Marine Ecology Enhancement Fund (MEEF)
Declaration

To: The Secretariat of the MEEF

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Project Title: Long-term Monitoring of Population Dynamics of Chinese White Dolphins (*Sousa chinensis*) in Lingding Bay of the Pearl River Delta Region: the Second Stage

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: 2019-11-25

MEEF2018006

Final Report

Long-term Monitoring of Population Dynamics of Chinese White Dolphins (*Sousa chinensis*) in Lingding Bay of the Pearl River Delta Region: the Second Stage

Submitted to

Marine Ecology & Fisheries Enhancement Funds Trustee Limited

Prepared by

South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences (SCSFRI, CAFS)

Supported by

Hong Kong Cetacean Research Project (HKCRP)

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Project Leader: Chen Tao

Executive summary

As a continuation of the 2017-18 project, the 2018-19 project conducted another one-year vessel-based dolphin monitoring programme to collect more systematic line-transect survey data and photo-identification data of the Chinese White Dolphins (CWD; *Sousa chinensis*). This project aims to investigate the latest situation of the CWD, as well as their fine-scale habitat use and individual ranging patterns, in Lingding Bay of the Pearl River Delta region.

A total of ten sets of dolphin line-transect surveys with 4,804 km of survey effort were conducted among six survey areas in Lingding Bay during August 2018 to May 2019. During these surveys, a total of 187 groups of 960 Chinese White Dolphins and six groups of 14 finless porpoises were sighted. The sightings of dolphins in 2018-19 were much fewer than the ones in 2017-18 (238 groups of 1,152 dolphins), despite the survey efforts were fairly similar between the two survey periods (4,852 km in 2017-18 with the same survey routes). Similar with the distribution pattern in 2017-18, dolphins were commonly sighted throughout the Lingding Bay in the present study period, 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.

In 2018-19, the combined estimate of dolphin abundance in Lingding Bay was 641 individuals during the present monitoring period, including 30 in North Lingding Bay (NLDB), 149 in Central Lingding Bay (CLDB), 279 in South Lingding Bay (SLDB), 150 in Macau (MA) and 33 in Southwest Macau (SWMA) (Aizhou area was excluded from the combined estimate due to zero on-effort sightings). Dolphin densities varied noticeably among different survey areas. MA and SLDB areas recorded the highest dolphin densities (56.0 and 54.1 individuals per 100 km^2, respectively), while NLDB areas recorded the lowest (7.4 individuals per 100 km^2). The overall estimate of dolphin abundance (641 individuals) in 2018-19 was much lower than the one in 2017-18 (945 individuals). The dramatic fluctuation of dolphin abundance may be relating to the abnormal precipitation in 2018-19, because the abnormally high precipitation could affect the distribution pattern of their prey species, such as the pelagic fishes, which are sensitive to salinity of the waters in Lingding Bay. To find out the cause of such dramatic fluctuation, attention should be paid to the dolphin abundance of Lingding Bay in the next few years. So continuous monitoring on population abundance in Lingding Bay, together with monitoring in the western PRE is critically needed to examine the temporal trend on abundance and movement patterns of the dolphins.

In 2018-19, the important dolphin habitats were mostly located in waters around the Datouzhou-Sanjiaoshan-Qingzhou islands (where the Guishan offshore wind farm is located), from the north of Guishan Islands to the west of Lantau Island, around the west artificial Island of the Hong Kong-Zhuhai-Macao Bridge (HZMB), and between Neilingding Island and Qi'ao Island. It seems that the frequently used habitats for dolphins have been changing in recent years.

The mean group size (5.13 ± 4.78) of dolphins in Lingding Bay in 2018-19 was slightly higher than the ones recorded in 2017-18 (4.86 ± 4.59) and 2005-06 (4.80 ± 4.91). The proportion of young calves from the total in 2018-19 (8.44%) was similar to the one in 2017-18 (8.16 %), but was still much lower than the one in 2005-06 (12.36 %). The overall decline in young calf occurrence 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.

The percentages of dolphin groups engaged in feeding and socializing activities in 2018-19 (52.9 % and 8.6 %, respectively) were both lower than the ones in 2017-18 (74.4% and 10.1%, respectively), showing some fluctuations in recent years. There were fewer groups of dolphins engaged in socializing activities in the western part of CLDB as well as the south portion of Lingding Bay in 2018-19 as compared to 2017-18, and socializing activities have been rare 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 2018-19 study period, 247 individual dolphins with 407 re-sightings were identified altogether. Among these individuals, 136 of them have never occurred in Hong Kong waters before in the past two decades of dolphin monitoring works, while the other 111 individuals have been sighted in different survey areas around Lantau Island. Among the 407 re-sightings, the majority of them were made in SLDB (48.6%) and CLDB (27.0%). Most dolphins occurred primarily in Hong Kong waters have strong site fidelity there, and many of them also ranged extensively across the border, with some utilizing the entire Lingding Bay as part of their ranges. In the past few years, 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.

The changes in dolphin abundance, habitat use, activities and individual range in Lingding Bay waters in the past decade are the consequences stemmed from the combination of existing threats. Serious cautions are needed to conduct any new offshore projects in the whole Lingding Bay, while the existing constructions and other human activities (such as large-scale sand mining) should be stringently regulated and monitored. Moreover, continuous monitoring on population dynamics in Lingding bay is critically needed to obtain the latest status and temporary trend of the dolphins, and monitoring in the western PRE is also urgent needed to figure out the movement patterns of the dolphins across the entire PRE.

1 Introduction

The Pearl River Estuary-Moyang River Estuary (PRE-MRE) population of Chinese White Dolphins (CWD; *Sousa chinensis*) is the largest known population throughout this species' range (Li et al., 2019; Chen et al., 2010), and Lingding Bay (LDB; including Hong Kong and Macau SAR waters) covers the major distribution range of this population with significant conservation importance. At the same time, the coastal region of LDB 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 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 in LDB which leads to direct habitat loss for the dolphins. Such intense coastal development could also affect the availability of prey resources and suitable habitats for the dolphins, which in turns, affecting their individual range use and movements. Therefore, it is critical to conduct long-term monitoring on the CWD in the Pearl River Delta, to track any temporal changes in their population dynamics.

A one-year CWD monitoring programme was completed in LDB by the South China Sea Fisheries Research Institute (SCSFRI) from 2017 to 2018. The latest information of these dolphins, including their distribution and abundance, individual ranging patterns (especially any cross-boundary movements) and fine-scale habitat use has been investigated. Noticeable decline in dolphin abundances of Lingding Bay was detected in the past decade but the decline trend appeared to become stable in recent years. Notably, the marine environment in some portions of LDB is constantly changing due to human activities, such as dredging (sand mining) in northern LDB, and construction of Guishan offshore wind power plant in southern LDB. To gain a comprehensive understanding of the trends in dolphin occurrences in LDB, the

one-year study in 2017-18 is certainly insufficient to assess any changes in population dynamics, and therefore a long-term dolphin monitoring programme would be needed.

As a continuation of the 2017-2018 project and other earlier dolphin monitoring works in the past two decades, the 2018-2019 project completed another year-long vessel-based dolphin monitoring programme in LDB, with the aims to collect systematic line-transect survey data and photo-identification data of CWD. The additional data can be integrated with past monitoring data collected in the past two decades, in order to assess the temporal trends in abundance and other population parameters such as fine-scale habitat use and individual range use in the PRE region. Based on the results collected from this monitoring programme, recommendations on conservation strategies can be made to relevant government departments and management authorities.

Several objectives were set for the 2018-19 project as follow:

1) To track the latest situation and temporal trend in population dynamics of the CWD in LDB of the Pearl River Delta region by further extending the monitoring works commenced in 2017-18. Population parameters, such as the distribution, abundance and age composition of dolphins in each survey area and the entire LDB from the present project will be compared to past monitoring results, especially in recent years of surveys, to examine their long-term temporal trend in population dynamics;

2) To examine the individual ranging patterns, especially any cross-boundary movements between Guangdong and Hong Kong waters, through long-term photo-identification of CWD in LDB and matching such photo-identification data with the one collected from Hong Kong waters;

3) To assess the fine-scale habitat use of CWD in LDB and the associated temporal changes, for a better understanding of the important habitats utilized by the dolphins; and

4) To make recommendations on management and conservation strategies to relevant authorities, for better implementation of conservation measures for the CWD population in the PRE region.

2 Work schedule

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

Time	Proposed activities	Completed activities
July 2018	Preparation for line-transect vessel surveys	Done accordingly
August 2018	The 1st line-transect vessel survey, individual identification	Done accordingly
September 2018	The 2nd line-transect vessel survey, individual identification	Done accordingly
October 2018	The 3rd line-transect vessel survey, individual identification	Done accordingly
November 2018	The 4th line-transect vessel survey, individual identification, submit interim report	Done accordingly, interim report (progress report) was submitted in December 2018
December 2018	The 5th line-transect vessel survey, individual identification	Done accordingly
January 2019	The 6th line-transect vessel survey, individual identification	Done accordingly
February 2019	The 7th line-transect vessel survey, individual identification	Done accordingly
March 2019	The 8th line-transect vessel survey , individual identification	Done accordingly
April 2019	The 9th line-transect vessel survey, individual identification	Done accordingly
May 2019	The 10th line-transect vessel survey, individual identification, analyses on individual movement	Done accordingly
June 2019	Estimation on population parameters (density/abundance/age composition/..., and comparing analyses with data in 2017-18 surveys); fine-scale habitat use (and comparing analyses with data in 2017-18 surveys); submit	Conducted analyses on estimates of density/abundance

	final report.	
July 2019	Extension	fine-scale habitat use, individual movement pattern
August 2019	Extension	comparing analyses with data in previous surveys
September 2019	Extension	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 CWD in LDB, which were then compared to the 2017-18 and 2005-06 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 in the North Lantau region of Hong Kong.

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). These survey areas covered the entire known range of CWD 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, were 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 2018 to May 2019.

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 and their habitat use patterns.

To ensure consistency, the 2018-19 surveys were conducted by the same group of observers of SCSFRI as in the 2017-18 study period. 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 CWD but also Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) as well) continuously through 7 × 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° and 90° (in relation to the bow, which is defined as 0°). 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.

Age composition of each dolphin group among different survey area was examined based on their colour patterns. 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 CWD was 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 1D and 1DX), 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 entire PRE CWD 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© 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© 3.1) to examine their distribution patterns during the entire study period.

