins (number of on-effort sightings per 100 km of survey effort and total number of dolphins per 100 km of survey effort) were calculated in each survey area and during different study periods in relation to the amount of survey effort conducted. The encounter rate can be used as an indicator to determine areas of importance to dolphins within the study area.

### **3.7 Abundance and density estimation**

Density and abundance of Chinese White Dolphins were estimated by line-transect analysis using systematic line-transect data collected from the present study. Survey effort conducted on each survey day was used as a single sample, thereby providing some measure of independence even when surveys were conducted on successive days. Estimates were calculated from dolphin sightings and effort data collected during conditions of Beaufort 0-3 (Jefferson 2000). The following formulae

were used to estimate density, abundance, and their associated coefficient of variation with the computer program DISTANCE Version 6.0 (Thomas et al. 2009):

$$\hat{D} = \frac{n\hat{f}(0)\hat{E}(s)}{2L\hat{g}(0)}$$

$$\hat{N} = \frac{n\hat{f}(0)\hat{E}(s)A}{2L\hat{g}(0)}$$

$$CV = \sqrt{\frac{\text{var}(n)}{n^2} + \frac{\text{var}[\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\text{var}[\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\text{var}[\hat{g}(0)]}{[\hat{g}(0)]^2}}$$

where D=density (of individuals), n=number of on-effort sightings, f(0)=trackline probability density at zero distance, E(s)=unbiased estimate of average group size, L=length of transect-lines surveyed on effort, g(0)=trackline detection probability at zero distance, N=abundance, A=size of the survey area, CV=coefficient of variation, and var=variance.

### 3.8 Habitat usage analysis

Quantitative grid analysis of habitat use (see Hung 2008) was conducted using positions of on-effort sightings of Chinese White Dolphins and survey effort from the present study. Sighting densities (number of on-effort sightings per km<sup>2</sup>) and dolphin densities (total number of dolphins from on-effort sightings per km<sup>2</sup>) were then calculated for each 1 km by 1 km grid with the aid of GIS. Sighting density grids and dolphin density grids were further normalized with the amount of survey effort conducted within each grid. The total amounts of survey effort spent on each grid were calculated by examining the survey coverage on each line-transect survey to determine how many times the grid has been surveyed during the study period. For example, when the survey boat traversed through a specific grid 10 times, 10 units of survey effort are counted for that grid. With the amount of survey effort calculated for each grid, the sighting density and dolphin density of each grid were then normalized (i.e. divided by the unit of survey effort).

Two phrases were used to quantify the usage of the habitat. The sighting density is termed SPSE, representing the number of on-effort sightings per 100 units of survey effort. In addition, the dolphin density is termed DPSE, representing the number of dolphins per 100 units of survey effort. Among the 1-km<sup>2</sup> grids that are partially covered by land, the percentage of sea area was calculated using GIS tools, and their SPSE and DPSE values were adjusted accordingly. The following formulae were used to estimate SPSE and DPSE in each 1-km<sup>2</sup> grid within the study area:

$$SPSE = ((S / E) \times 100) / SA\%$$

$$DPSE = ((D / E) \times 100) / SA\%$$

where S = total number of on-effort sightings

D = total number of dolphins from on-effort sightings

E = total number of units of survey effort

SA% = percentage of sea area

The SPSE/DPSE values for those grids that recorded survey effort were first deduced. For the grids that were not covered by the survey effort, the densities of those were estimated from the surrounding grids with deduced densities. For instance, if there were only three surrounding grids with known SPSE/DPSE values, then the average would be taken from those three grids. If there were seven surrounding grids, then the average would be taken from those seven grids with known SPSE/DPSE values.

Although the survey transects are 3 km apart in Lingding Bay, the resulting density pattern with 1×1 km grid would provide a continuous gradient based on empirical data, and such pattern would give better resolution of habitat use pattern and allow direct comparison across the territorial border. On the other hand, if 3×3 km grid (the vessel transects are 3 km apart) is adopted, the habitat use pattern would be coarse and would not provide any mean to examine any change in habitat use pattern for any particular area of interest.

## **4 Results and discussions**

### **4.1 Survey effort, dolphin and porpoise sightings**

A total of ten sets of line-transect vessel surveys were completed in Lingding Bay of the Pearl River Estuary from August 2017 to April 2018, with one set in each month except March 2018 when two sets were conducted (see Table 1 and Table 2). From these line-transect surveys, a total of 4,852 km of survey effort was conducted among the six survey areas, including 703 km in NLDB, 1,341 km in CLDB, 1,399 km in SLDB, 710 km in MA, 433 km in SWMA, and 267 km in AZ. Most survey effort (82%) was conducted under favorable sea conditions (Beaufort 3 or below with good visibility). The great proportion of survey effort conducted under favorable sea state is critical as only these data were used for line-transect analysis and encounter rate analysis.

During these surveys, a total of 238 groups of 1,152 Chinese White Dolphins were sighted (Table 1). Among them, 218 groups of 1,077 dolphins were sighted

during on-effort search. The majority of these sightings were made in CLDB (75 sightings), SLDB (66 sightings) and MA (49 sightings) survey areas, while only 16 and 11 sightings were made in NLDB and SWMA survey areas respectively. Dolphins were rarely observed in AZ survey area with only two groups of four dolphins being sighted (Figure 2). Most sightings (204 groups of 1,009 dolphins) were made during sea state Beaufort 0-3, which were used to estimate density and abundance.

In addition, five groups of 11 Indo-Pacific finless porpoises were sighted in SWMA only (Figure 3) during the present study period, with one to three individuals in each group.

#### **4.2 Distribution pattern**

Distribution pattern of dolphin and porpoise sightings in Lingding Bay of the Pearl River Estuary during the 2017-18 study period is shown in Figure 3. Dolphins were commonly sighted throughout the study area, but were mostly absent from the northernmost (i.e. northern part of NLDB) and the southeastern portion (including most of AZ area and the eastern part of SWMA) of Lingding Bay. Sightings of the dolphins were concentrated at several locations, including the waters to the northwest of Neilingding Island, around Datouzhou-Sanjaoshan-Qingzhou islands (within and around the general area of Guishan offshore wind farm) and to the west of Lautau Island. Dolphins were also frequently observed in the waters to the north of the Hong Kong-Zhuhai-Macau Bridge (HZMB) alignment. The five groups of porpoises were all observed in the southernmost portion of Lingding Bay (Figure 3), where no dolphin was sighted.

Dolphin distribution pattern in 2017-18 was similar to the one in 2005-06 (Figure 4, note: surveys were not conducted in SWMA and AZ in 2005-06). It should be noted that this doesn't mean the dolphins' critical habitat were shifting. It was not feasible to identify the relative importance for the dolphin' habitat simply relying on distribution patterns alone because the survey effort coverage was uneven among different survey period. The fine-scale habitat use of the dolphins, which provided quantifiable information on distribution and density of dolphins by taking the survey effort into account, is presented in Section 4.8.

#### **4.3 Encounter rates**

The dolphin encounter rates among the six survey areas from each survey were calculated using on-effort survey data collected in Beaufort 0-3 condition only (Figure 5). Encounter rates using combined survey effort were also calculated and compared

among different survey areas (Figure 6) to provide indication of relative importance of each area for the dolphins. Among the six survey areas, MA had the highest dolphin encounter rate (7.50 groups per 100 km), whereas CLDB and SLDB recorded the second and the third highest encounter rate with 6.34 and 5.58 groups per 100 km respectively (Figure 6). NLDB and SWMA survey areas were used by the dolphins to a much smaller extent, while dolphins were rarely sighted in AZ waters.

The overall encounter rate in Lingding Bay from 2017-2018 was 5.14 groups per 100 km (25.41 dolphins per 100 km), which was slightly higher than the one in 2005-06 (4.16 groups per 100 km; 20.81 dolphins per 100 km).

#### **4.4 Density and abundance**

The density and abundance of Chinese White Dolphins were estimated for each survey area using the line-transect analysis method, following the similar approach as in previous monitoring period in Lingding Bay. Only effort and sighting data collected from the areas under favorable sea conditions were used in the analysis. Since AZ area recorded only a handful of sightings with a very small sample size unsuitable for the line-transect analysis, it was excluded for the density/abundance estimation. Abundance and density estimation of dolphins among the four areas of major dolphin occurrences (i.e. NLDB, CLDB, SLDB, MA) as well as SWMA, were calculated using a total of 3,776 km of survey effort and 198 dolphin groups sighted during Beaufort 0-3 condition. These estimates and their associated parameters from each of the survey areas are shown in Table 3.

Based on AIC values, the hazard rate model with a cosine adjustment was chosen to estimate the  $f(0)$ , and the estimated effective strip width (ESW) was 224 m. Dolphin densities varied noticeably among different survey areas in Lingding Bay. MA and SWMA areas recorded the highest (89 individuals per 100 km<sup>2</sup>) and lowest (6.01 individuals per 100 km<sup>2</sup>) dolphin densities respectively. The combined dolphin abundance estimates for the Lingding Bay were 945 individuals during the 2017-18 monitoring period, with the moderate level of statistical precisions (CV=20.34% - 28.66%) in CLDB, SLDB and MA, which indicated the resulted estimates should be reliable. On the contrary, the NLDB and the SWMA areas had lower statistical precision (CV=43.46% and 70.02% respectively) due to the smaller amount of on-effort sightings.

During 2005-06 survey period, the total dolphin abundance was estimated to be 1,052 individuals in wet season (April to September) and 1,273 individuals in dry season (October to March) for Lingding Bay, based on 12-month surveys (Chen et al.,

2010). To compare with those results, the survey data from October 2017 to March 2018 were extracted to estimate the abundance in dry season (the abundance in wet season was not able to calculate due to the lack of surveys in the annual fishing moratorium from May to July). The combined dolphin abundance estimates for dry season during 2017-18 monitoring period were 990 individuals (Table 4), which was approximately 78% of the estimate in the dry season during 2005-06 (1,273 individuals,) with a 22% decline, or an average rate of decline at 2.07% per annum. These showed a pronounced decline for dolphin abundance in the past decade. This was in accordance with the declining tendency of the young calves' occurrence, in which the proportion from the total sighted dolphins dropped from 12.36 % in 2005-06 to 8.16 % in 2017-18. This could mean a continuous low level of recruitment for the local dolphin population (which will be discussed later in Section 4.6).

Fishery resources were declined in Lingding Bay due to the overfishing. For example, the catch of light maigre croaker (*Collichthys lucidus*), which is one of the favorite preys of humpback dolphin, has rapidly reduced according to the fishermen. The catching season of Lingding Bay for this species is usually in dry season (especially December to March), and it was almost disappeared in recent years. The depletion of fishery resource could be related to the decline of dolphin abundance (in dry season) in the past decades.

Meanwhile, habitat for dolphins were deteriorating and losing in the past decade, which was brought by a great amount of reclamations, offshore constructions and other activities (e.g. sand mining in the NLDB) in Lingding Bay. This could also contribute to the reduction of abundance of the young calves as well as the total abundance of dolphins in the past decades.

On the other hand, when comparing with the estimates during 2015-16 (the surveys were also conducted during August to April), it showed the overall dolphin abundance of Lingding Bay in 2017-18 (945 individuals) was only slightly lower than the one in 2015-16 (957 individuals, <http://www.hzmb.org/cn/bencandy.asp?id=3903>). The slight difference between the two periods could be attributed to the deviations in abundance estimation. Continuous monitoring on population dynamics are needed to figure out if the declining trend in dolphin abundance in Lingding Bay has ceased in recent years.

#### **4.5 Group size**

During the 2017-18 study period, the group sizes of Chinese White Dolphins in Lingding Bay ranged from singles to 32, with an average of  $4.86 \pm 4.59$  dolphins per

group. Most dolphin groups sighted were quite small, with 38.0% of the groups composed of 1-2 animals, and 76.0% of the groups with fewer than six animals (Figure 7). Only 11.0% (26 out of the 237 groups) contained more than ten animals per group. The average group size was very similar with the result from the previous surveys in 2005-06 ( $4.80 \pm 4.91$ ). The group size compositions were also similar across the two monitoring periods (Figure 8), indicating that there has been very little change in group dynamics for Chinese White Dolphins in Lingding Bay in the past decade.

Large dolphin groups with more than 10 individuals were found throughout the distribution range in CLDB and SLDB in 2017-18 (Figure 9). In contrast, the dolphin groups were predominantly small in size in NLDB, with only one large group being sighted. It appeared that dolphins tended to gather in larger groups in the western side of Lingding Bay in recent years than before (in 2005-06 monitoring periods). Another apparent change in distribution of large dolphin groups was that they appeared more often in the waters around the Datouzhou-Sanjiaoshan-Qingzhou islands in 2017-18, where the Guishan offshore wind farm is located. The large aggregation of dolphins may imply more prey resources in these areas, which could in turn provide better feeding opportunities for dolphins to form larger groups (see discussion also in Section 4.8).

#### **4.6 Calf occurrence**

Among the 238 dolphin groups in Lingding Bay sighted during the 2017-18 monitoring period, 21 groups contained unspotted calves (UCs), while 64 groups contained UCs or unspotted juveniles (UJs). A total of 24 UCs and 70 UJs were identified, or 8.16% of the total number of the dolphins sighted in the present study period.

In 2017-18, dolphin calves (including UCs and UJs) were regularly seen throughout the survey areas similar to the overall dolphin distribution in Lingding Bay. Moreover, the comparison of the distribution patterns for occurrence of calves across the present and past monitoring periods revealed some subtle differences, with the majority of calves sighted in the western side of Lingding Bay in 2017-18 (Figure 10).

Encounter rates of young calves were calculated among different survey areas (Figure 11), which was similar to the overall dolphin encounter rates in 2017-18. The results showed that MA had the highest occurrence of young calves (encounter rate of 3.35 sightings of young calves per 100 km of survey effort) among all survey areas, followed by SLDB (1.83 sightings per 100 km) and CLDB (1.27 sightings per 100

km). The high occurrences of young calves among these three areas highlighted their importance for the long-term survival of the population. In contrast, the encounter rate of young calves was much lower in NLDB, and there was no calf occurrence at all in AZ waters.

Temporal trend in occurrence of young calves was examined by comparing the percentages of sightings and individuals of young calves (UCs and UJs combined) in the present study period to the ones in past monitoring periods (Figure 12 and 13). The proportion of young calves from the total dropped from 12.36 % in 2005-06 to 8.16 % in 2017-18 (Figure 12). Similar trend was also observed with the proportion of sightings associated with young calves (Figure 13). However, the results cannot simply be interpreted as an increase in calf mortality in Lingding Bay, as the proportion of young calves can fluctuate within a few years. Nevertheless, the overall reduction of young calves in the past decade is of grave concern as it is closely related to the future survival of the PRE dolphin population, and therefore the calf occurrences in Lingding Bay should be continuously monitored in the near future.

#### **4.7 Activities and boat associations**

Dolphin activities were recorded when they were sighted during the line-transect surveys, to determine the important areas for feeding, socializing, traveling and resting activities within the study area. A total of 177 and 24 groups of dolphins were observed to be engaged in feeding and socializing activities respectively in 2017-18, comprising of 74.4% and 10.1% of all dolphin groups. In addition, there were 10 groups engaged in traveling activity, and another 15 groups engaged in milling/resting activity during the study period.