3.6 Encounter rate analysis

The encounter rates of CWD (including the 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 CWD 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):

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

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

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

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 CWD and survey effort from the present study. Sighting densities (number of on-effort sightings per km^2) and dolphin densities (total number of dolphins from on-effort sightings per km^2) 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 parameters were used to quantify the usage of the habitat. The sighting density was termed SPSE, representing the number of on-effort sightings per 100 units of survey effort. In addition, the dolphin density was termed DPSE, representing the number of dolphins per 100 units of survey effort. Among the 1-km^2 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^2 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 (i.e., transect lines have not covered those grids), 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. The resulting density pattern would provide a continuous gradient based on empirical data, and such

pattern would give better resolution of habitat use pattern and allow direct comparison to the one in Hong Kong across the border. On the other hand, if 3×3 km grid (the vessel transects are 3km apart in Lingding Bay) is adopted, the habitat use pattern would be too coarse and could not provide the necessary resolution 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 2018 to May 2019, with one set in each month (see Table 1 and Table 2). From these line-transect surveys, a total of 4,804 km (as compared to 4,852km in 2017-18 period) of survey effort was conducted among the six survey areas, including 694 km in NLDB, 1,371 km in CLDB, 1,421 km in SLDB, 716 km in MA, 348 km in SWMA, and 255 km in AZ. Most survey effort (3,971 km, 86%) 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 187 groups of 960 Chinese White Dolphins were sighted (Table 1). Among them, 173 groups of 905 dolphins were sighted during on-effort search. The majority of these sightings were made in CLDB (54 sightings), SLDB (71 sightings) and MA (37 sightings) survey areas, while only 5 and 6 sightings were made in NLDB and SWMA survey areas respectively. No on-effort sighting of dolphin was made in AZ survey area during the present survey period (Figure 2).

The on-effort sightings in the present study period (173 groups of 905 dolphins) was fewer than in 2017-18 period (218 groups of 1,077 dolphins), while the survey effort for the two study period were about the same. Besides SLDB, on-effort sightings in the other five survey areas recorded in the 2018-19 study period were also fewer than in 2017-18 period (Figure 3).

In addition, six groups of 14 Indo-Pacific finless porpoises (*Neophocaena phocaenoides phocaenoides*) were sighted in the southeastern portion of Lingding Bay (Figure 4) during the present study period, with one to five individuals in each group.

4.2 Dolphin distribution

Distribution of dolphin and porpoise sightings in Lingding Bay of the Pearl River Estuary during the 2018-19 study period is shown in Figure 4. 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 AZ area and the eastern part of SWMA) of Lingding Bay. On the contrary, sightings of the dolphins were more concentrated at several locations, including the waters to the northwest of Neilingding Island, around Datouzhou-Sanjiaoshan-Qingzhou islands (within and around the general area of Guishan offshore wind farm), to the west of Lautau Island and to the north of Guishan Islands. Dolphins were also frequently observed in the waters around the west artificial island of the Hong Kong-Zhuhai-Macau Bridge (HZMB) alignment. The six groups of porpoises were all observed in the southeastern limit of the dolphin distribution range. (Figure 4).

Dolphin distribution pattern in 2018-19 had a few notable differences from the one in 2017-18. Fewer dolphins were sighted in the northern part of Lingding Bay (NLDB) and in the southwestern portion of MA survey area in 2018-19 than in 2017-18 study period. (Figure 5, note: surveys were not conducted in SWMA and AZ in 2005-06). When compared to the earlier period in 2005-06, another notable difference was observed with lower dolphin occurrences in LDB just to the west of the Sha Chau and Lung Kwu Chau Marine Park as well as the Chek Lap Kok Airport (i.e., near the boundary between CLDB and SLDB) but higher occurrences around Neilingding Island in 2018-19 and 2017-18 than in 2005-06 (Figure 5). The relative importance for the dolphin' habitat in different parts of LDB will be further examined using quantitative grid analysis in Section 4.8, which can provide more quantifiable information on distribution and density of dolphins.

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 6). Encounter rates using combined survey effort were also calculated and compared among different survey areas (Figure 7) to provide indication of relative importance of each area for the dolphins. Among the six survey areas, MA had the highest dolphin encounter rate (5.81 groups per 100 km), whereas SLDB and CLDB recorded the second and the third highest encounter rate with 5.46 and 4.31 groups per 100 km respectively (Figure 7). NLDB and SWMA survey areas were used by the dolphins to a much lower extent, while no on-effort sighting was recorded in AZ waters.

A comparison with the dolphin encounter rates in 2017-18 study period (Figure 8) showed that the encounter rates in the 2018-19 study period were lower in all six survey areas. The overall encounter rates in Lingding Bay from 2018-2019 were 3.95 groups and 20.29 dolphins per 100 km), which was about 20% lower than the ones recorded in 2017-2018 (5.14 groups and 25.41 dolphins per 100 km).

4.4 Density and abundance

The density and abundance of Chinese White Dolphins were estimated for each survey area (except in AZ where no dolphin was sighted during on-effort search) using the line-transect analysis method, following the similar approach as in 2017-18 and previous monitoring periods in Lingding Bay. Only effort and sighting data collected from the areas under sea conditions Beaufort 3 were used in the analysis. Abundance and density estimation of dolphins among the five areas of dolphin occurrences (i.e. NLDB, CLDB, SLDB, MA and SWMA) were calculated using a total of 3,946 km of survey effort and 157 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 267 m. Dolphin densities varied noticeably among different survey areas in Lingding Bay. MA and SLDB areas recorded the highest dolphin densities (56.0 and 54.1 individuals per 100 km^2, respectively), while the density in NLDB was the lowest (7.4 individuals per100 km^2). The combined dolphin abundance estimates for the Lingding Bay were 641 individuals during the 2018-19 monitoring period, with the moderate level of statistical precisions (CV=20.44-24.87%) in SLDB, CLDB and MA, which indicated the resulted estimates in these three areas should be reliable. On the contrary, the NLDB and the SWMA areas had lower statistical precision (CV=69.78% and 79.11% respectively) due to the smaller amount of on-effort sightings (only five each for both areas).

When comparing with the dolphin abundance estimates during 2017-18, it showed that with the exception of SWMA, the abundance in the other five survey areas in 2018-19 were all less than the one in 2017-18 (Table 4). The combined dolphin abundance estimates in Lingding Bay in 2018-19 (641 individuals) was also much lower than in 2017-18 (945 individuals). However, the overall abundance in 2017-18 was only slightly lower than the one in 2015-16 (957 individuals, see the 2017-18 MEEF report). It was quite surprising to find that there was a 30% decline in dolphin abundance in just one year, while there is no mass stranded or dead dolphins were

reported in the past year. A plausible explanation for such dramatic decline could be some dolphins moving away from LDB to further south or west in 2018-19.

Chen et al. (2010) reported that seasonal variations in dolphin distribution in the Pearl River Estuary were evident. During the wet season when more waters pour into Lingding Bay, the dolphins in Lingding Bay appeared to be 'pushed'to further west into the western PRE, and then moved back into Lingding bay during the dry season. Variations in dolphin distribution during the wet and dry seasons were probably associated with movements of their prey species, which were indirectly affected by the amount of fresh water output from the Pearl River. Data from the Guangdong Hydrological Bureau (source: http://swj.gd.gov.cn/tjxx_sqjb/index.html) showed that the average precipitation of the Pearl River Basin (consist of Xijing River Basin, Beijiang River Basin and Dongjiang River Basin) during the present monitoring period (August 2018 to May 2019, 4,849 mm) was noticeably higher than the one from August 2017 to May 2018 (2,678 mm, see Tables 5 and 6). The waters in Lingding Bay should be lower in salinity in the 2018-19 study period than in 2017-18 period due to higher amount of freshwater outflow from the Pearl River, which may in turn affect the distribution pattern of the pelagic fishes. Such change can indirectly affect the distribution of dolphins within LDB. Continuous monitoring on population abundance in Lingding bay, together with monitoring in the western PRE, will be needed to figure out the temporal trend on abundance and movement patterns of the dolphins across the entire Pearl River Delta region.

To compare with results during dry season, the survey data from October to March (in next year) were extracted to estimate the abundance (the abundance in the wet season was not able to calculate due to the lack of surveys in June and July). The combined dolphin abundance estimated for the dry season during 2018-19 monitoring period was 577 individuals (Table 7), which was much lower than the result of 2017-18 dry season (990 individuals, Table 8), and was also lower than the one for 2018-19 monitoring period (641 individuals, approximately annual average, Table 3). We know that the dolphin abundance of dry season is generally higher than that of wet season in Lingding Bay (Chen et al., 2010), but in 2018-19, the abundance of dry season was lower than that of wet season. The dolphin abundance was abnormal in 2018-19 dry season. This abnormity further supports that the very high rainfall maybe had influenced the dolphin distribution / abundance in Lingding Bay during 2018-19, including during the (abnormally wet) dry season.

4.5 Group size

The CWD group sizes in LDB Bay ranged from singles to 28, with an average of 5.13 ± 4.78 dolphins per group during the present study period. Most dolphin groups sighted were quite small, with 38.0% of the groups composed of 1-2 animals, and 72.2% of the groups with fewer than six animals (Figure 9). Only 10.7% (20 out of the 187 groups) contained more than ten animals per group (similar to the percentage in 2017-18). The average group size was slightly higher than the ones from the previous surveys in 2017-18 (4.86 ± 4.59) and 2005-06 (4.80 ± 4.91). The group size compositions were also similar across the three monitoring periods (Figure 10), indicating that there has been very little change in dolphin group dynamics in LDB in the past decade.

Large dolphin groups with more than 10 individuals were found throughout the distribution range in SLDB and MA in 2018-19 (Figure 11). In contrast, larger dolphin groups were seldom sighted in the northern and southern ends in Lingding Bay, with only one large group being sighted each in NLDB and SWMA. It appeared that the area dolphins tended to gather in larger groups continued to change in recent years (Figure 11). However, in the present study period, large dolphin groups appeared more often again in the waters around the Datouzhou-Sanjiaoshan-Qingzhou islands, 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 187 dolphin groups in Lingding Bay sighted during the present monitoring period, 14 groups contained unspotted calves (UCs), while 54 groups contained UCs or unspotted juveniles (UJs). A total of 15 UCs and 66 UJs were identified, or 8.44% of the total number of the dolphins sighted in the present study period.

In 2018-19, 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 (Figure 12).

Encounter rates of young calves during the present monitoring period were calculated among different survey areas (Figure 13), which was similar to the overall dolphin encounter rates. The results showed that SWMA had the highest occurrence

of young calves (encounter rates of 1.89 sightings and 3.78 individuals of young calves per 100 km of survey effort) among all survey areas, followed by SLDB (1.82 sightings and 2.69 individuals per 100 km) and MA (1.45 sightings and 2.74 individuals per 100 km). In contrast, the encounter rate of young calves was much lower in NLDB, and there was no calf (dolphins) 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 14 and 15). The proportion of young calves from the total in 2018-19 (8.44%) was similar with the one in 2017-18 (8.16%), but it was still much lower than in 2005-06 (12.36%, Figure 14). Similar trend was also observed with the proportion of sightings associated with young calves (Figure 15). 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. Although it seems that the declining trend of the calf occurrence has stabilized in recent years (2017-2019), as the proportion of young calves can still fluctuate within a few years, continuous monitoring on this important parameter will still be critical 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. In the present study period, a total of 99 and 16 groups of dolphins were observed to be engaged in feeding and socializing activities respectively, comprising of 52.9% and 8.6% of all dolphin groups. The percentages of dolphin groups engaged in feeding and socializing activities in 2018-19 were both lower than the ones in 2017-18 (74.4% and 10.1%, respectively), showing a probable temporary fluctuation. In addition, six dolphin groups were engaged in traveling activity, and another eight groups were engaged in milling/resting activity during the 2018-19 study period.

Distribution of dolphin groups engaged in feeding activities during the 2018-19 survey period (and 2017-18 period) is shown in Figure 16 (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 and such distribution patterns showed little differences between 2018-19 and 2017-18 monitoring periods. Distribution of dolphin groups engaged in socializing activities in Lingding Bay in both survey periods is shown in Figure 17. Fewer groups were engaged in socializing activities in the western part of CLDB, as well as the southern portion of LDB in

2018-19 than in 2017-18. There were only a few sightings engaged in socializing activities to the north and west of Neilingding Island, where dredging (i.e. sand mining) activities had been operating throughout the entire monitoring period of the present study. The near 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 187 groups of dolphins sighted during the present study period, only 15 (8.0 %) of them were associated with operating fishing boats, including five gill-netters, four single trawlers, three hang trawlers, two purse-seiners and one shell trawlers. Dolphin groups associated with operating fishing boats were sighted throughout Lingding Bay, which was also similar to the overall distribution (Figure 18).

The percentage of dolphin groups associated with operating fishing boats in the present study period was only slightly lower than the one in 2017-18 (9.7 %). It should be noted that such percentages in recent years 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 CWD 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 (including AZ area which no dolphins were sighted) during the 2018-19 study period (Figure 19).

In 2018-19, the high density areas of dolphins were located in waters around the Datouzhou-Sanjiaoshan-Qingzhou islands (where the Guishan offshore wind farm is located), from the north of Guishan Islands to the west of Lantau Island, around the west artificial Island of the HZMB and between Neilingding Island and Qi'ao Island. These areas should all be considered as important dolphin habitats within the

Lingding Bay. Most of these areas with high dolphin densities were located around islands and near man-made structures such as bridge piers and the monopoles 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, including the waters in the northernmost part of Lingding Bay, on the western side of CLDB, and to the east of Guishan Islands. It appeared that these areas were actively avoided by the dolphins as they are either in very shallow water, or receives very little influence from the Pearl River outflow (which in turn is occupied by finless porpoises such as the waters of the southeast Lingding Bay).

Habitat use pattern of CWD in the present study period was compared to the patterns during 2017-18 monitoring period to examine any temporal change in densities at various important dolphin habitats in Lingding Bay (Figure 20). The notable differences included more dolphins occurring between Neilingding Island and Qi'ao Island and between Guishan Islands and Lantau Island, but fewer dolphins occurring in the central part of Lingding Bay, and between Neilingding Island and Lung Kwu Chau in 2017-18 than in 2015-16. Moreover, less intense dolphin usage near the HZMB alignment was also observed in 2018-19 than in 2017-18.

It seems that the frequently used habitat for dolphins have been changing in recent years, which may be related to the changes of their prey distribution. Similar to the 2017-18 period, there was no sign showing that the dolphins have avoided the area where the main infrastructure projects (e.g. HZMB and Guishan offshore wind farm) located. 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 several years, and the impacts on habitat use of the dolphins may have lessened since then. Moreover, the bridge piers and the monopoles 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 around these once-degraded habitats.

4.9 Summary of photo-identification works

During the study period of August 2018 to May 2019, over 33,000 photographs were taken during the course of the surveys conducted in Lingding Bay. A total of 247 individual Chinese White Dolphins were re-sighted 407 times through photo-identification analysis. Among these individual dolphins, 136 of them have never occurred in Hong Kong waters before in the past two decades of dolphin monitoring works, while the other 111 individuals have been sighted in different survey areas around Lantau Island. Moreover, more than half of the individuals have only been sighted once during the study period, while 106 individuals were sighted 2-3 times, and another five individuals were sighted four times. The most frequently sighted individuals were CH227 and MA94 with five re-sightings each, both of which have only occurred in LDB with no cross-boundary movements.

Among the 407 re-sightings, the majority of them were made in SLDB (48.6%) and CLDB (27.0%). On the contrary, there were 63, 19 and 14 re-sightings made in MA, SWMA and NLDB respectively. Notably, only three individuals (i.e. CH47, CH227 and CH326) were identified in AZ survey area from the photo-ID catalogue. 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 2018-19, 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

A total of 167 individuals were assessed for their ranging patterns that were re-sighted during the 2018-19 EPRE surveys as well as with at least 5 re-sightings in the past. Among them, 55 individuals have only occurred in Lingding Bay in the past but have never been re-sighted in Hong Kong waters, and they have various degrees of preference to use different parts of Lingding Bay (see examples of individuals that ranged primarily in northern part (Figure 21), southern part (Figure 22) and central part of Lingding Bay (Figure 23), while some have spanned their ranges across several survey areas in EPRE (see examples in Figure 24). On the other hand, for the 112 individuals that primarily occurred in Hong Kong waters in the past, 34 of them were re-sighted in Lingding Bay but were quite close to the western territorial border of Hong Kong (see example of individuals in Figure 25).

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 26), 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 27), but with some notable exceptions. For example, 17 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 quite far apart from their normal ranges in West and Southwest Lantau waters (see examples in Figure 28). In addition, there were at least six individuals that occurred primarily in West Lantau waters, but were also found in MA survey area (see examples in Figure 29). 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 four individuals sighted during the 2018-19 Lingding Bay surveys were those that have regularly occurred in Hong Kong waters, but have disappeared from there for at least two years (see Figure 30). In the past few years, a number of frequently sighted individuals in Hong Kong have disappeared from there (see Hung 2018, 2019), 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. The overall estimate of dolphin abundance (641 individuals) in 2018-19 was much less than the one in 2017-18 (945 individuals). It was inferred the dolphins may move offshore and to the west water of the PRE because there was more amount of fresh water output from the Pearl River due to more precipitation of the Pearl River Basin in 2018-19 , which could affect the distribution pattern of the pelagic fishes, then may affect the distribution of the dolphins.

The mean group size of dolphins in Lingding Bay in 2017-18 was only slightly higher than the ones from the previous surveys. Whereas the proportion of young calves from the total in 2018-19 (8.44%) was similar with the one in 2017-18 (8.16 %), but was still much lower than in 2005-06 (12.36 %). The overall reduction of young calves in the past decade could indicate a very low level of recruitment. Sightings associated with feeding activities was lower than in 2017-18, showing a probably temporary fluctuation. As in 2017-18, there were still little groups engaged in socializing activities to the north and west of Neilingding Island where dredging (i.e. sand mining) activities had been operating in 2018-19, which may signal the deterioration in habitat quality of this area,

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 mostly located in waters around the Datouzhou-Sanjiaoshan-Qingzhou islands (where the Guishan offshore wind farm is located), from the north of Guishan Islands to the west of Lantau Island, around the west artificial Island of the Hong Kong-Zhuhai-Macao Bridge and between Neilingding Island and Qi'ao Island. It seems that the frequently used habitat for dolphins were changing during the recent years.

During the 2018-19 study period, 247 individual dolphins with 407 re-sightings were identified altogether. Among these individuals, 136 of them have never occurred in Hong Kong waters before in the past two decades of dolphin monitoring works, while the other 111 individuals have been sighted in different survey areas around Lantau Island. Most dolphins occurred primarily in Hong Kong waters have strong site fidelity there, and many of them also ranged extensively across the border, with some utilizing the entire Lingding Bay as part of their ranges. 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.

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 the entire PRE-MRE population are needed to figure out the temporal trend in dolphins' distribution, habitat use, abundance and movement.

6 Evaluation and benefits

As a continuation of the 2017-18 project, this project achieved the objectives proposed in the application form after aother year-round study, The latest situation of the Chinese White Dolphins, the cross-boundary movements and the fine-scale habitat use in Lingding Bay were obtained. Several recommendations on management and conservation strategies for the Chinese White Dolphins in Lingding Bay were also presented.

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 myself, and the Organisation:

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;

2. have not used any money obtained from the Marine Ecology Enhancement Fund or the related Top-up Fund (and any derived surplus), in any unlawful manner, whether involving bribery, money-laundering, terrorism or infringement of any international or local law; and

3. have used the funds received (and any derived surplus) solely for the studies or projects which further the MEEF Objectives and have not distributed any portion of such funds (including any derived surplus) to members of the recipient organization or the public.