The proportion of sightings associated with feeding activities in Lingding Bay in recent years was much higher than the one recorded in Hong Kong waters (11.9 % in 2016-17, see Hung 2017). It may imply that there is a lack of food resources for the dolphins in Lingding Bay and they were forced to spend more time looking for food, which may have been persistent for several years. Decline in fisheries resources could be one of the threats for Chinese White Dolphins in this area.

The distribution patterns of dolphin groups engaged in feeding activities and socializing activities were shown in Figure 14 (note: such data was not available for the 2005-06 monitoring as activity data was not routinely recorded). The feeding activities could be found throughout Lingding Bay, while fewer groups engaged in socializing activities was found to the north and west of Neilingding Island in 2017-18. Notably, dredging (i.e. sand mining) activities had been operating to the

north and west of Neilingding Island (just near the northern boundary of the Guangdong Pearl River Estuary Chinese White Dolphin National Nature Reserve) throughout the entire monitoring period of the present study. The absence of socializing activities which serve important functions in the daily lives of the dolphins may signal the deterioration in habitat quality of this area.

Among the 237 groups of dolphins sighted during the present study period, only 23 (9.7%) of them were associated with operating fishing boats, including 12 gill-netters, four purse-seiners, three single trawlers, two shell trawlers, one pair trawlers and one hang trawler. Dolphin groups associated with operating fishing boats were sighted throughout Lingding Bay, which was also similar to the overall distribution (Figure 15).

It should be noted that the percentage of dolphin sightings associated with fishing boats was much lower than the one in 2005-06 (15.0 % of the total sightings). The noticeable decline in fishing boat association in recent years was probably related to the reduction of trawl fishing within Lingding Bay, which was a result of either the bottom-trawling ban implemented by the management authorities, or fishery resource being depleted to the point that fishing boats would rather operate in more offshore waters. Nevertheless, the diminished reliance on feeding behind fishing boats may have affected the dolphins' foraging strategies, as they may need to spend more time and energy to search for food, as mentioned above that the proportion of sightings associated feeding activities remained very high in recent years.

#### **4.8 Habitat use**

Fine-scale pattern of dolphin habitat use from quantitative grid analysis allows direct comparison in densities between different survey areas where Chinese White Dolphins are known to occur. The SPSE and DPSE values (i.e. sighting densities and dolphin densities respectively) were calculated in all grids among the six survey areas during the present study period.

In 2017-18, the high density areas of dolphins were located in waters around the Datouzhou-Sanjiaoshan-Qingzhou islands (where the Guishan offshore wind farm is located), between Neilingding Island and Lung Kwu Chau, to the southwest of Lantau Island, and some areas within the Guangdong Pearl River Estuary Chinese White Dolphin National Nature Reserve including waters along the Hong Kong-Zhuhai-Macao Bridge (Figure 16). These areas should all be considered as important dolphin habitats within the Lingding Bay.

Notably, most of these areas with high dolphin densities were located around islands and near man-made structures such as bridge piers and the pedestals of the offshore wind turbine. These physical features could generate stronger eddy currents with waters flowing past these ‘barriers’ during flood and ebb tides, thereby trapping fishes and attracting dolphins to feed there (Scheidat et al., 2011; Lindeboom et al., 2011).

On the contrary, several areas recorded zero to very low densities in most grids in those areas. These included the waters in the northernmost part of Lingding Bay, to the northeast of Macau, to the east of Guishan Island and to the west of Dong’ao Island. It appeared that these areas were actively avoided by the dolphins as they either were in very shallow water, or received very little influence from the Pearl River outflow (which in turns was occupied by finless porpoises such as the waters to the west of Dong’ao Island).

It seems that the main infrastructure projects in Lingding Bay such as the HZMB and Guishan offshore wind farm have little effects on the habitat usage of the Chinese White Dolphins in the 2017-18 period, and no signals have shown that the dolphins have avoided these areas. This could be due to the fact that the most intensive underwater operations of these constructions such as piling, tunneling, pouring and engineering vessels shuttling in the central and south Lingding Bay have almost ceased for two or three years, and the impacts on habitat use of the dolphins may have lessened since then. Moreover, the bridge piers and the pedestals of the offshore wind turbine may function like the artificial reefs which could enrich fishery resources and then attract dolphins to feed there. Purse-seiners were frequently observed fishing in the wind farm area and along the bridge side in recent years, indicating that there could be more fishes in these areas. Long-term monitoring in the future in these important dolphin habitats would be needed to confirm the continuous recovery of habitat use by the dolphins.

#### **4.9 Summary of photo-identification works**

During the study period of August 2017 to April 2018, over 36,000 photographs were taken during the course of the surveys conducted in Lingding Bay. The photo-identification analysis identified a total of 162 individual dolphins that were re-sighted 279 times altogether. Among these individual dolphins, 43 of them have never occurred in Hong Kong waters before in the past two decades of dolphin monitoring works, while the other 119 individuals have been regularly sighted in different survey areas around Lantau Island. Moreover, most individuals have only been re-sighted once during the study period, while 66 individuals were sighted 2-3

times, and another eight individuals were sighted four times. The most frequently sighted individuals were WL129 and NL269 with five and six re-sightings respectively, both of which have regularly occurred in Hong Kong waters in the past with frequent movements across the border into Lingding Bay.

Among the 279 re-sightings, the majority of them (78.8% of total) were made in CLDB and SLDB. On the contrary, there were 41 and 17 re-sightings made in NDLB respectively, while only one individual (MA29) was identified in SWMA survey area from the photo-ID catalogue. None of the few individuals sighted in AZ matched with the catalogued individual dolphins. Notably, 136 individuals were identified in the western part of Pearl River Estuary during 2007-11, but none of them were re-identified during the Lingding Bay surveys in 2017-18, even though the SWMA and MA survey areas were known to be the areas where individual dolphins from the eastern and western sides of the Pearl River Estuary occurred (Chen et al. 2010).

#### **4.10 Individual ranging patterns and movements**

From the ranging pattern analysis using the photo-identification data, the results revealed that among the individuals being sighted rarely in Hong Kong waters, they have some preference of range use in different parts of Lingding Bay [see examples of individuals that ranged primarily in northern part (Figure 17), southern part (Figure 18) and central part of Lingding Bay (Figure 19)]. On the other hand, for individuals that primarily occurred in Hong Kong waters in the past, many of them were re-sighted in Lingding Bay but close to the western territorial border of Hong Kong (see example in Figure 20).

For those that showed some cross-boundary movements between Hong Kong and Guangdong waters, the individuals from the northern social cluster in Hong Kong (i.e. mainly found in North Lantau waters) mostly occurred in the upper part of the Lingding Bay (see examples in Figure 21), while the one from the southern social cluster (mainly found in West and Southwest Lantau waters) normally occurred in the lower part of the Lingding Bay (see examples in Figure 22), but with some notable exceptions. For example, at least twelve individuals from the western social cluster waters showed up in the upper part of Lingding Bay, with a few occurred in NLDB where their northernmost occurrences were at least 20-30 km apart from their normal ranges in West and Southwest Lantau waters (see examples in Figure 23). In addition, there were at least six individuals that occurred primarily in West Lantau waters, but were also found in the Guishan wind farm area in MA waters (see examples in Figure 24). These extensive movements showed that even most dolphins occurred primarily in Hong Kong waters have strong site fidelity there, many of them also ranged

extensively across the border, with some utilizing the entire Lingding Bay as part of their ranges.

It should also be mentioned that a number of individuals sighted during the 2017-18 Lingding Bay surveys were those that have regularly occurred in Hong Kong waters, but have disappeared from there for at least two years (see examples in Figure 25). In the past few years, a number of frequently sighted individuals in Hong Kong have disappeared from there (see Hung 2016, 2017), and some of them have re-appeared in Lingding Bay, implying that they may have moved permanently away from Hong Kong waters. Therefore, it is crucial to continue the long-term monitoring surveys throughout Lingding Bay to confirm the presence or absence of these individuals that were known to occur regularly in Hong Kong waters in the past. Moreover, such large-scale surveys would also help greatly improve the understanding of individual ranging patterns with cross-boundary movements, as well as the changes in population dynamics within Hong Kong waters, especially in light of various on-going large-scale infrastructure projects and existing threats in Hong Kong.

#### **4.11 References**

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## **5 Summary and way forward**

The latest situation of the Chinese White Dolphins in Lingding Bay of the Pearl River Delta region was investigated through one-year study in the past year, and the long-term temporal trend in population dynamics of the dolphins in Lingding Bay was also examined by comparing the results in present survey period and the past monitoring periods. Noticeable decline in dolphin abundances of Lingding Bay was detected in the past decade. The dolphin abundance estimate in the dry season during 2017-18 (990 individuals) was approximately 78% of the estimates in the dry season during 2005-06 (1,237 individuals) with an average rate of decline at 2.07% per annum. However, dolphin abundance of Lingding Bay in 2017-18 was fairly similar with the one in 2015-16, indicating the declining trend has likely stabilized in the past few years.

The mean group size of dolphins in Lingding Bay in 2017-18 was very similar with the results from the previous surveys. Whereas the proportion of young dolphin calves was on the decline from 12.36 % in 2005-06 to 8.16 % in 2017-18. The overall reduction of young calves in the past decade could indicate a very low level of recruitment. Sightings associated with feeding activities took a great proportion of the total sightings (74.4%) in recent years, which may imply a lack of food resources for the dolphins in Lingding Bay and they are forced to spend more time looking for food. Fewer groups engaged in socializing activities to the north and west of Neilingding Island in 2017-18, signaling the deterioration in habitat quality of this area, where dredging (i.e. sand mining) activities had been operating.

The fine-scale habitat use of Chinese White Dolphins in Lingding Bay were examined and compared with the previous results for ascertaining the important habitats utilized by the dolphins as well as the temporal trend for habitat shifting. The important dolphin habitats were mainly located in waters around the islands in Lingding Bay, and some areas within the Guangdong Pearl River Estuary Chinese White Dolphin National Nature Reserve including waters along the Hong Kong-Zhuhai-Macao Bridge. It appeared that the impacts of the main infrastructure projects in Lingding Bay such as the HZMB and Guishan offshore wind farm on habitat usage of the Chinese White Dolphins have lessened in recent years and the dolphins have not avoided these areas in the past year.

The individual ranging patterns and the cross-boundary movements were investigated based on 162 identified individual dolphins. Most dolphins have strong site fidelity which occurred primarily in Hong Kong waters or have some preference of range use in different parts of Lingding Bay. Meanwhile many of them also ranged extensively across the border, with some utilizing the entire Lingding Bay as part of their ranges. A number of frequently sighted individuals in Hong Kong have disappeared from there, and some of them have re-appeared in Lingding Bay in the past few years, implying that they may have moved permanently away from Hong Kong waters.

All of the changes in dolphin abundance, activities, and dolphin utilization of Lingding Bay waters in the past decade are the consequences stemmed from the combination of existing threats such as on-going offshore development (e.g. the HZMB, the wind farm and the sand mining) and lack of fisheries resources. Although results shows the declining trend for dolphin abundance (as well as the proportion of the young dolphin calves) has likely stabilized in the past few years, and dolphins didn't avoid the waters along HZMB and in Guishan offshore wind farm during the 2017-18 survey period, it still need to be quite cautious to conduct any new offshore projects in the whole Lingding Bay and the existing construction should be stringently monitored. Moreover, the large-scale sand mining activities near Neilingding Island in the north part of Lingding Bay should be strictly controlled, as the number of dredging boats (about 60 to 70 at present) should be largely reduced and the illegal dredging in the waters of the dolphin reserve should be prohibited. A better management with stringent control over fishing activities is also urgently needed in Lingding Bay, to protect the dolphins' prey in their habitat.

The objectives of this study for monitoring of population dynamics of Chinese White Dolphins in Lingding Bay had achieved and in the long run, long-term monitoring surveys throughout Lingding Bay are still needed to figure out the temporal trend in dolphins' distribution, habitat use, abundance in Lingding Bay, and to confirm the presence or absence of those individuals that were known to occur regularly in Hong Kong waters in the past.

## **6 Evaluation and benefits**

After a one-year study, this project achieved the objectives proposed in the application form. The latest situation of the Chinese White Dolphins, the individual ranging patterns (especially the cross-boundary movements) and the fine-scale habitat use in Lingding Bay of the Pearl River Delta region were obtained. Several

recommendations on management and conservation strategies for the Chinese White Dolphins in Lingding Bay were also presented.

In consideration of it was a scientific research project, the benefits brought by this project are that we have obtained the knowledge that the declining trend for dolphin abundance in Lingding Bay has likely stabilized in the past few years. Meanwhile, based on the results, recommendations on management and conservation strategies for the dolphins would be demonstrated on the related academic conference and submitted to government departments and management authorities, which could benefit for better conservation of the Chinese White Dolphins in Lingding Bay and the wider PRE region.

## **7 Declaration**

I hereby irrevocably declare, warrant and undertake to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that I /we:

1. do not deal with, and are not in any way associated with, any country or organization or activity which is or may potentially be relevant to, or targeted by, sanctions administered by the United Nations Security Council, the European Union, Her Majesty's Treasury-United Kingdom, the United States Department of the Treasury's Office of Foreign Assets Control, or the Hong Kong Monetary Authority, or any sanctions law applicable; and

2. shall not use any money obtained from the Marine Ecology Enhancement Fund or the related Top-up Fund, in any unlawful manner, whether involving bribery, money-laundering, terrorism or infringement of any international or local law.