Signature

The applicant: Chen Tao

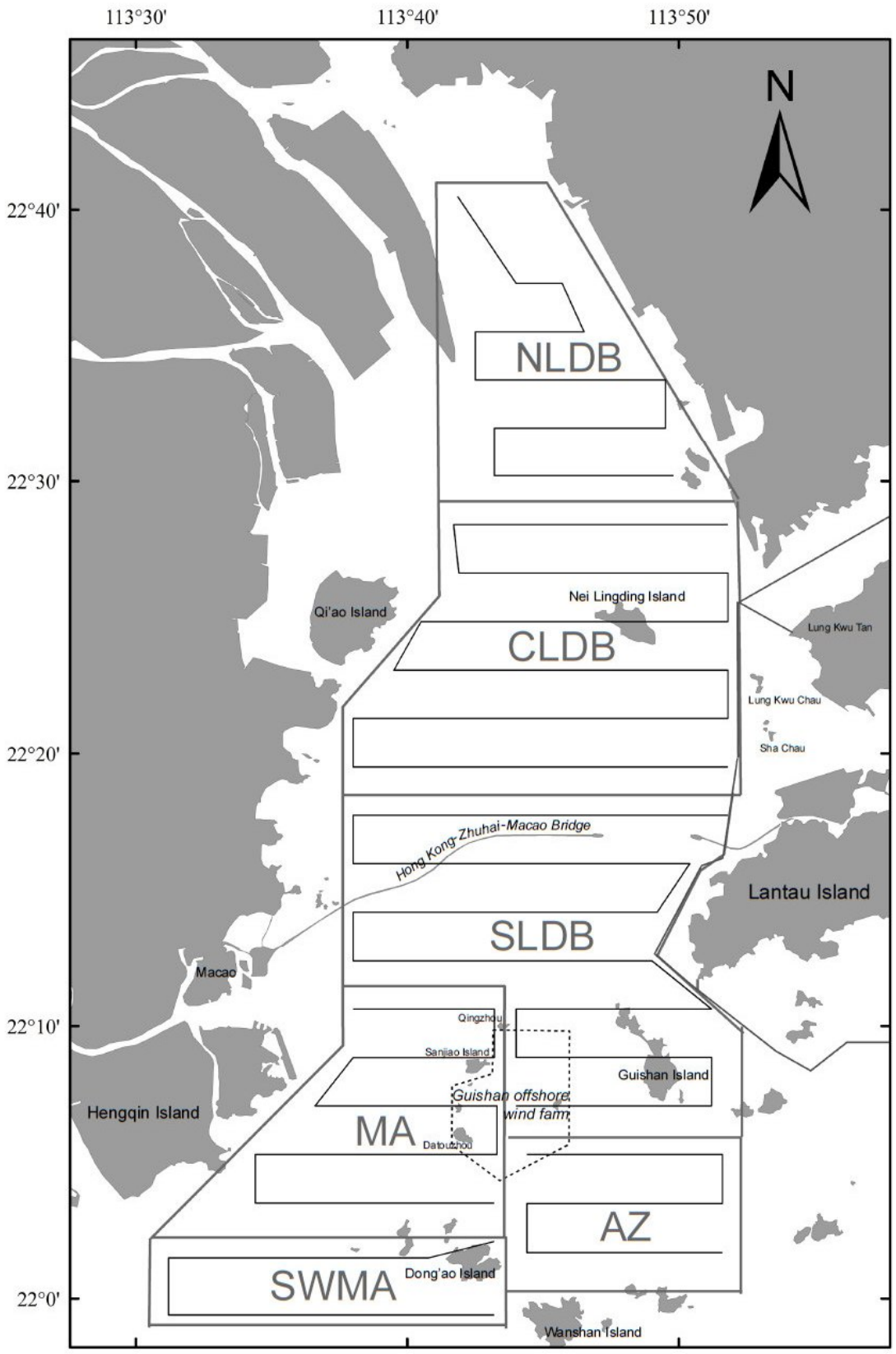

Figure 1. Survey areas and transect lines in Lingding Bay (2018-19)

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

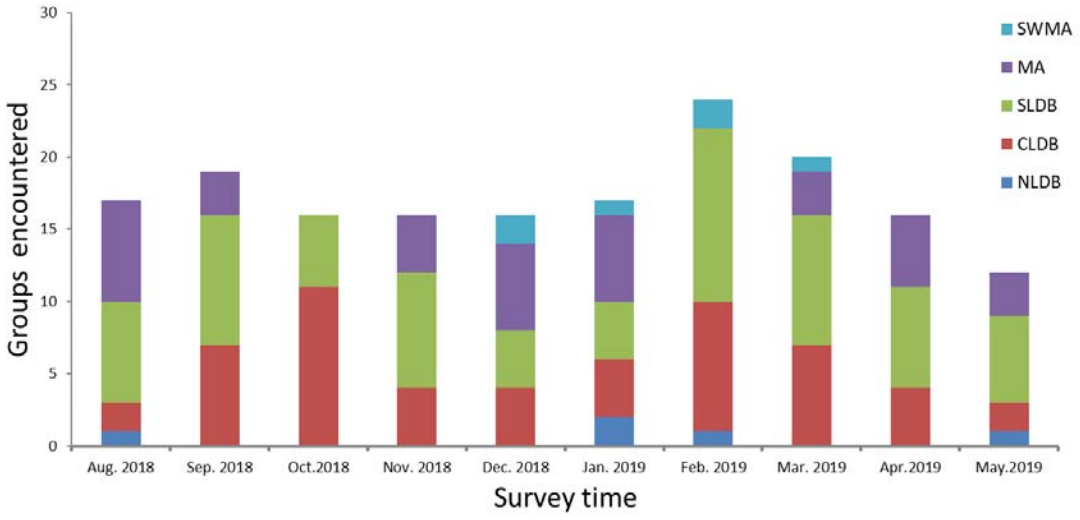

Figure 2. Monthly on-effort sightings of Chinese White Dolphin groups in the six survey areas in Lingding Bay (2018-19)

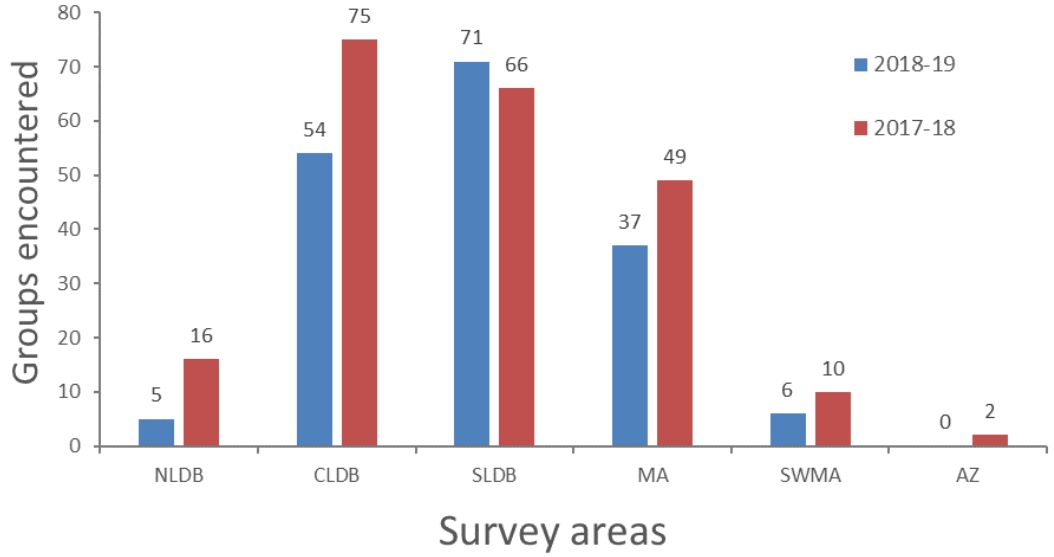

Figure 3. Comparison of the on-effort sightings of Chinese White Dolphin groups in the six survey areas in Lingding Bay between 2018-19, 2017-18 and 2005-06 monitoring periods

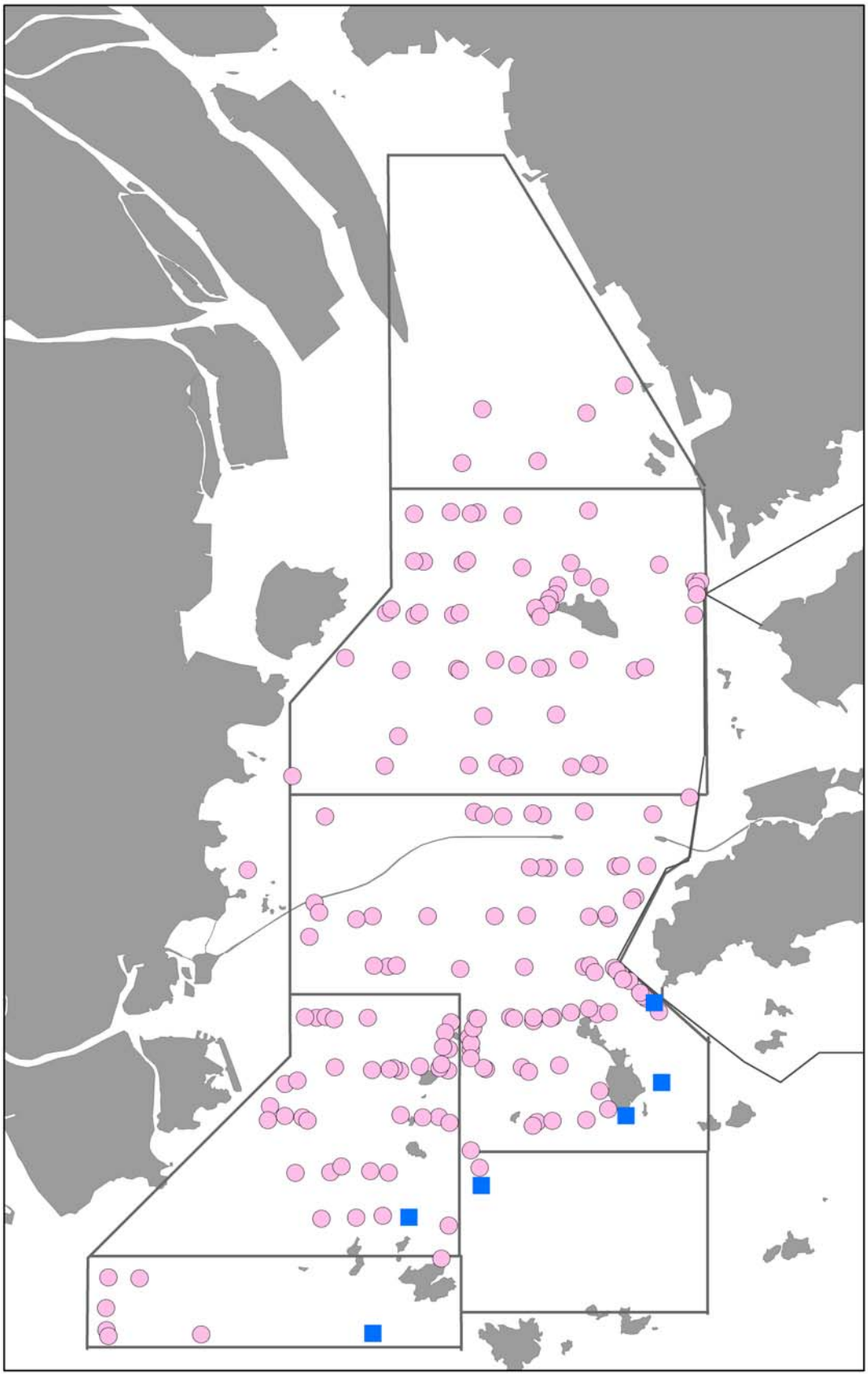

Figure 4. Distribution of Chinese White Dolphin (red dots) and Indo-Pacific finless porpoise (blue square) sightings in Lingding Bay (2018-19)