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Signature

The applicant: Chen Tao

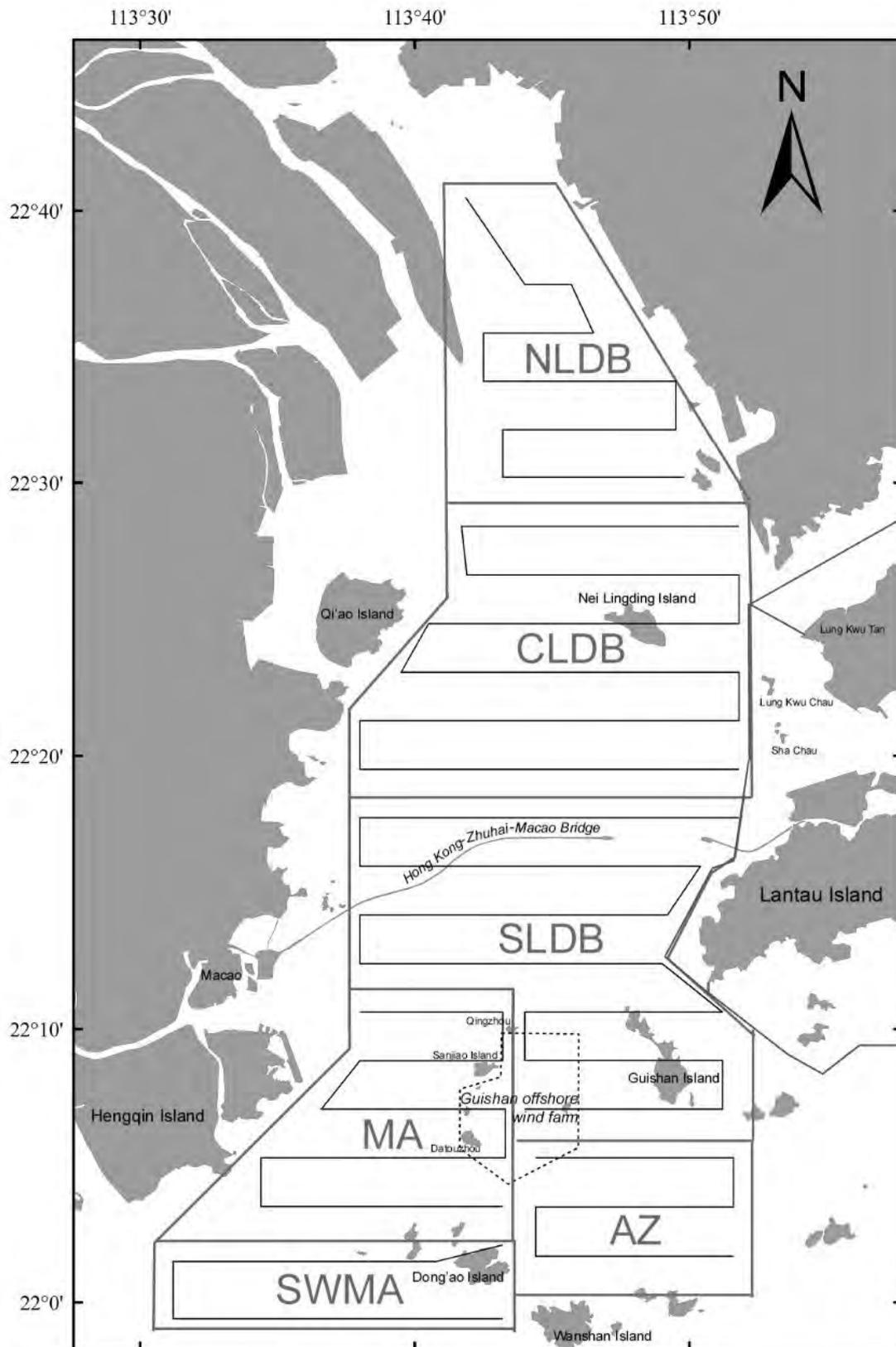


Figure 1. Survey areas and transect lines in Lingding Bay (2017-18)

NLDB, North Lingding Bay; CLDB, Central Lingding Bay; SLDB, South Lingding Bay; MA, Waters surround Macau; SWMA, Southwest waters to Macau; AZ, West waters to Aizhou Island

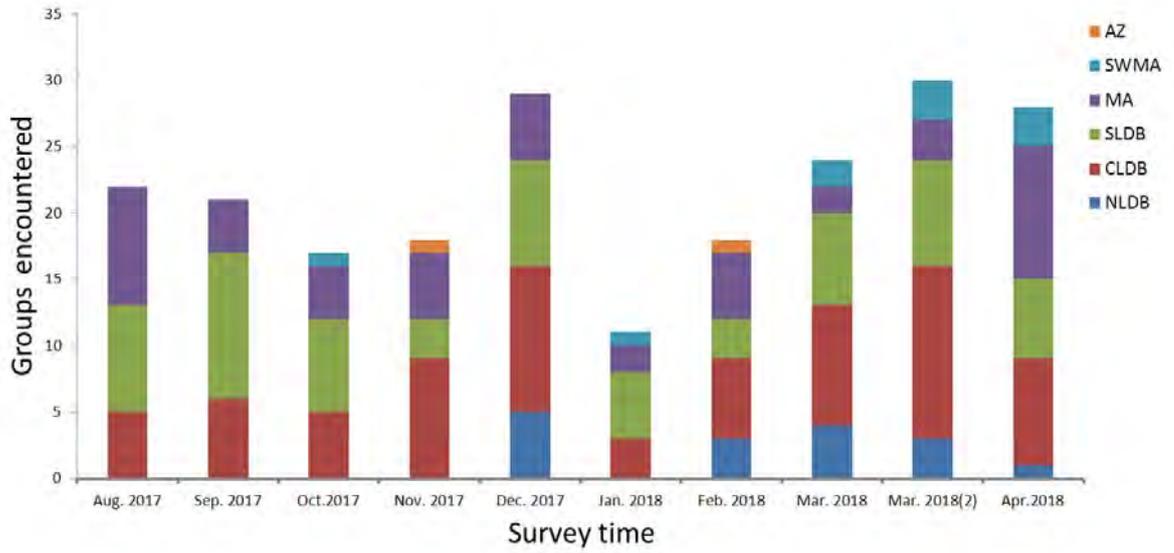


Figure 2. On-effort sightings of Chinese White Dolphin groups in the six survey areas in Lingding Bay (2017-18)

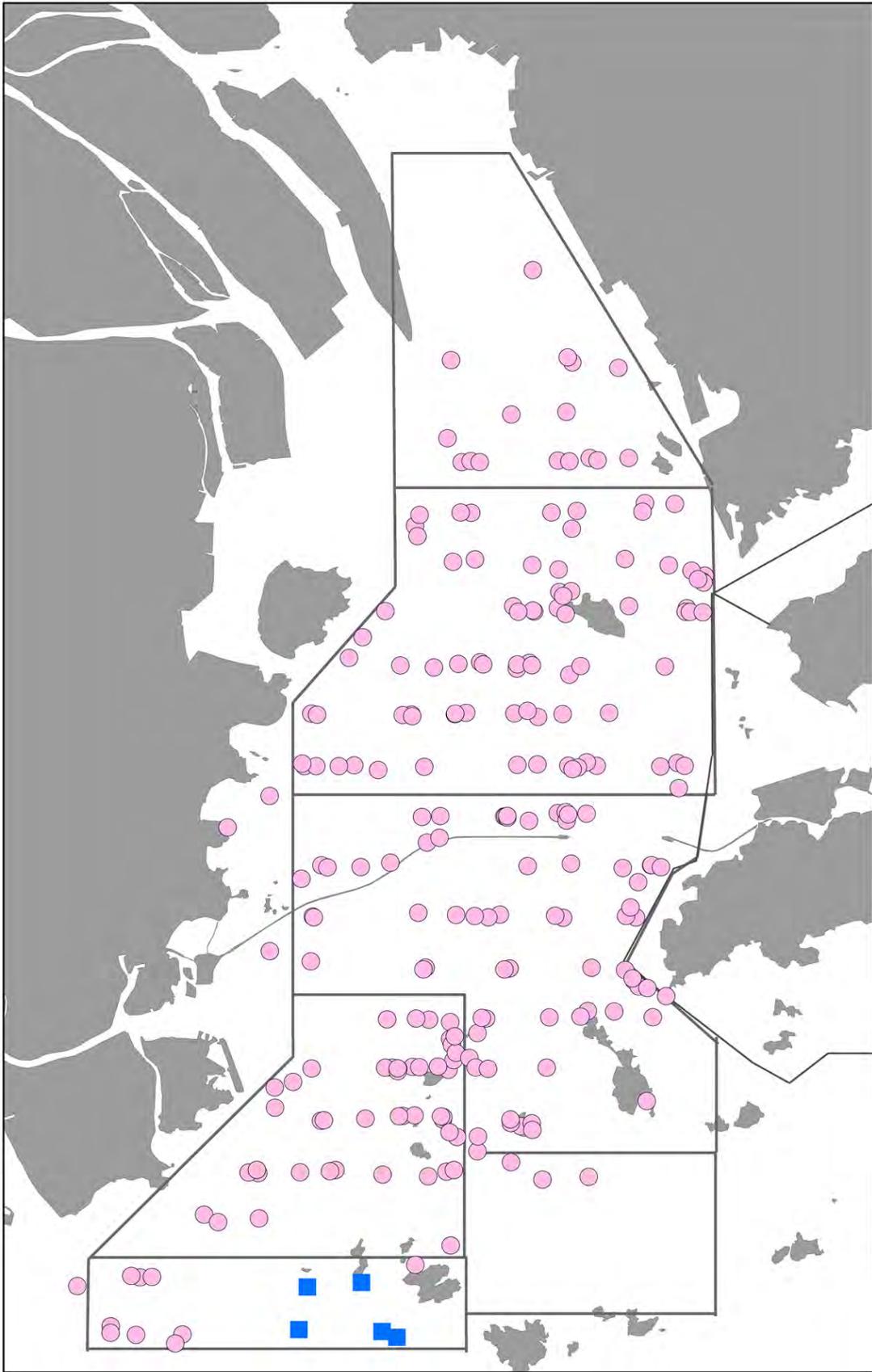


Figure 3. Distribution of Chinese White Dolphin (red dots) and Indo-Pacific finless porpoise (blue square) sightings in Lingding Bay (2017-18)

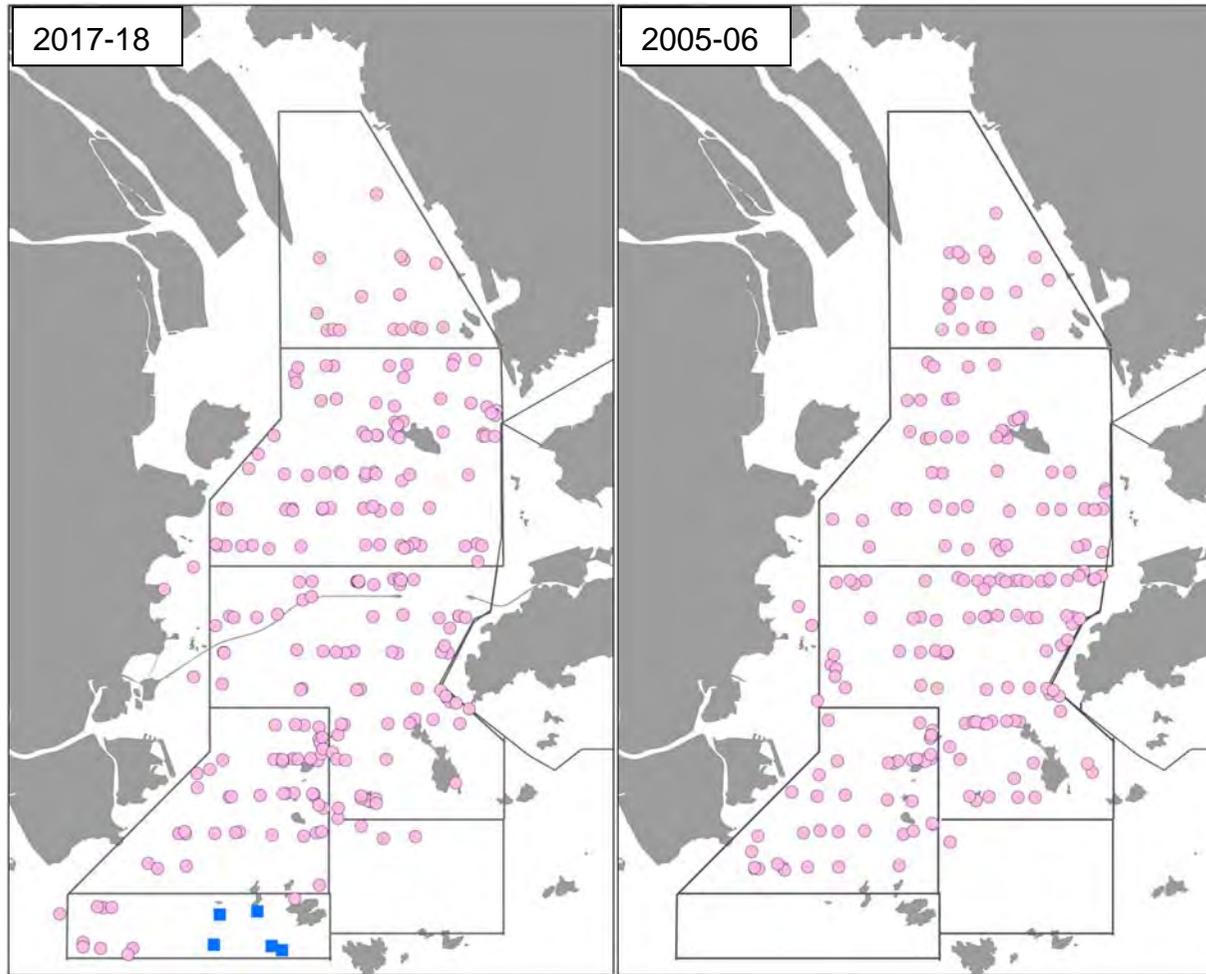


Figure 4. Comparison of the distribution patterns of Chinese White Dolphins in Lingding Bay between 2017-18 and 2005-06 monitoring periods.

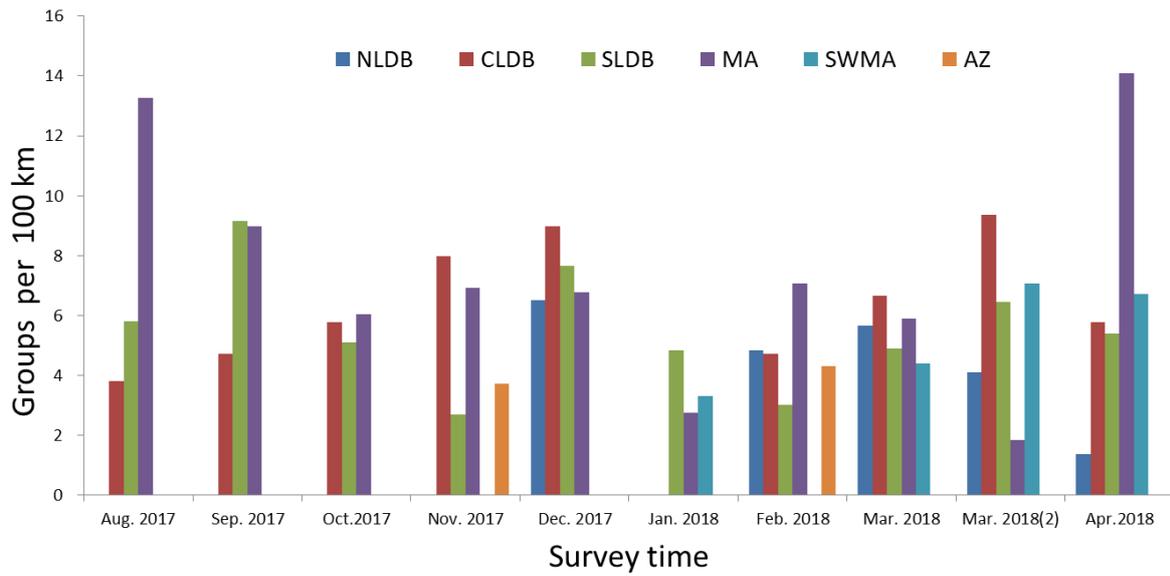


Figure 5. Encounter rates of Chinese White Dolphin groups in the six survey areas in Lingding Bay (2017-18)

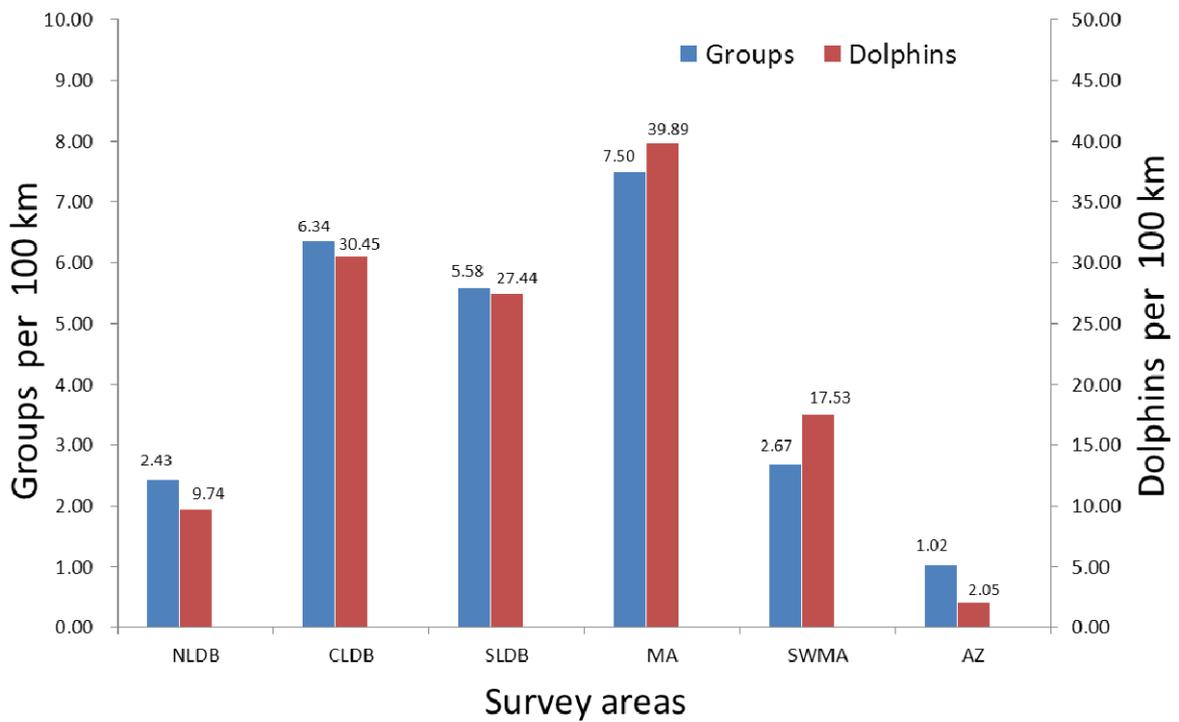


Figure 6. Combined encounter rates for the six survey areas in Lingding Bay (2017-18)

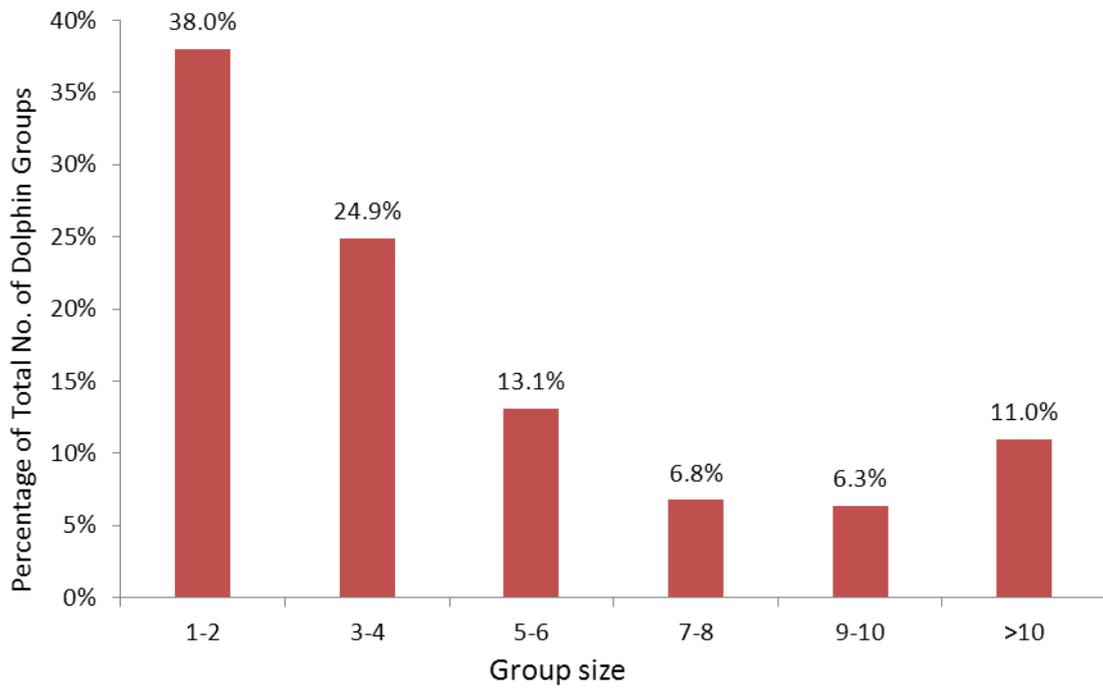


Figure 7. Percentages of different group sizes of Chinese White Dolphins in Lingding Bay (2017-18)

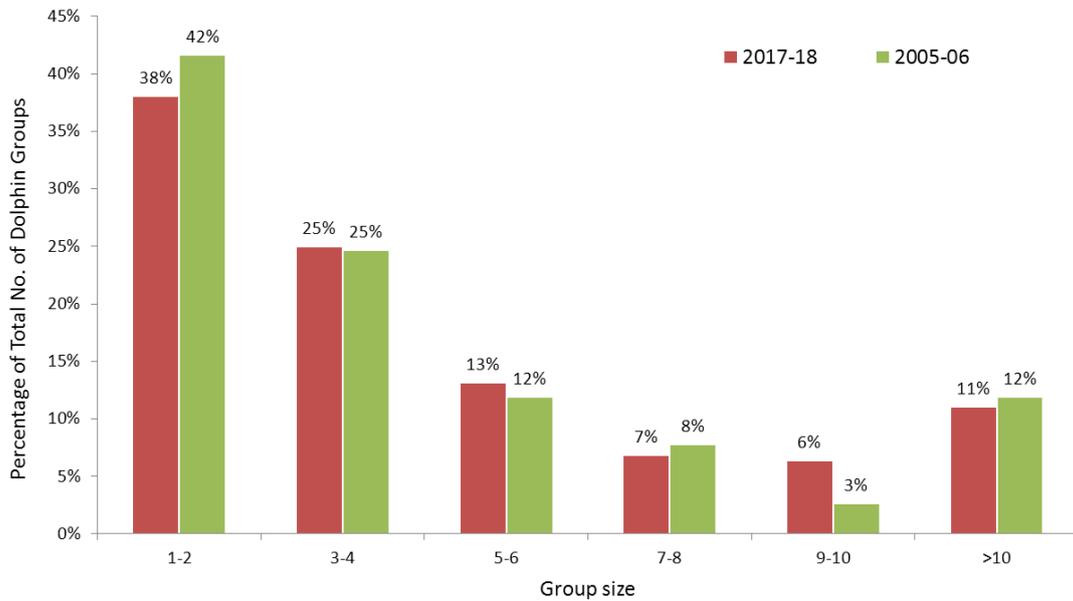


Figure 8. Composition of group size of Chinese White Dolphins in Lingding Bay during 2017-18 and 2005-06 monitoring periods

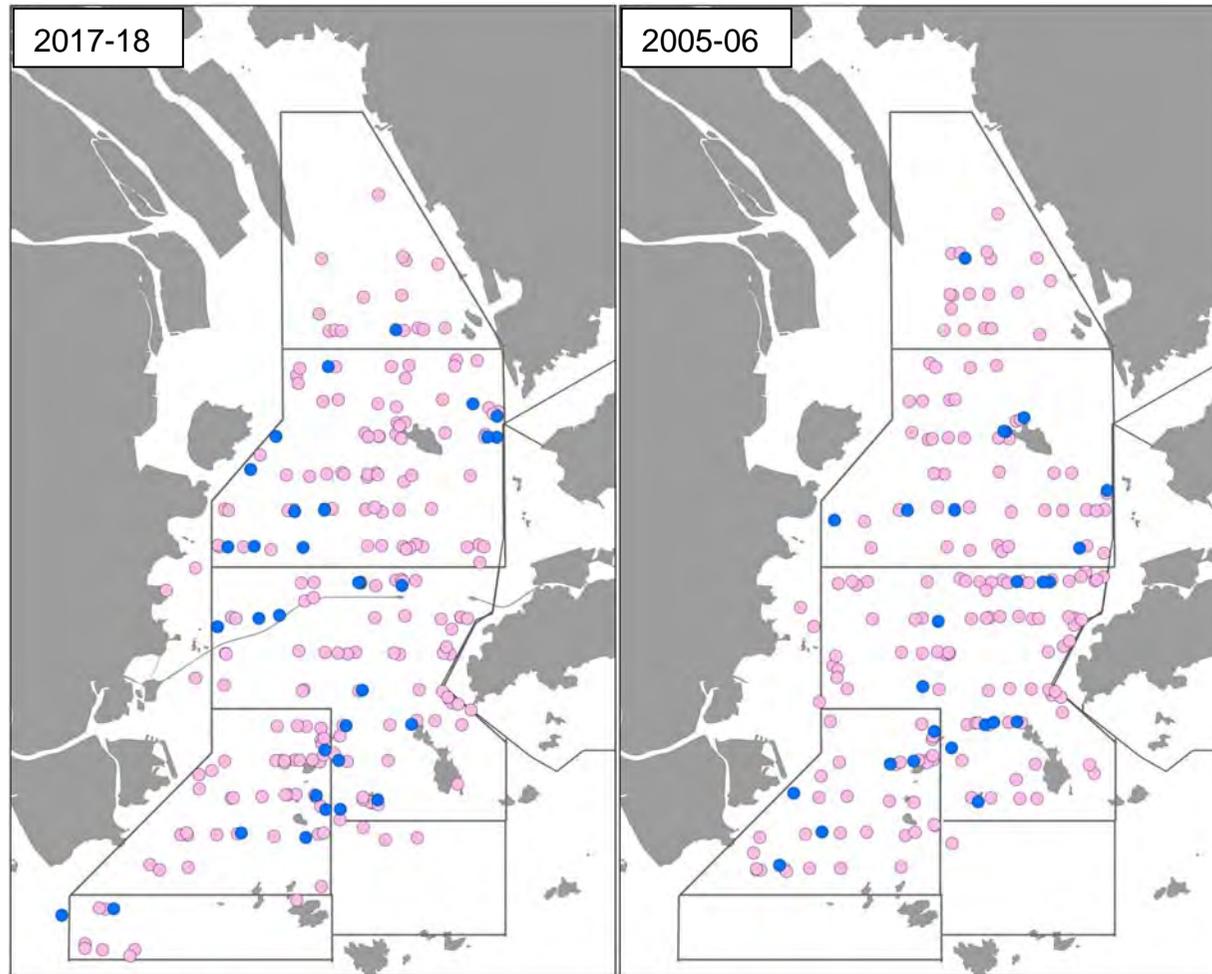


Figure 9. Distribution of dolphin sightings of large groups with more than 10 individuals (blue dots) in Lingding Bay during 2017-18 and 2005-06 monitoring periods

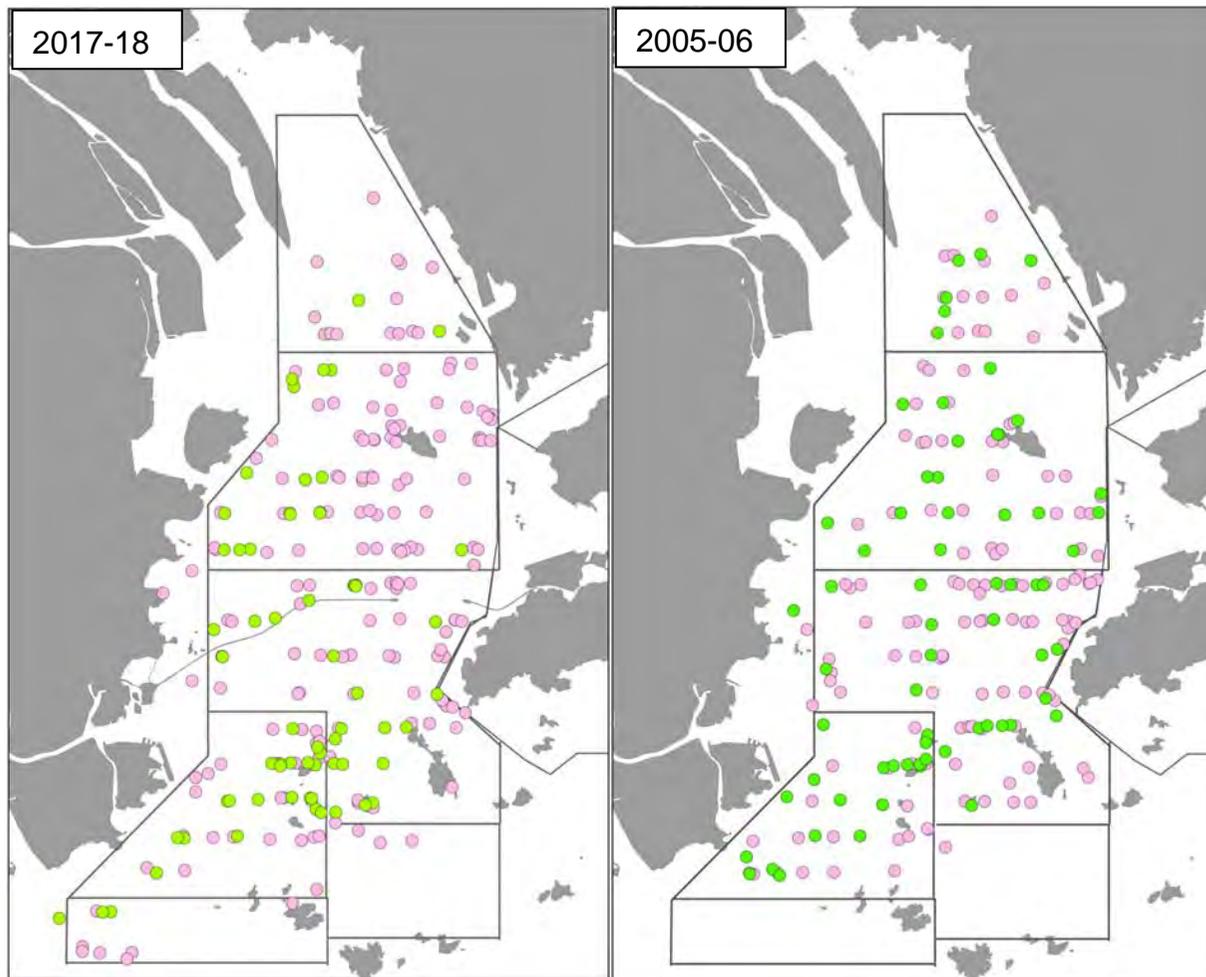


Figure 10. Distribution of young calves (Unspotted Calves and Unspotted Juveniles, green dots) distribution in Lingding Bay during 2017-18 and 2005-06 monitoring periods