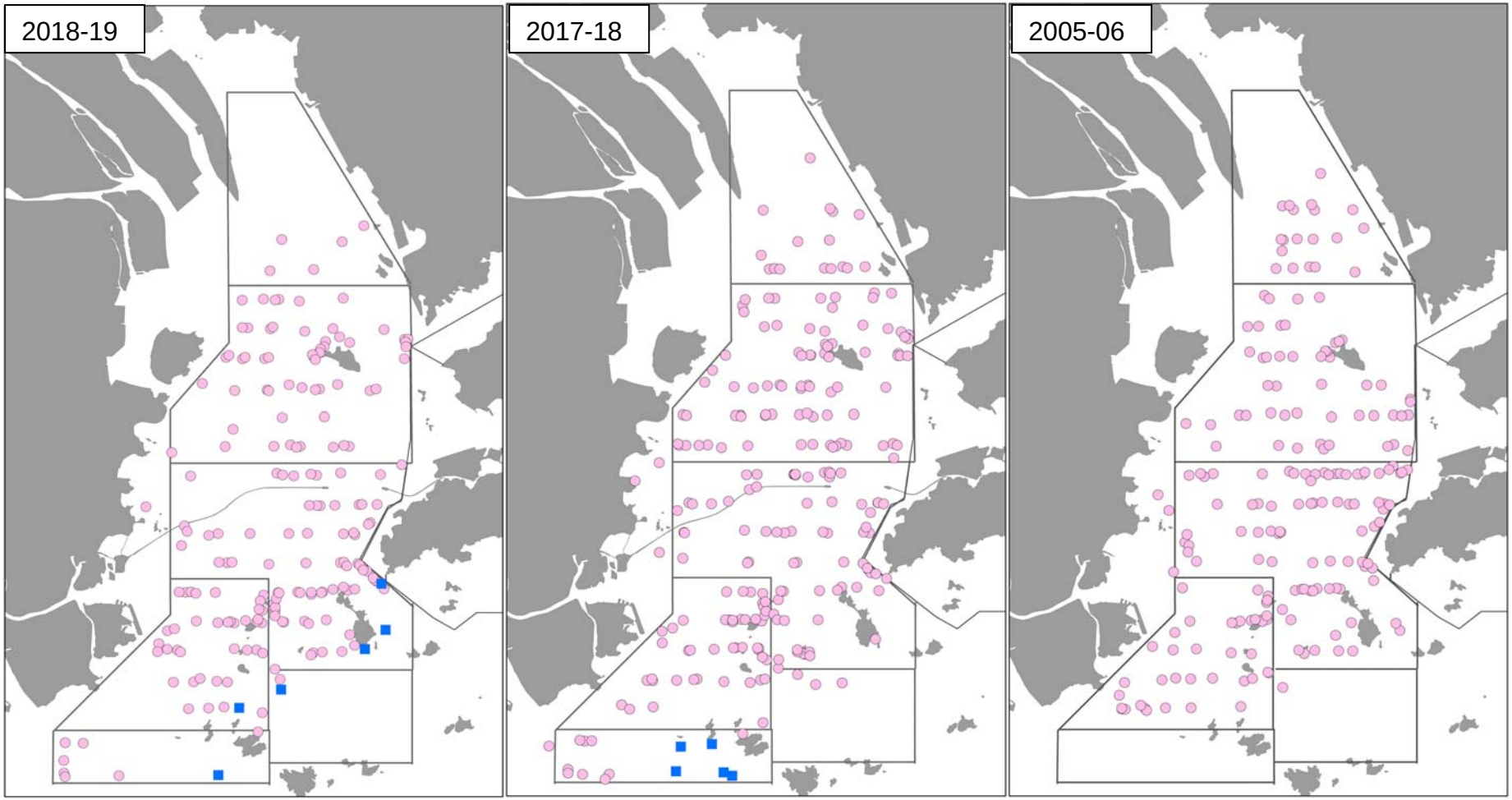

Figure 5. Comparison of the distribution patterns of Chinese White Dolphins in Lingding Bay between 2018-19, 2017-18 and 2005-06 monitoring periods.

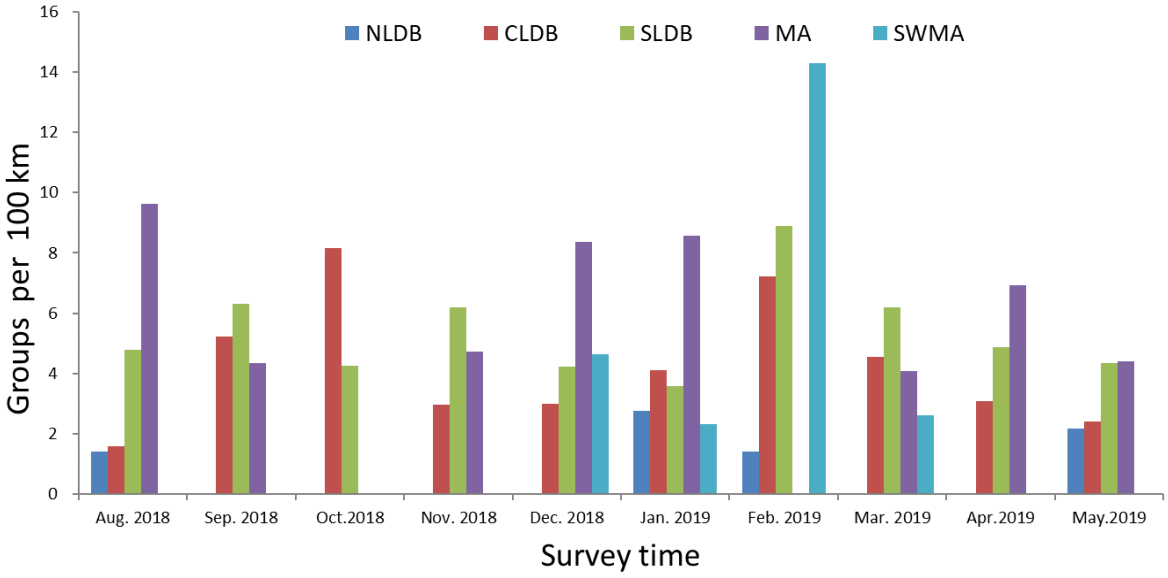

Figure 6. Monthly encounter rates of Chinese White Dolphin groups in the six survey areas in Lingding Bay (2018-19)

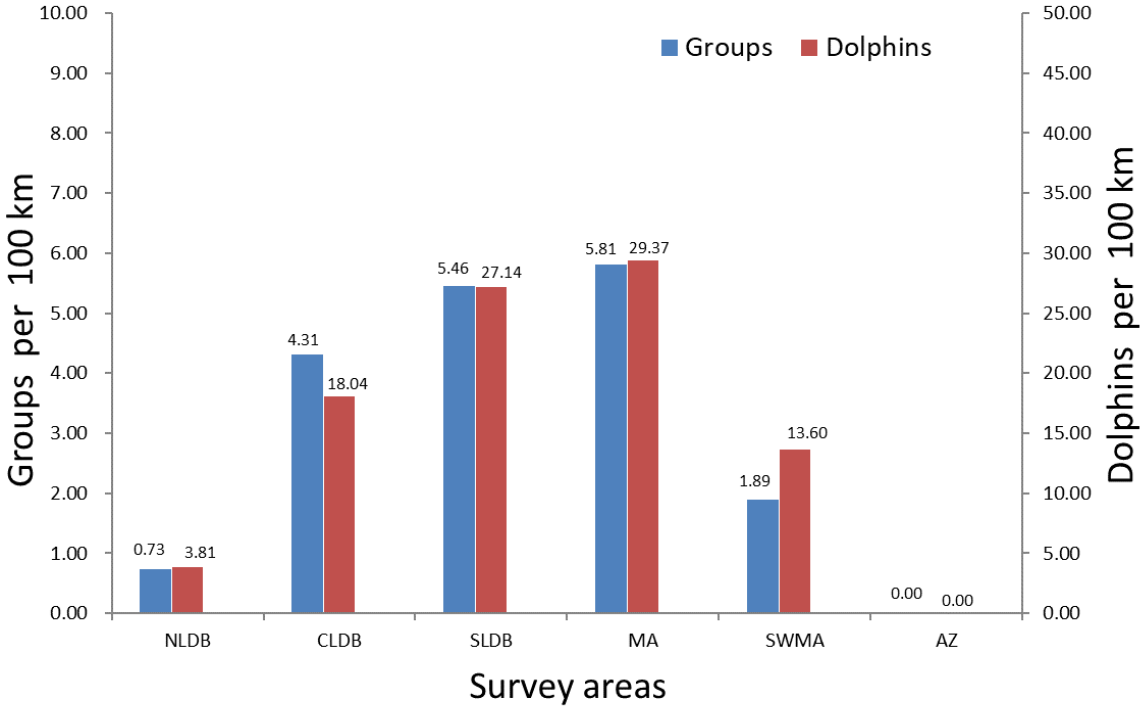

Figure 7. Combined encounter rates for the six survey areas in Lingding Bay (2018-19)

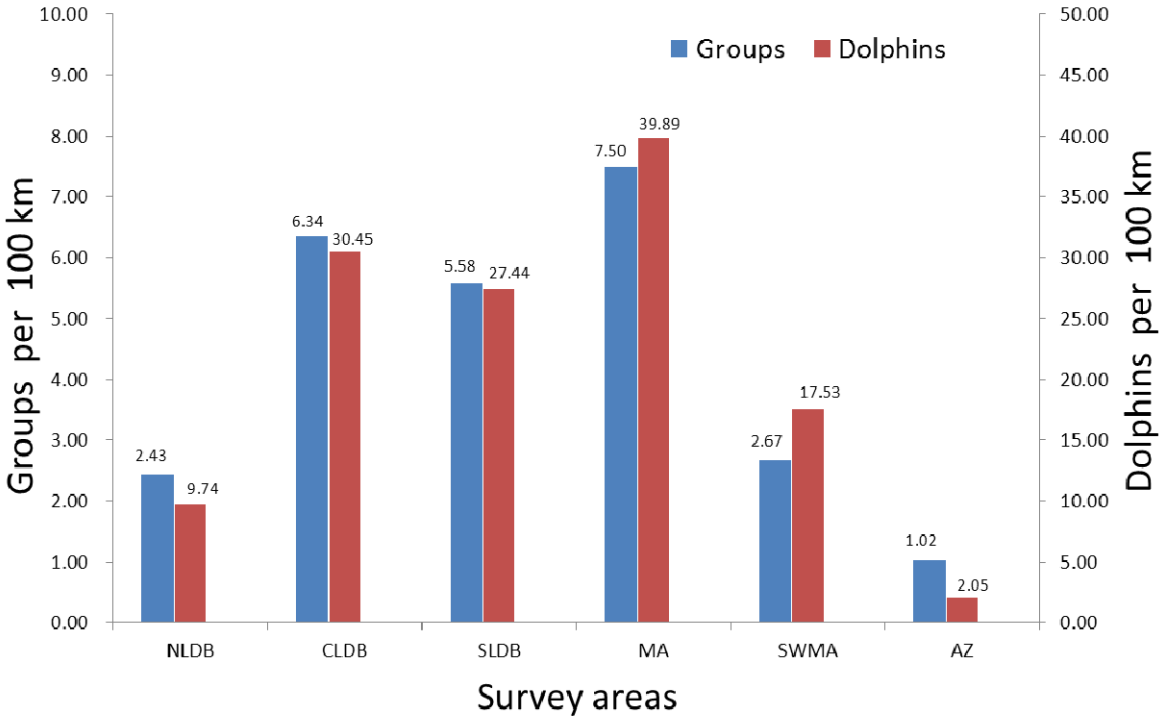

Figure 8. Combined encounter rates for the six survey areas in Lingding Bay (2017-18)

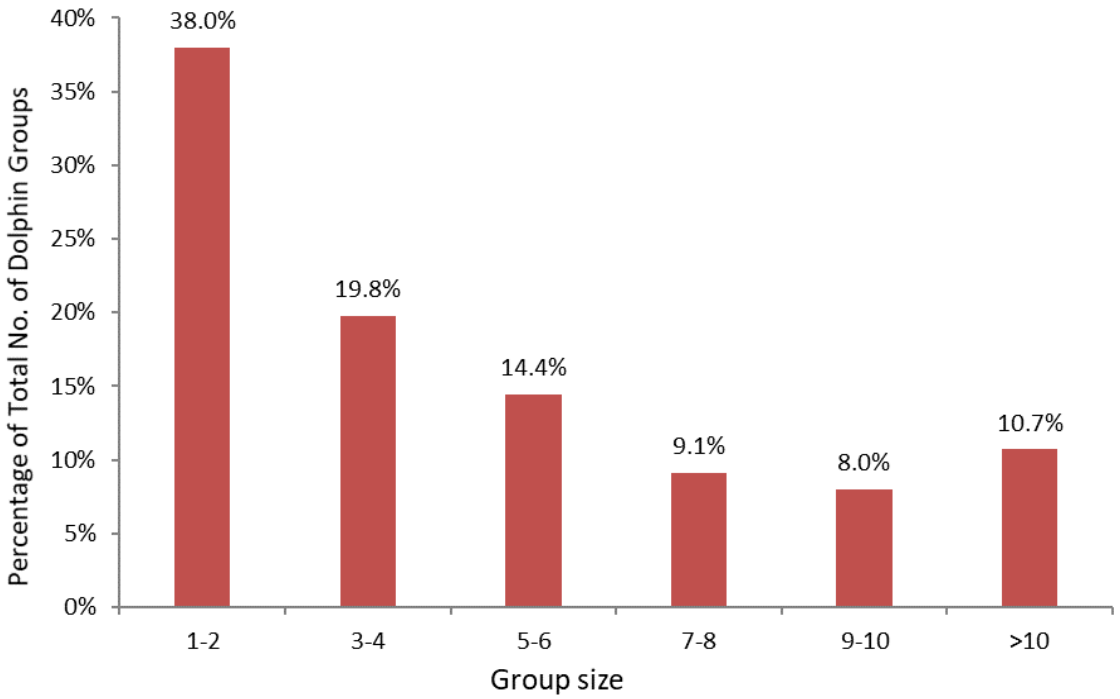

Figure 9. Percentages of different group sizes of Chinese White Dolphins in Lingding Bay (2018-19)

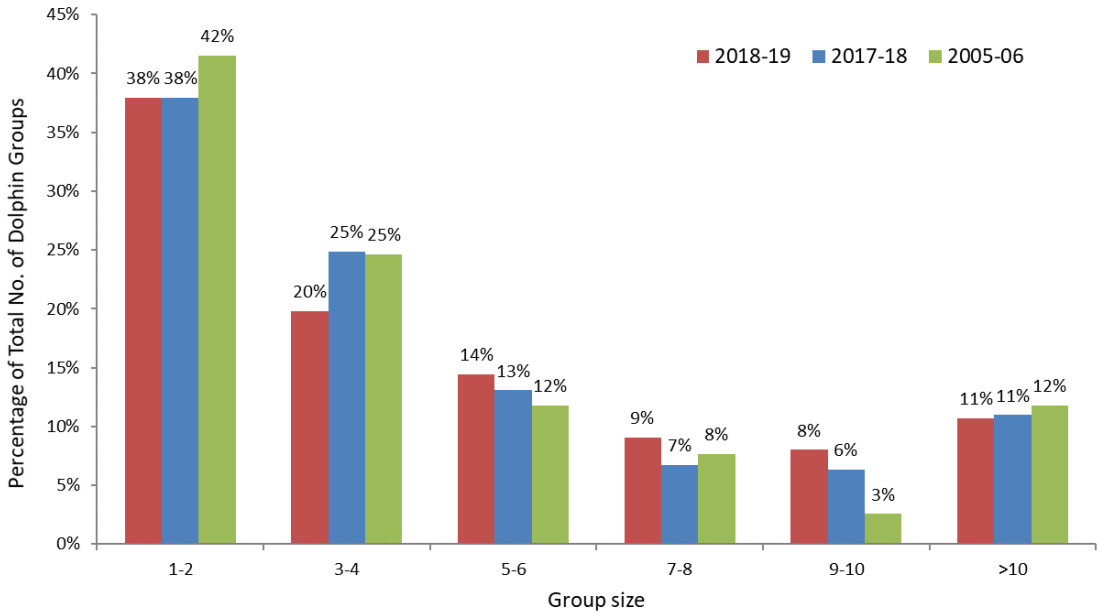

Figure 10. Composition of group size of Chinese White Dolphins in Lingding Bay during 2018-19, 2017-18 and 2005-06 monitoring periods

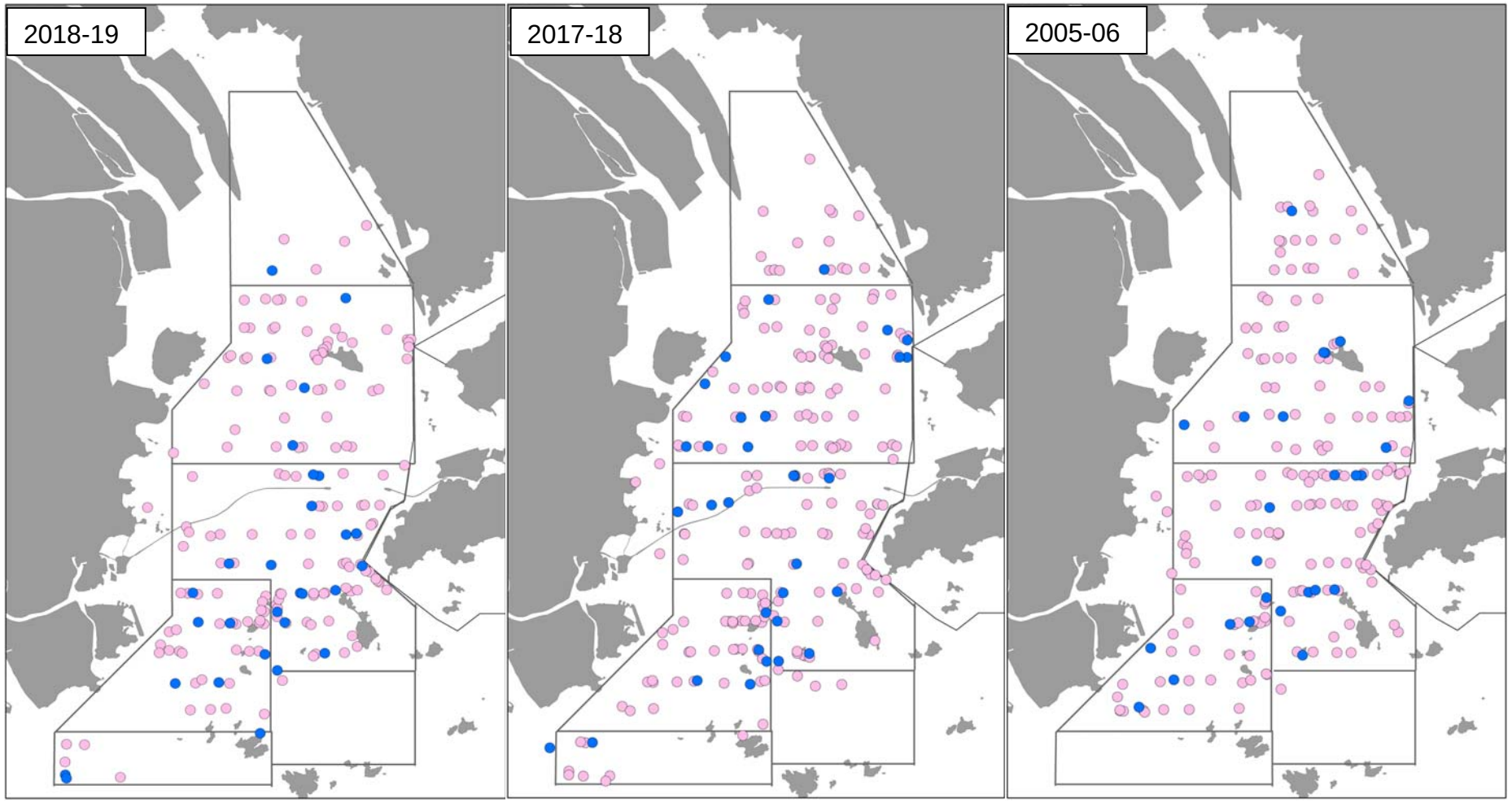

Figure 11. Distribution of dolphin sightings of large groups with more than 10 individuals (blue dots) in Lingding Bay during 2018-19, 2017-18 and 2005-06 monitoring periods