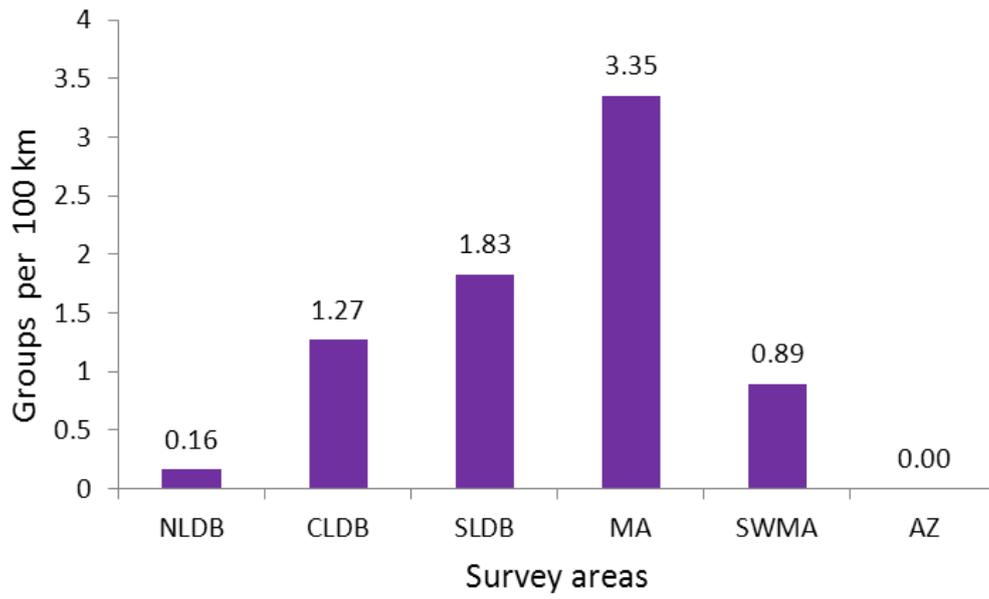


Figure 11. Encounter rates of young calves (Unspotted Calves and Unspotted Juveniles) in the six survey areas in Lingding Bay (2017-18)

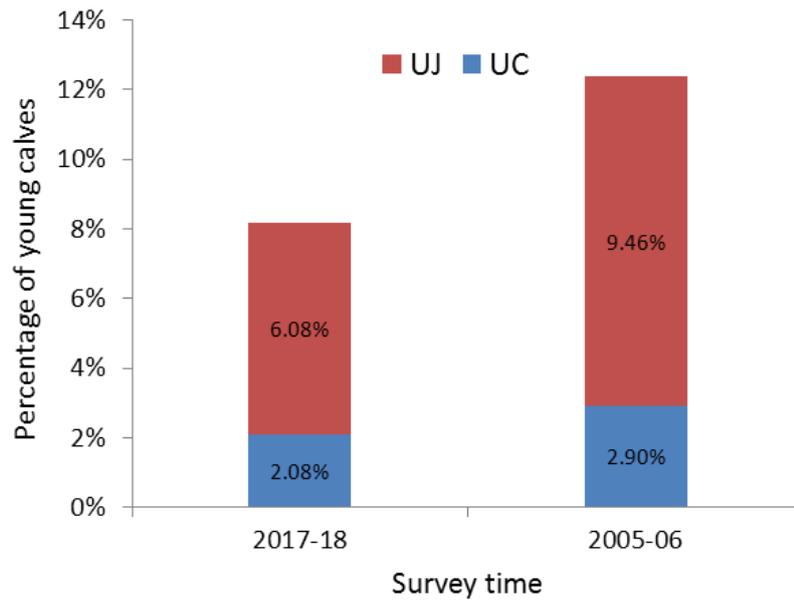


Figure 12. Percentages of young calves (Unspotted Calves and Unspotted Juveniles) among all dolphin groups in Lingding Bay during 2017-18 and 2005-06 monitoring periods

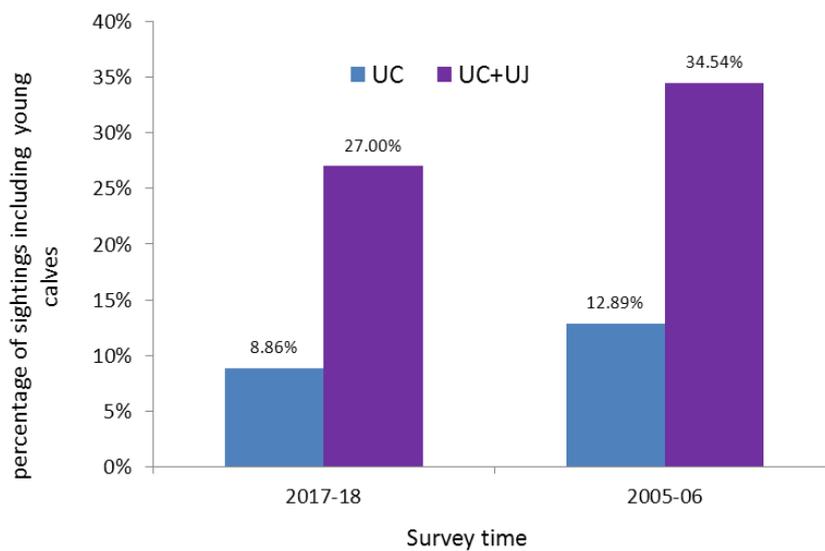


Figure 13. Percentages of sightings including young calves (Unspotted Calves and Unspotted Juveniles) in Lingding Bay during 2017-18 and 2005-06 monitoring periods

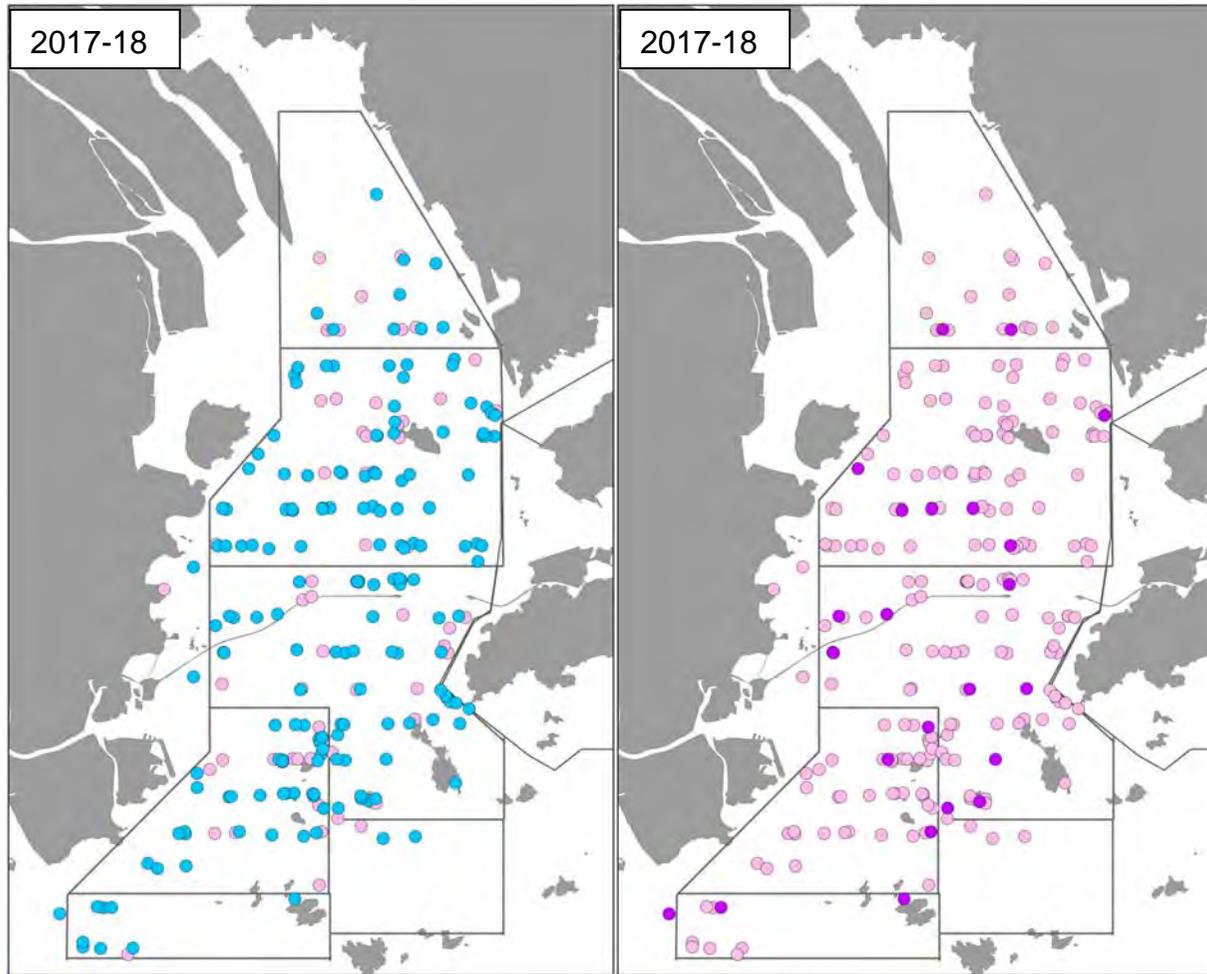


Figure 14. Distribution of Chinese White Dolphins engaged in feeding activities (left, cyan dots) and socializing (right, pink dots) activities in Lingding Bay during 2017-18 monitoring period

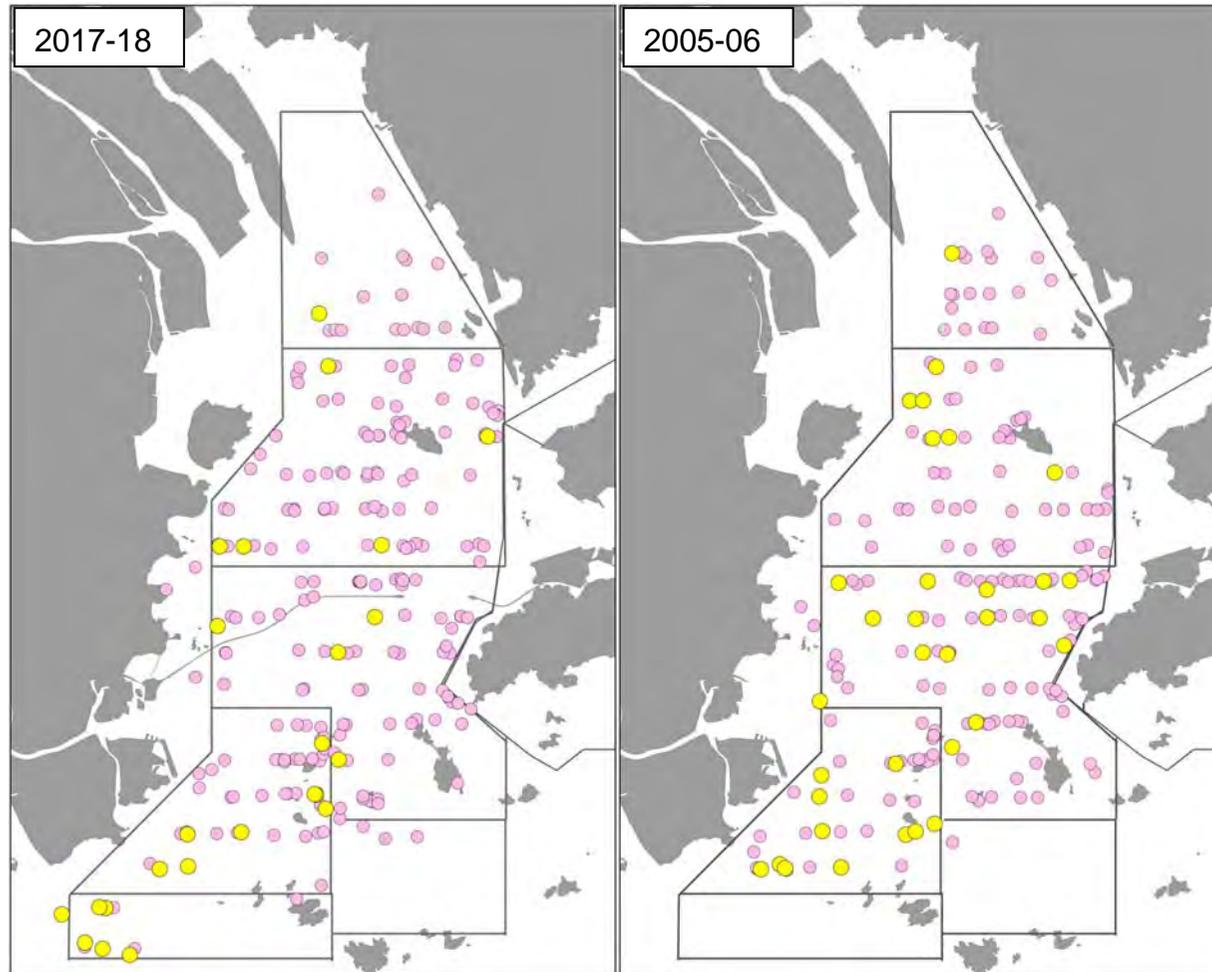


Figure 15. Distribution of dolphin sightings associations with fishing boats in Lingding Bay during 2017-18 and 2005-06 monitoring periods