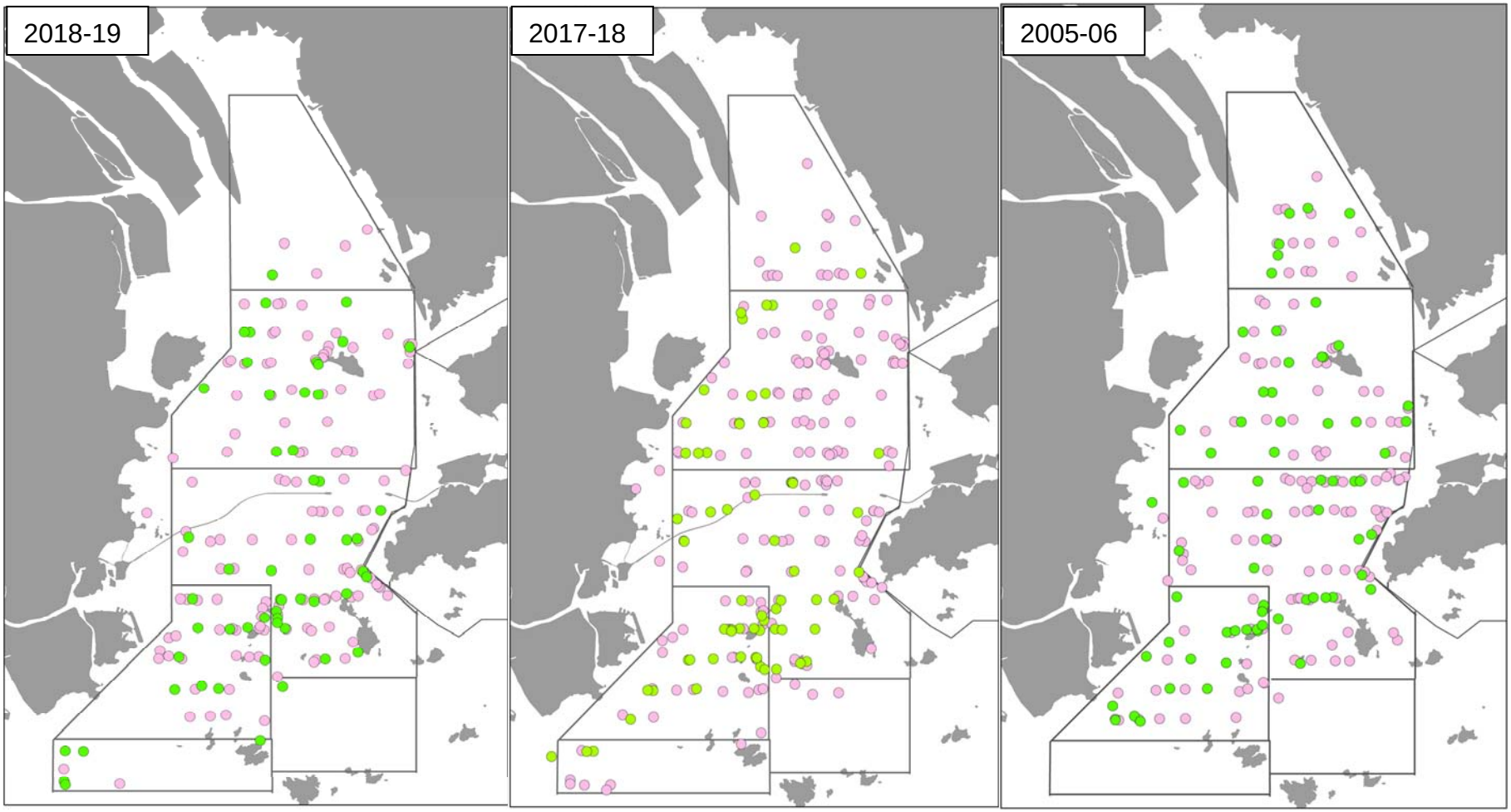

Figure 12. Distribution of young calves (Unspotted Calves and Unspotted Juveniles, green dots) distribution in Lingding Bay during 2018-19, 2017-18 and 2005-06 monitoring periods

Figure 13. Encounter rates of young calves (Unspotted Calves and Unspotted Juveniles) in the six survey areas in Lingding Bay (2018-19)

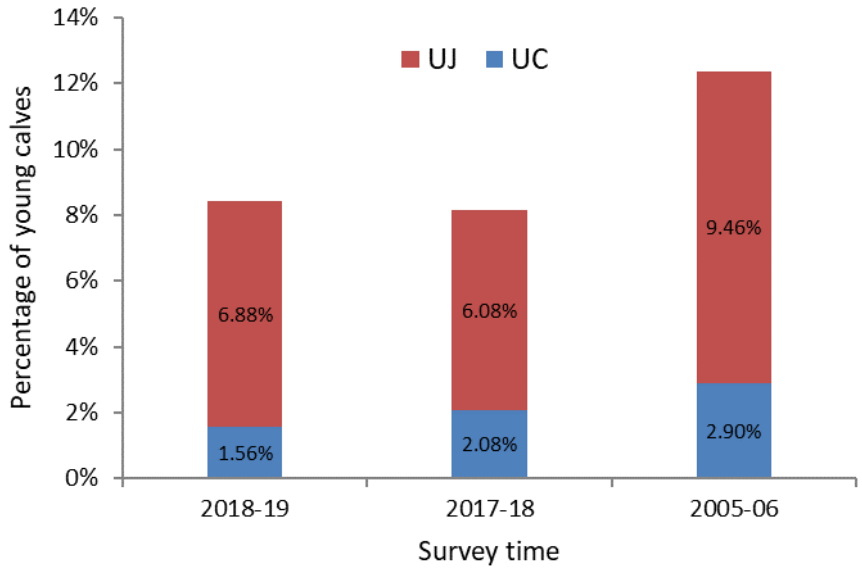

Figure 14. Percentages of young calves (Unspotted Calves and Unspotted Juveniles) among all dolphin groups in Lingding Bay during 2018-19, 2017-18 and 2005-06 monitoring periods

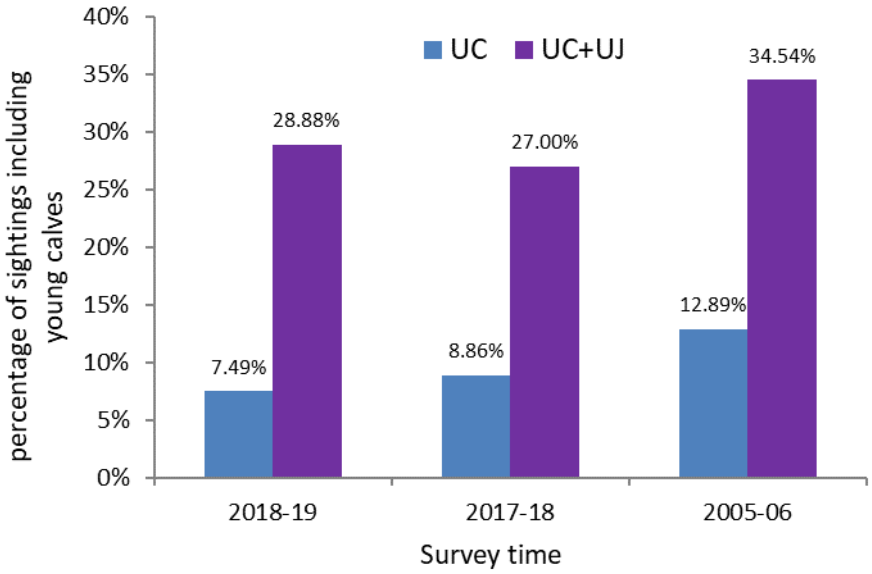

Figure 15. Percentages of sightings including young calves (Unspotted Calves and Unspotted Juveniles) in Lingding Bay during 2018-19, 2017-18 and 2005-06 monitoring periods

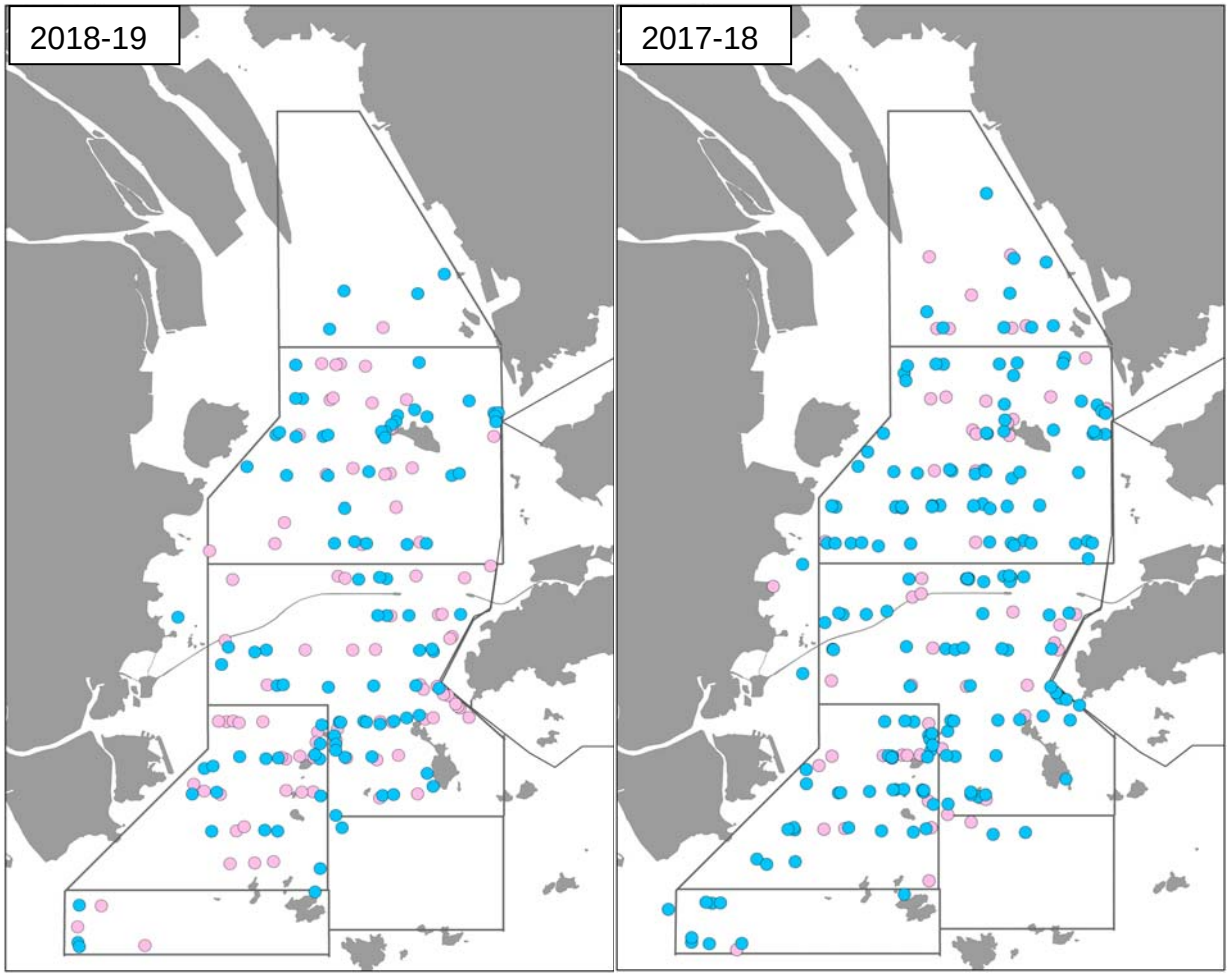

Figure 16. Distribution of Chinese White Dolphins engaged in feeding activities (cyan dots) in Lingding Bay during 2018-19 and 2017-18 monitoring period