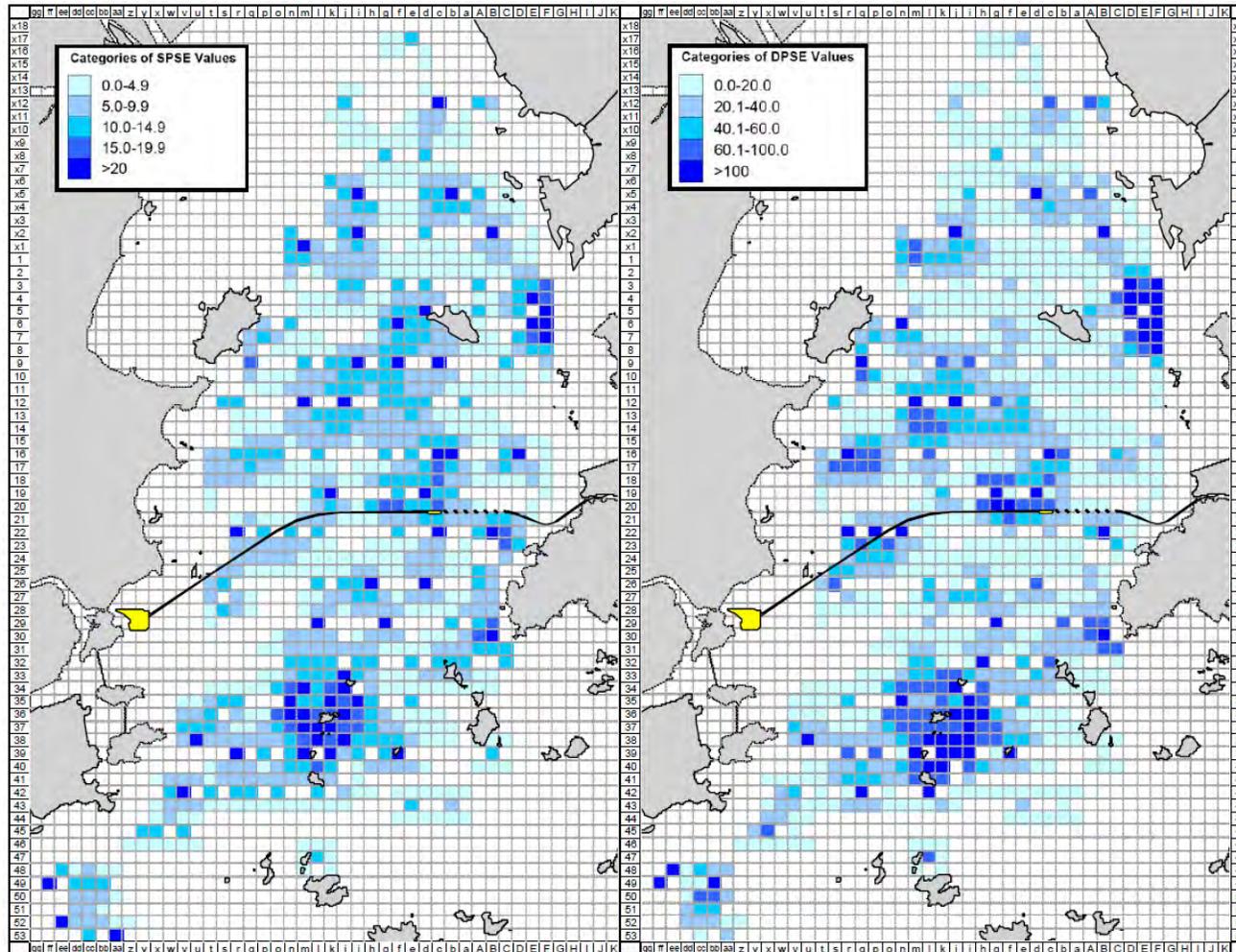


Figure 16. (left) Sighting density of Chinese White Dolphins with corrected survey effort per km<sup>2</sup> in the Pearl River Estuary, using on-effort survey data from 2017-18 (SPSE values in legend represent no. of on-effort dolphin sightings per 100 units of survey effort);

(right) Density of Chinese White Dolphins with corrected survey effort per km<sup>2</sup> in the Pearl River Estuary, using on-effort survey data from 2017-18 (DPSE values in legend represent no. of dolphins from on-effort sightings per 100 units of survey effort)

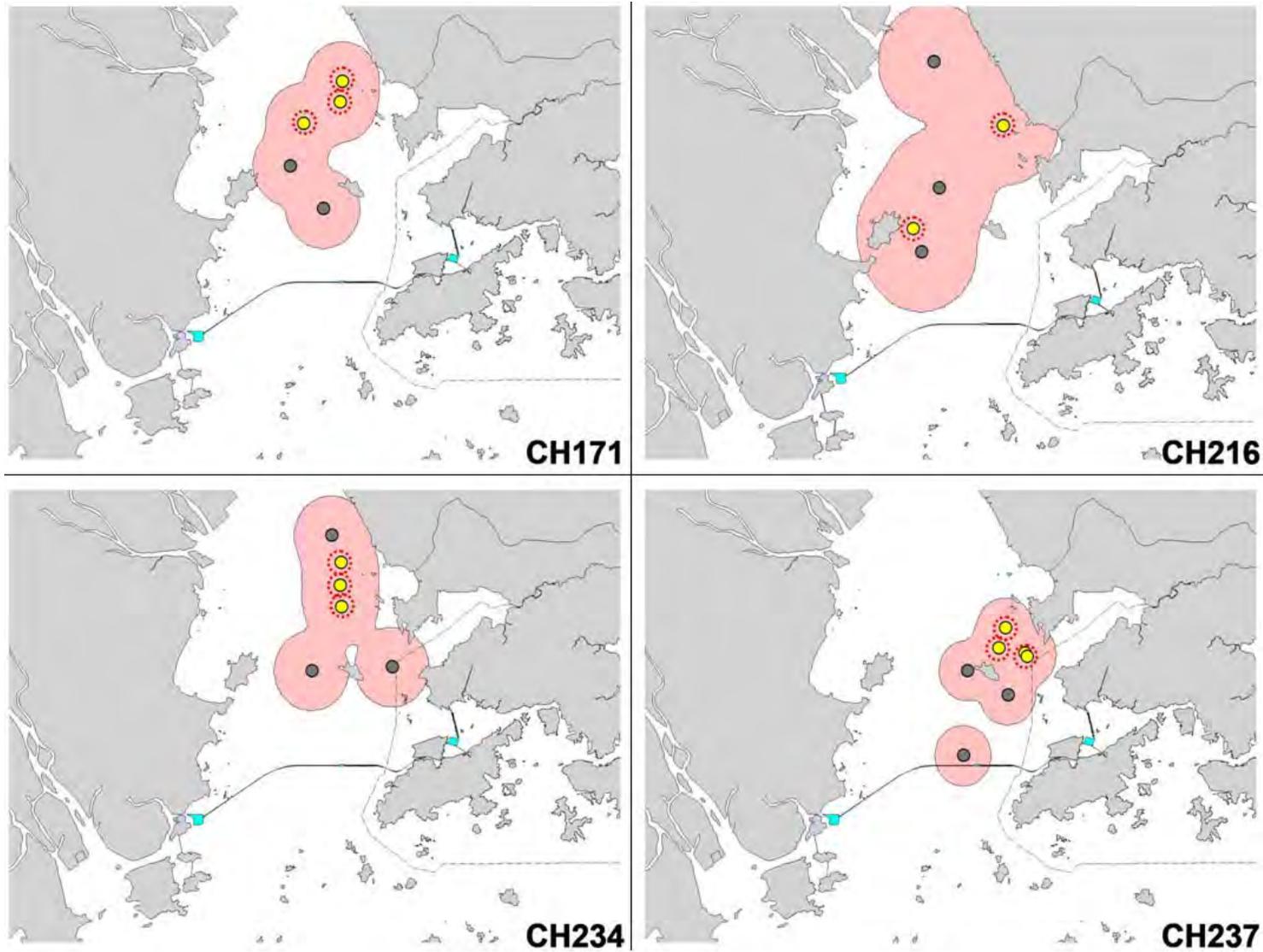


Figure 17. Examples with four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in northern part of Lingding Bay (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

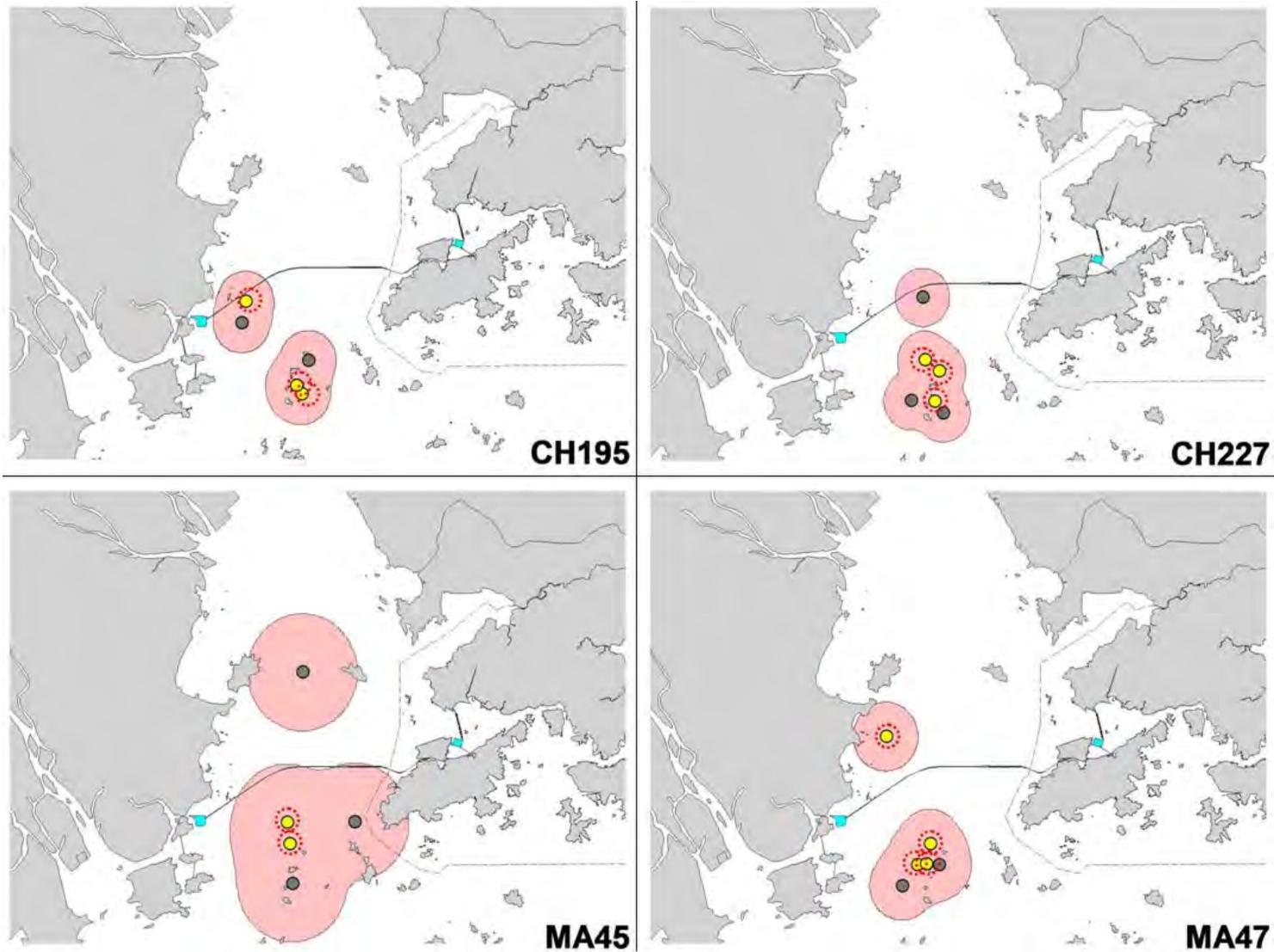


Figure 18. Examples with four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in southern part of Lingding Bay (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

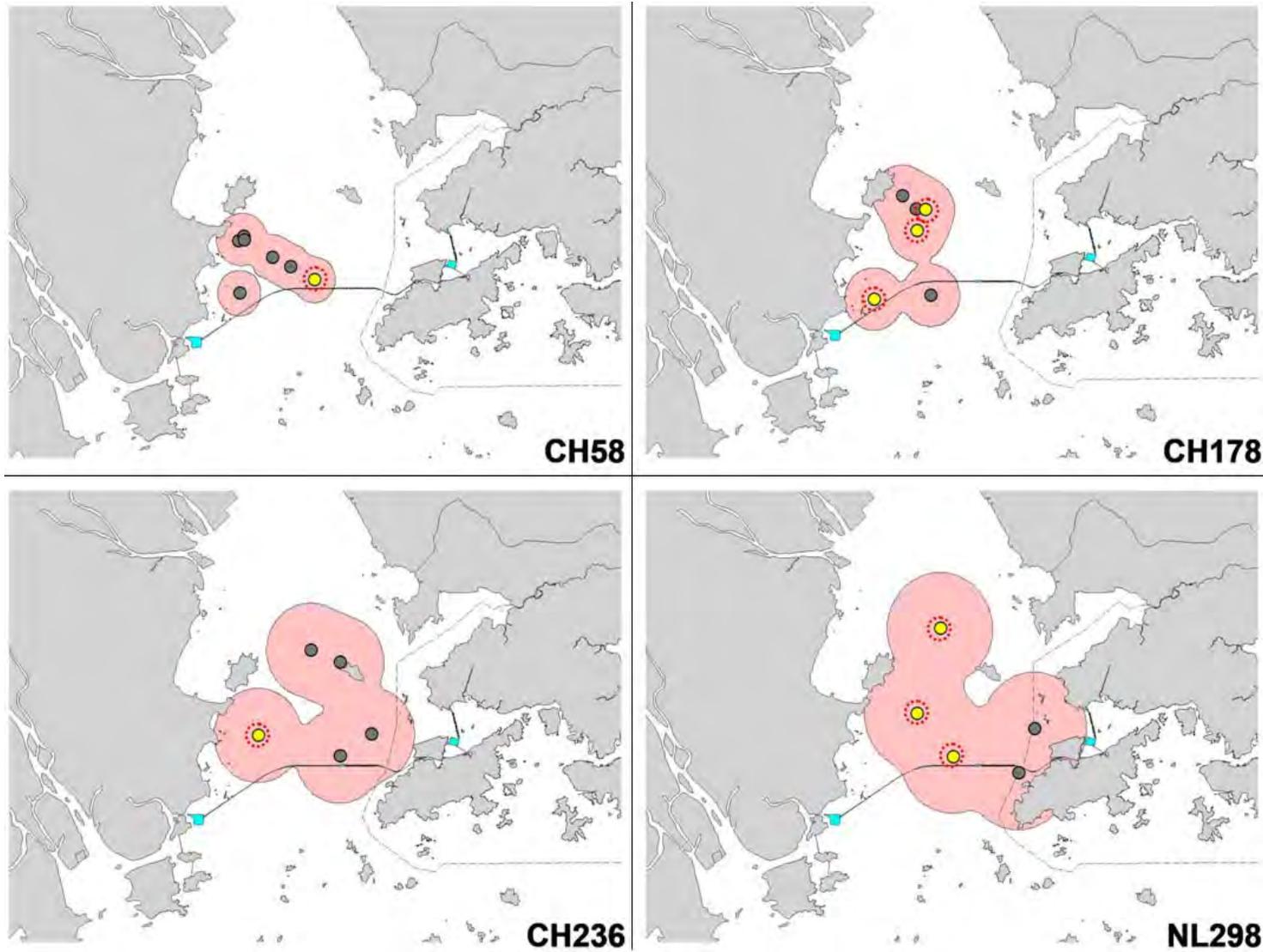


Figure 19. Examples four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in central part of Lingding Bay (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

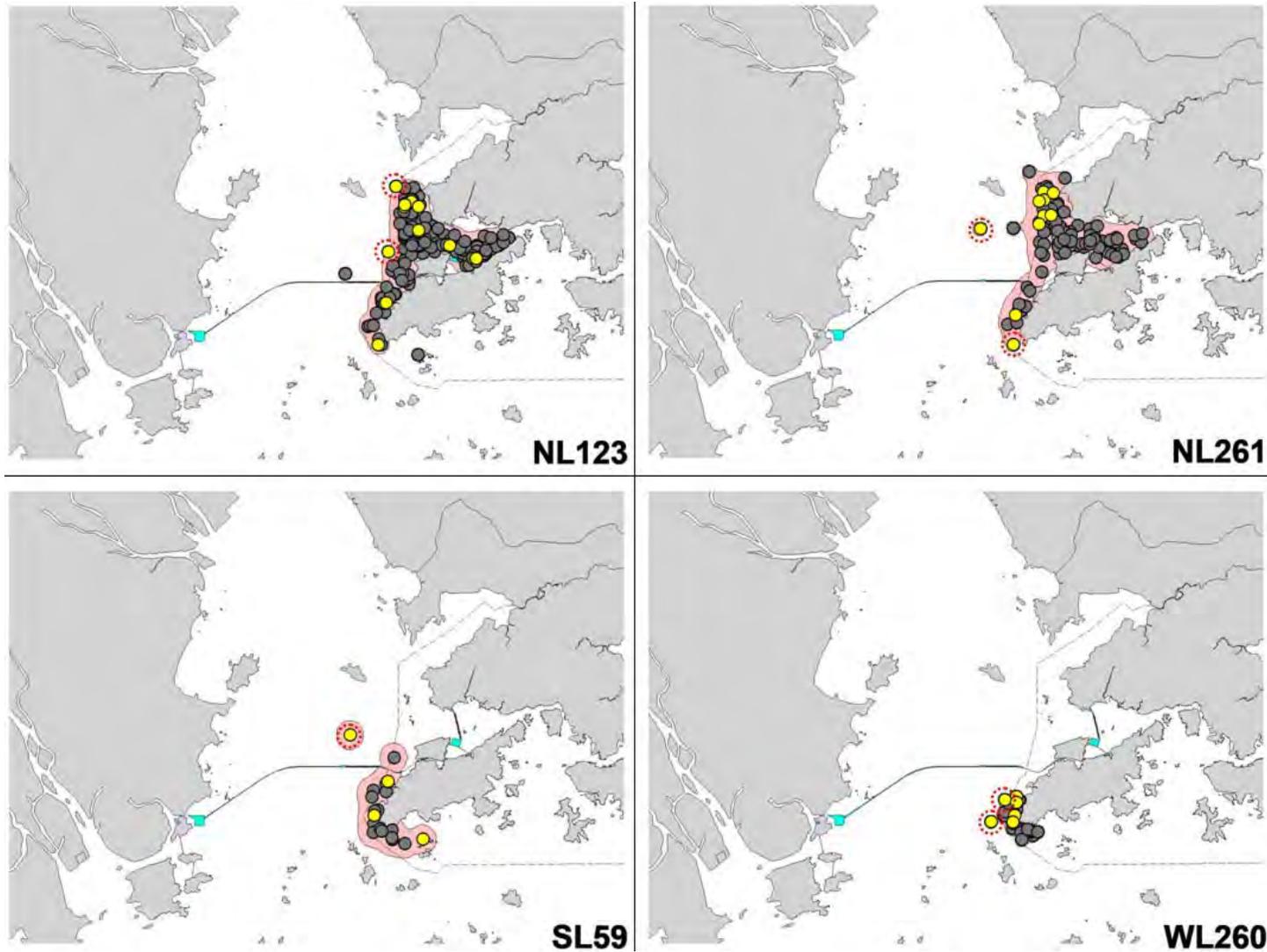


Figure 20. Examples four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in HK waters and occurred only close to the western territorial boundary (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

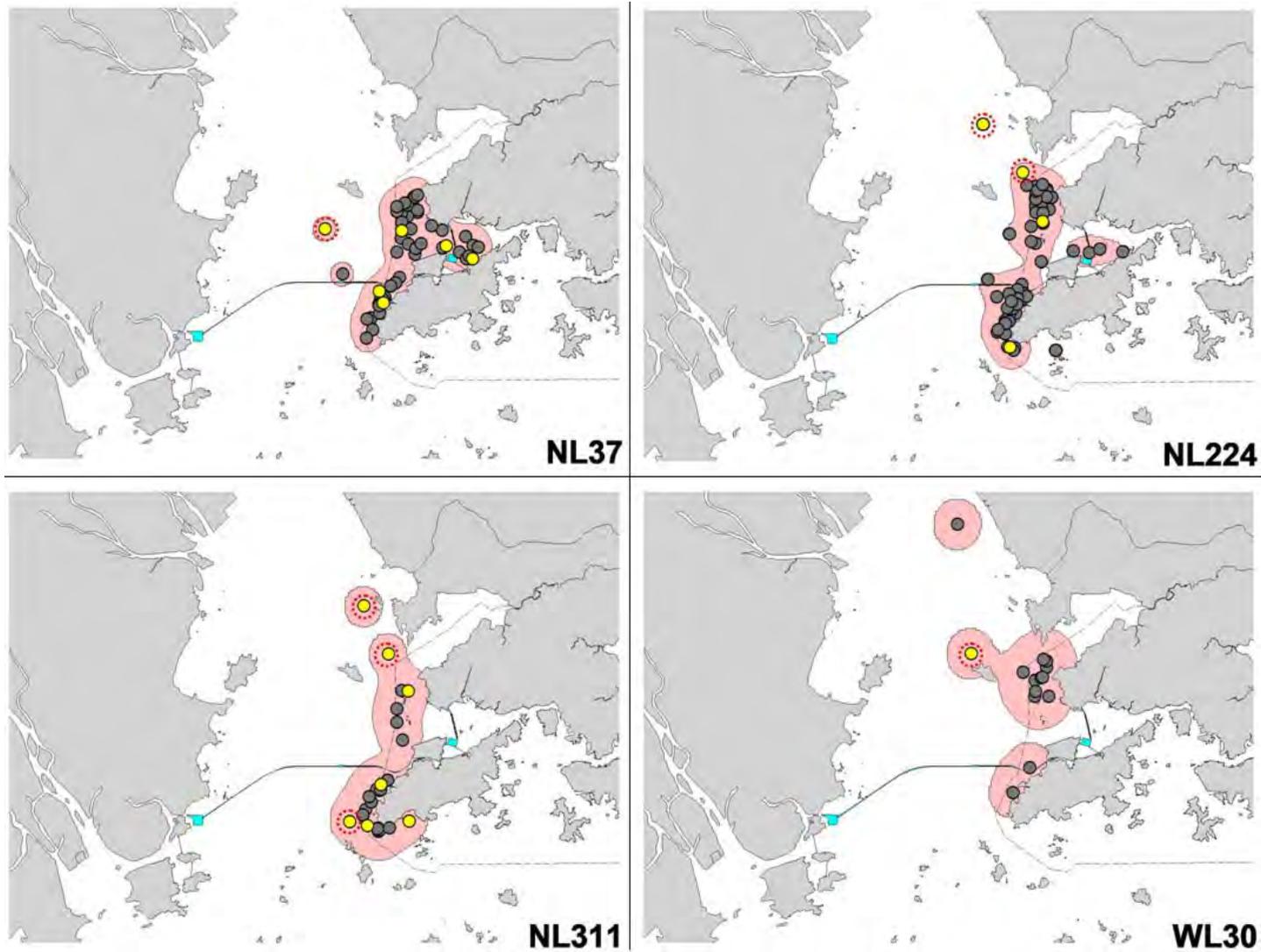


Figure 21. Examples four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in North Lantau waters in HK but also showed extensive movements within Lingding Bay (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

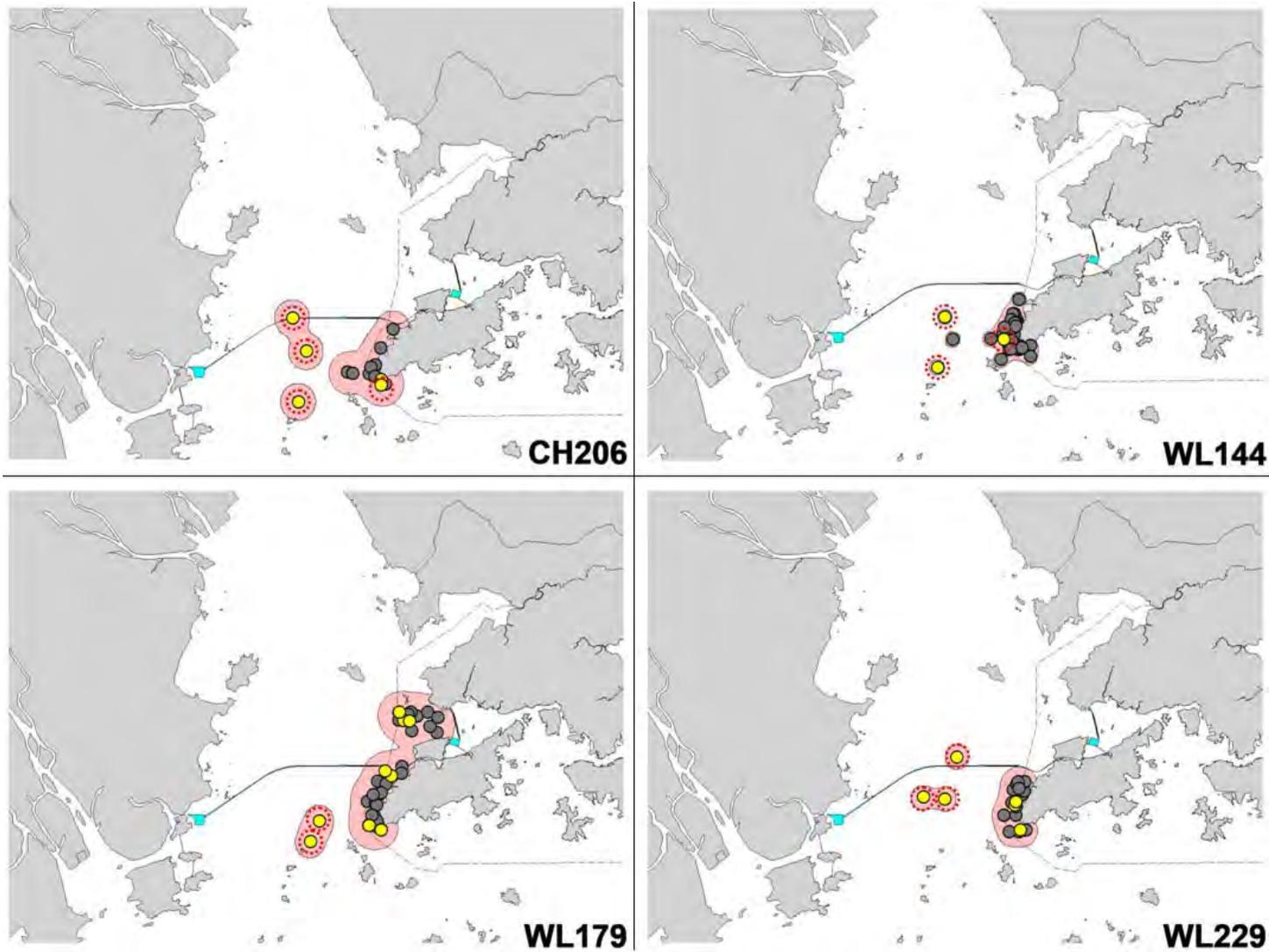


Figure 22. Examples four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in West Lantau waters in HK but also showed extensive movements within Lingding Bay (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

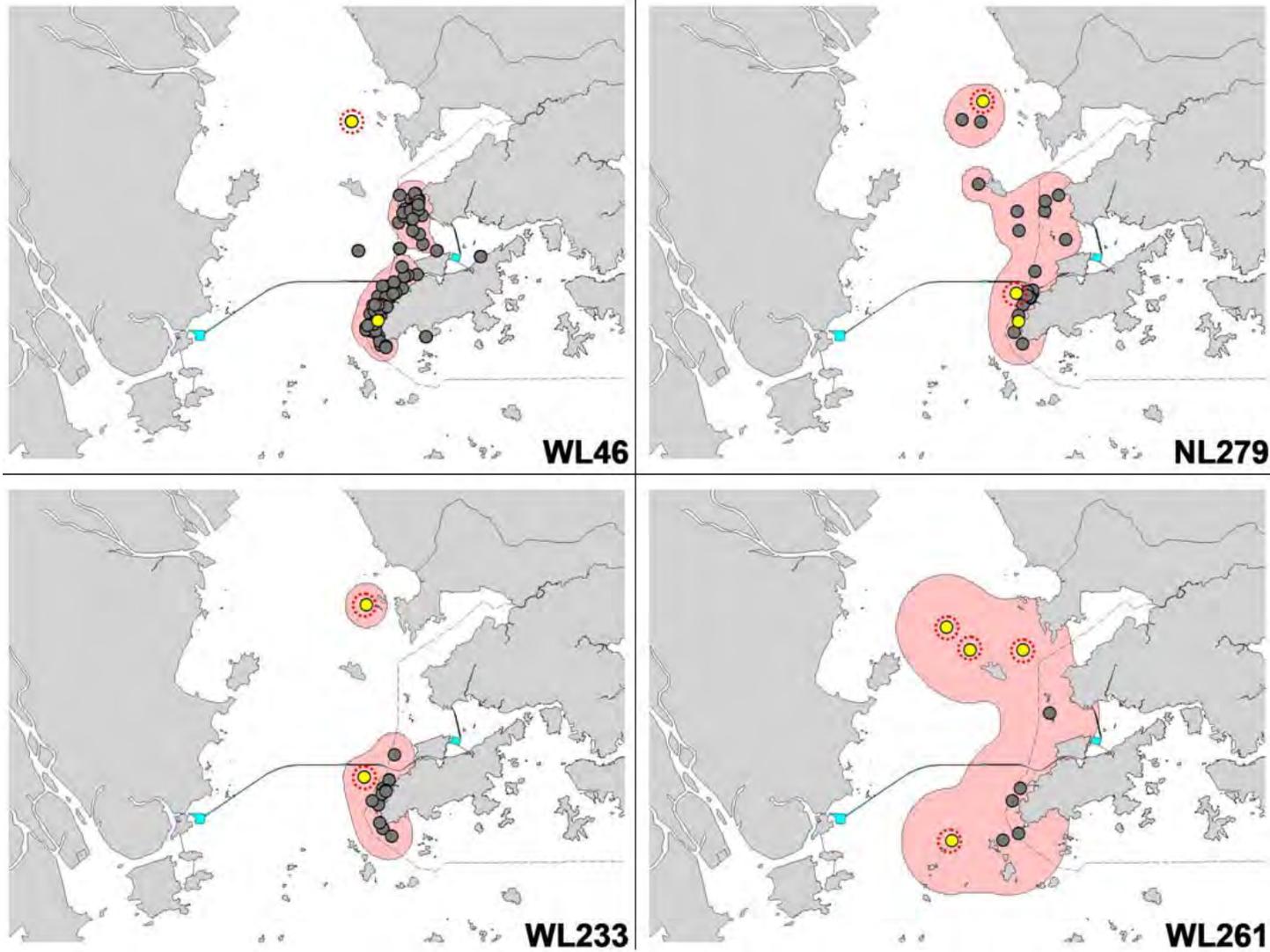


Figure 23. Examples four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in West Lantau waters in HK but occurred much further up in northern part of Lingding Bay (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

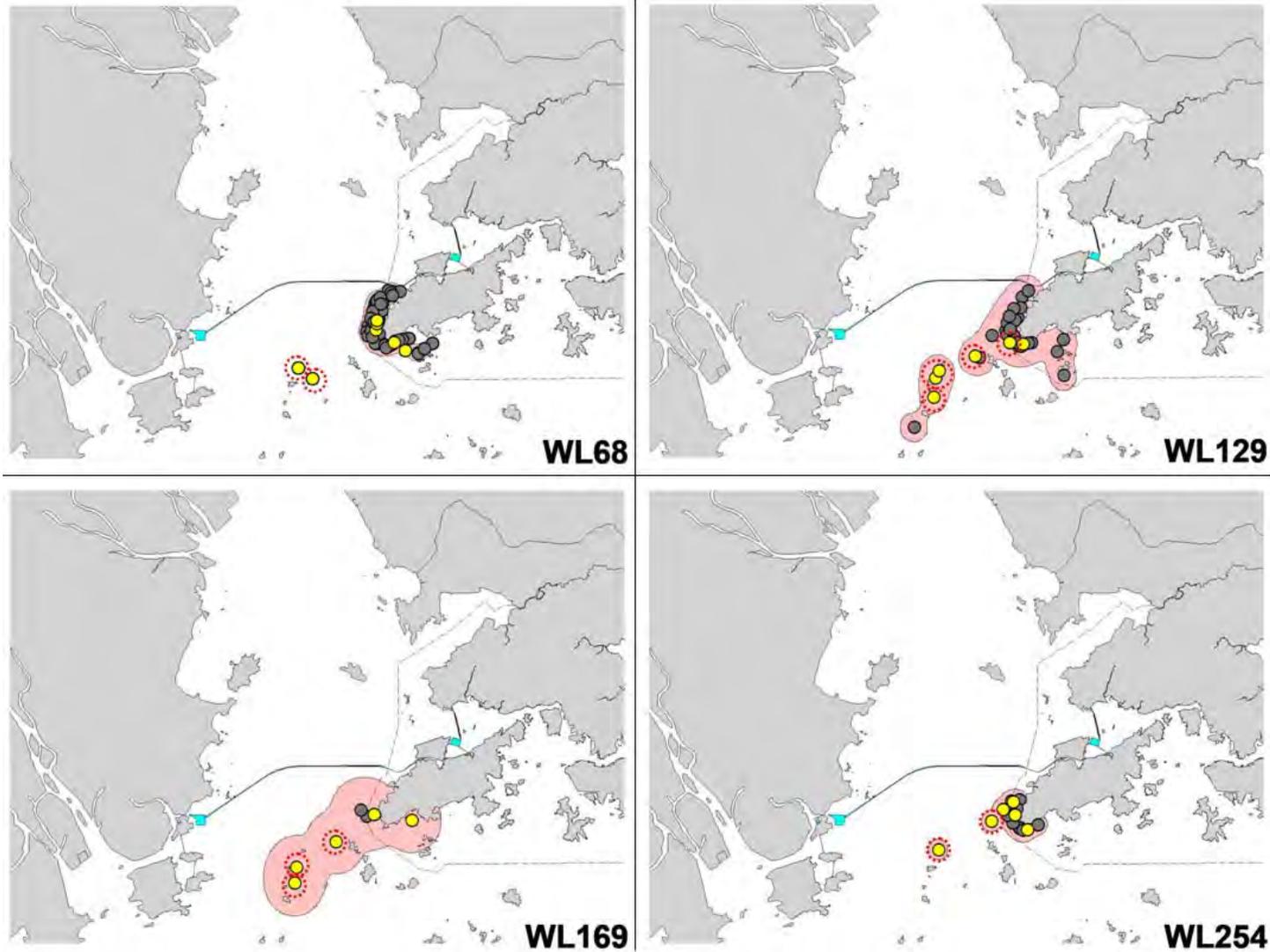


Figure 24. Examples four individuals sighted during the 2017-18 surveys in Lingding Bay that have ranged mostly in West Lantau waters in HK but extended ranges to Guishan windfarm area recently (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

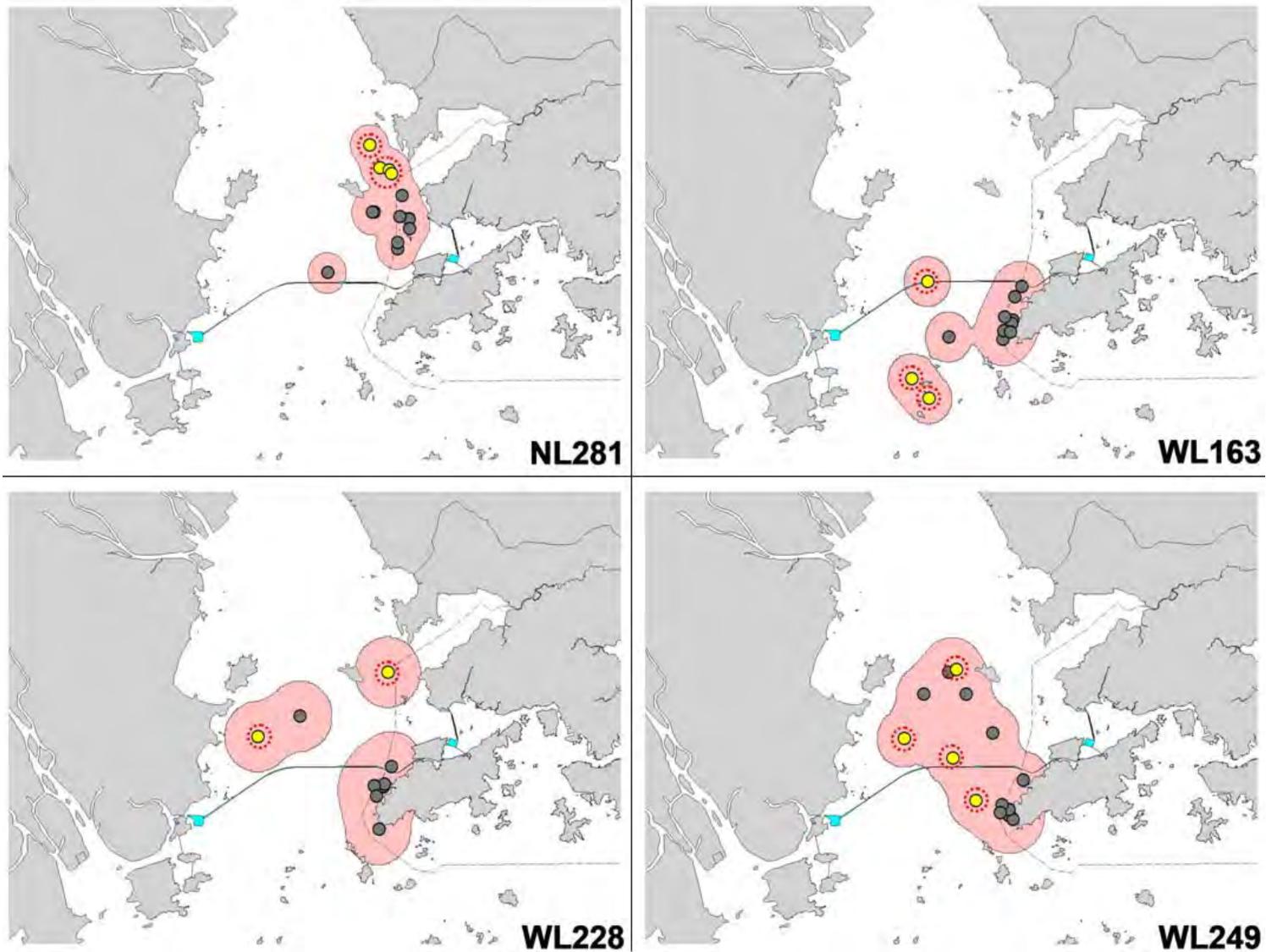


Figure 25. Examples four individuals sighted during the 2017-18 surveys in Lingding Bay that have disappeared from Hong Kong waters for at least two years (yellow dots: sightings made in August 2017-April 2018; red circle: sightings made during 2017-18 EPRE surveys in Lingding Bay)

Table 1. Survey effort and sightings of Chinese White Dolphins in Lingding Bay (August 2017 - April 2018)

Surveys	Length of transect-lines (km)	Encounter groups	Encounter dolphins
Aug. 2017	487.8	23	93
Sep. 2017	469.7	22	118
Oct. 2017	479.6	20	102
Nov. 2017	486.3	20	95
Dec. 2017	487.1	32	179
Jan. 2018	485.1	12	51
Feb. 2018	465.3	22	102
Mar. 2018	495.4	25	95
Mar. 2018(2)	495.7	33	196
Apr. 2018	499.8	29	121
Total	4851.8	238	1152

Table 2. Survey effort, number of groups and individuals of Chinese White Dolphins in all weather conditions and under calm conditions (Beaufort 0-3) in each of the survey areas in Lingding Bay (August 2017 - April 2018)

Survey time	Survey areas	Survey Effort (km)		Encountered groups		Encountered dolphins	
		All states	Beaufort 0-3	All states	Beaufort 0-3	All states	Beaufort 0-3
Aug.2017	NLDB	72.1	72.1	0	0	0	0
	CLDB	139.0	131.1	5	5	18	18
	SLDB	138.1	138.1	8	8	38	38
	MA	67.9	67.9	9	9	36	36
	SWMA	43.2	43.2	0	0	0	0
	AZ	27.5	27.5	0	0	0	0
	Total	487.8	479.9	22	22	92	92
Sep.2017	NLDB	59.9	59.9	0	0	0	0
	CLDB	130.9	126.8	6	6	28	28
	SLDB	139.0	109.3	11	10	70	59
	MA	70.5	44.6	4	4	18	18
	SWMA	42.2	11.7	0	0	0	0
	AZ	27.2	27.2	0	0	0	0
	Total	469.7	379.5	21	20	116	105
Oct.2017	NLDB	69.1	65.9	0	0	0	0
	CLDB	133.1	69.2	5	4	27	24
	SLDB	137.5	137.5	7	7	35	35
	MA	70.0	66.2	4	4	32	32
	SWMA	42.6	31.1	1	0	2	0
	AZ	27.3	18.7	0	0	0	0
	Total	479.6	388.6	17	15	96	91
Nov.2017	NLDB	64.7	41.7	0	0	0	0
	CLDB	136.7	113.0	9	9	35	35
	SLDB	142.7	74.4	3	2	17	14
	MA	72.1	72.1	5	5	38	38
	SWMA	43.2	24.2	0	0	0	0
	AZ	26.9	26.9	1	1	1	1
	Total	486.3	352.2	18	17	91	88
Dec.2017	NLDB	75.4	61.5	5	4	28	22
	CLDB	122.7	122.7	11	11	59	59
	SLDB	142.7	91.6	8	7	25	24
	MA	73.7	73.7	5	5	43	43
	SWMA	44.8	24.2	0	0	0	0
	AZ	27.8	13.0	0	0	0	0
	Total	487.1	386.7	29	27	155	148
Jan.2018	NLDB	73.7	36.0	0	0	0	0

	CLDB	137.9	21.8	3	0	14	0
	SLDB	137.6	82.8	5	4	13	8
	MA	72.5	72.5	2	2	16	16
	SWMA	41.9	30.2	1	1	7	7
	AZ	21.5	0.0	0	0	0	0
	Total	485.1	243.3	11	7	50	31
Feb.2018	NLDB	70.7	62.1	3	3	19	19
	CLDB	124.9	106.2	6	5	26	23
	SLDB	133.7	99.8	3	3	16	16
	MA	70.6	70.6	5	5	17	17
	SWMA	42.0	39.3	0	0	0	0
	AZ	23.4	3.7	1	1	3	3
	Total	465.3	381.7	18	17	81	78
Mar.2018	NLDB	70.6	70.6	4	4	11	11
	CLDB	138.4	135.3	9	9	36	36
	SLDB	143.2	143.2	7	7	38	38
	MA	70.1	33.9	2	2	5	5
	SWMA	45.5	45.5	2	2	3	3
	AZ	27.6	27.6	0	0	0	0
	Total	495.4	456.1	24	24	93	93
Mar.2018(2)	NLDB	73.1	73.1	3	3	7	7
	CLDB	138.7	138.7	13	13	79	79
	SLDB	140.8	123.8	8	8	52	52
	MA	71.7	54.2	3	1	20	3
	SWMA	42.5	42.5	3	3	29	29
	AZ	28.9	22.1	0	0	0	0
	Total	495.7	454.4	30	28	187	170
Apr.2018	NLDB	73.2	73.2	1	1	1	1
	CLDB	138.6	138.6	8	8	34	34
	SLDB	143.6	92.6	6	5	19	16
	MA	71.0	71.0	10	10	42	42
	SWMA	44.7	44.7	3	3	20	20
	AZ	28.7	28.7	0	0	0	0
	Total	499.8	448.8	28	27	116	113

Table 3. Estimates of abundance and associated parameters for Chinese White Dolphins in different survey areas in Lingding Bay (Monitoring period: August 2017 - April 2018)

Survey area	$L$ (km)	$n$	$f(0)$ (km <sup>-1</sup> )	$E(s)$	$D$ (100 km <sup>-2</sup> )	$N$	CV (%)
<b>NLDB</b> (403.81 km <sup>2</sup> )	616.07	14	4.46	4.07	20.63	83	43.46
<b>CLDB</b> (463.74 km <sup>2</sup> )	1103.4	70	4.46	4.80	67.89	315	22.06
<b>SLDB</b> (515.68 km <sup>2</sup> )	1093.1	59	4.46	4.85	58.33	301	20.34
<b>MA</b> (267.96 km <sup>2</sup> )	626.7	47	4.46	5.32	88.93	238	28.66
<b>SWMA</b> (128.36 km <sup>2</sup> )	336.6	8	4.46	1.13	6.01	8	70.20

Symbols used:  $L$ , total length of transect surveyed;  $n$ , number of on-effort sightings;  $f(0)$  trackline probability density;  $E(s)$ , unbiased mean group size;  $D$ , individual density;  $N$ , individual abundance; and CV, coefficient of variation

Table 4. Estimates of abundance and associated parameters for Chinese White Dolphins in different survey areas in Lingding Bay (Dry season: October 2017 - March 2018)

Survey area	$L$ (km)	$n$	$f(0)$ (km <sup>-1</sup> )	$E(s)$	$D$ (100 km <sup>-2</sup> )	$N$	CV (%)
<b>NLDB</b> (403.81 km <sup>2</sup> )	410.87	13	4.24	4.31	28.92	117	41.32
<b>CLDB</b> (463.74 km <sup>2</sup> )	706.85	51	4.24	5.02	76.84	356	26.05
<b>SLDB</b> (515.68 km <sup>2</sup> )	753.10	37	4.24	5.00	52.12	269	24.91
<b>MA</b> (267.96 km <sup>2</sup> )	479.90	28	4.24	6.14	76.04	204	30.04
<b>SWMA</b> (128.36 km <sup>2</sup> )	237.00	5	4.24	7.60	34.02	44	71.87

Symbols used:  $L$ , total length of transect surveyed;  $n$ , number of on-effort sightings;  $f(0)$  trackline probability density;  $E(s)$ , unbiased mean group size;  $D$ , individual density;  $N$ , individual abundance; and CV, coefficient of variation

## **Appendix: Financial information**

Project expenditure details are not disclosed due to confidentiality reason.