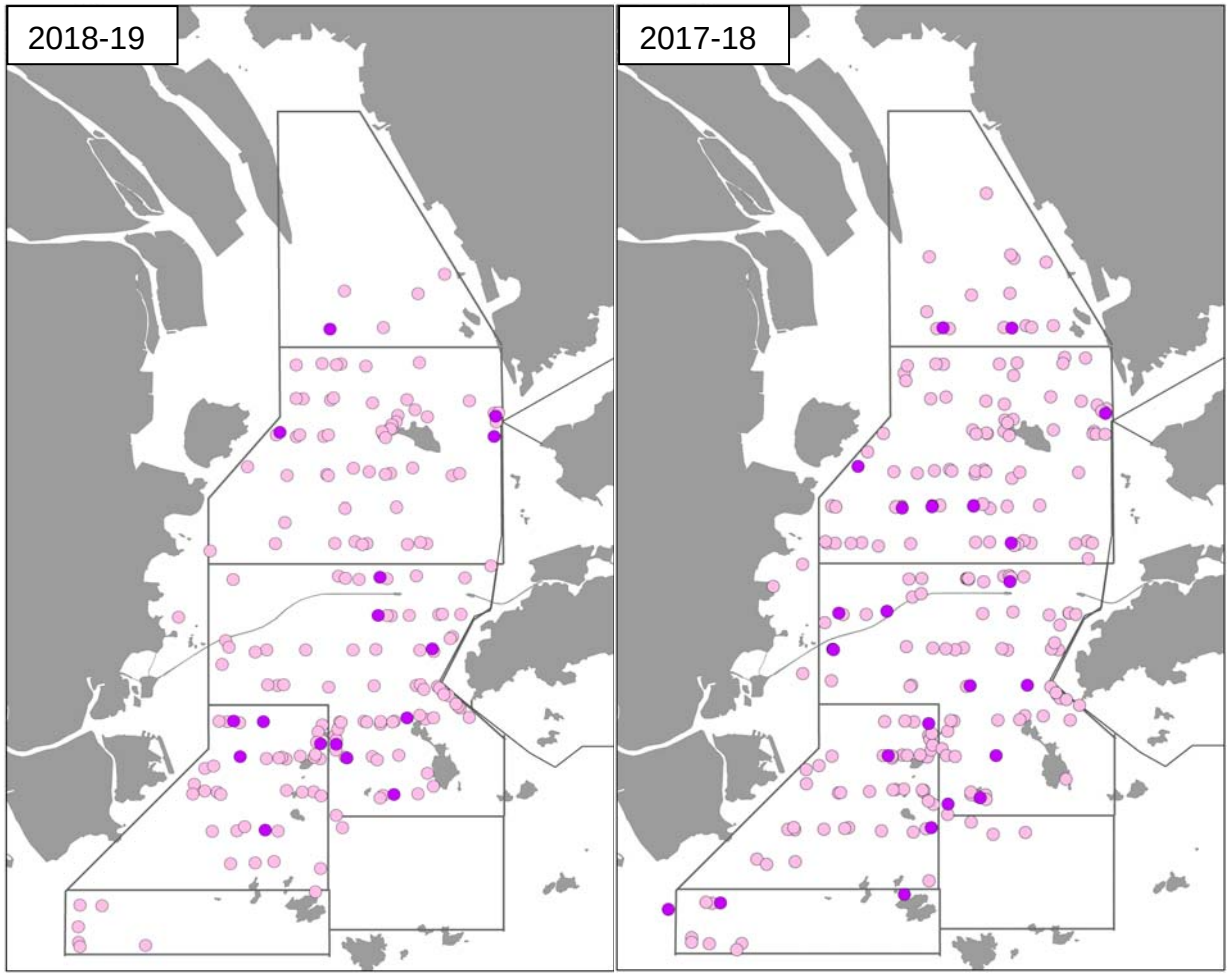

Figure 17. Distribution of Chinese White Dolphins engaged in socializing activities (purple dots) in Lingding Bay during 2018-19 and 2017-18 monitoring period

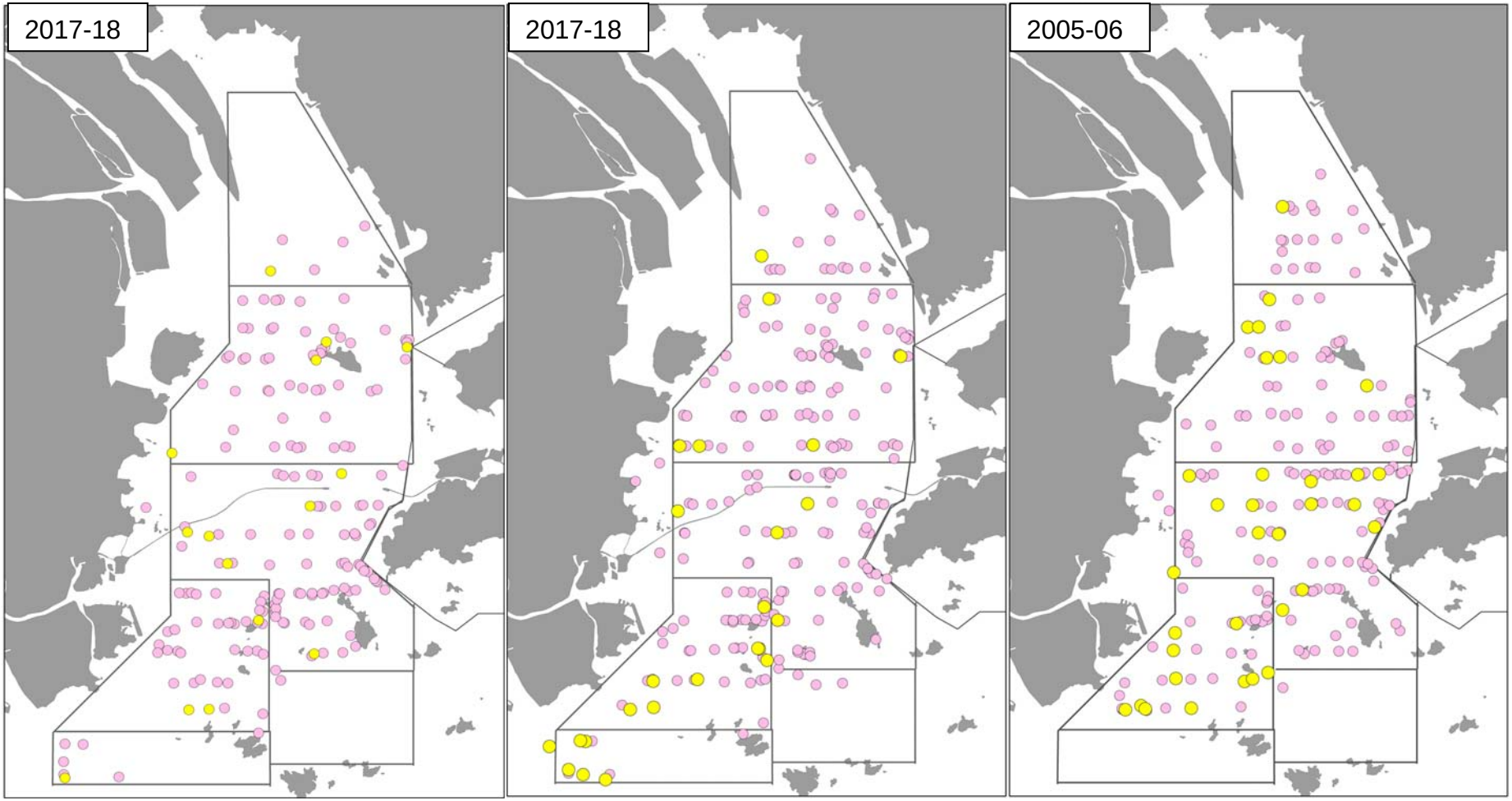

Figure 18. Distribution of dolphin sightings associations with fishing boats in Lingding Bay during 2018-19, 2017-18 and 2005-06 monitoring periods

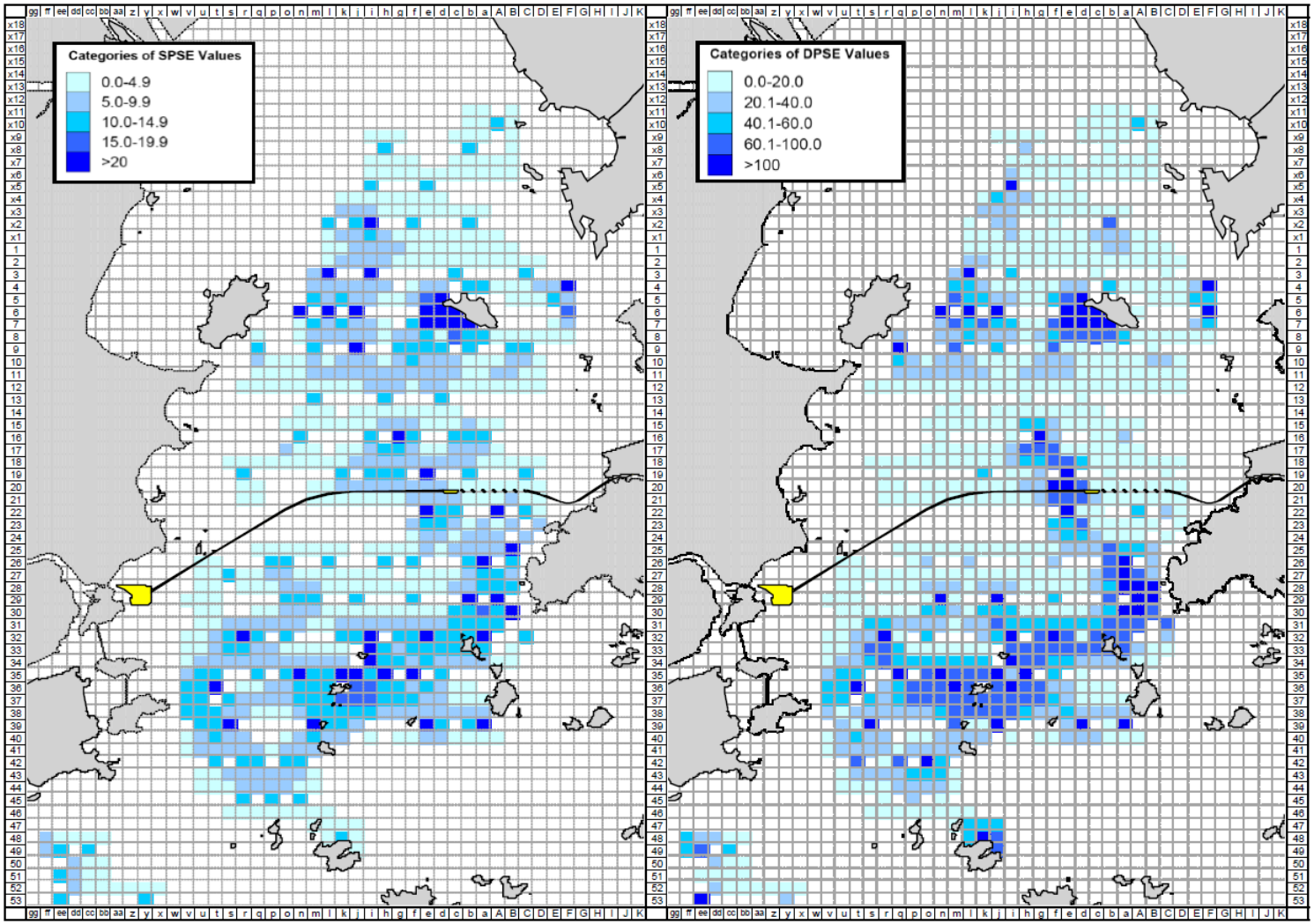

Figure 19. (left) Sighting density of Chinese White Dolphins with corrected survey effort per km^2 in the Pearl River Estuary, using on-effort survey data from 2018-19 (SPSE values in legend represent no. of on-effort dolphin sightings per 100 units of survey effort); (right) Density of Chinese White Dolphins with corrected survey effort per km^2 in the Pearl River Estuary, using on-effort survey data from 2018-19 (DPSE values in legend represent no. of dolphins from on-effort sightings per 100 units of survey effort)

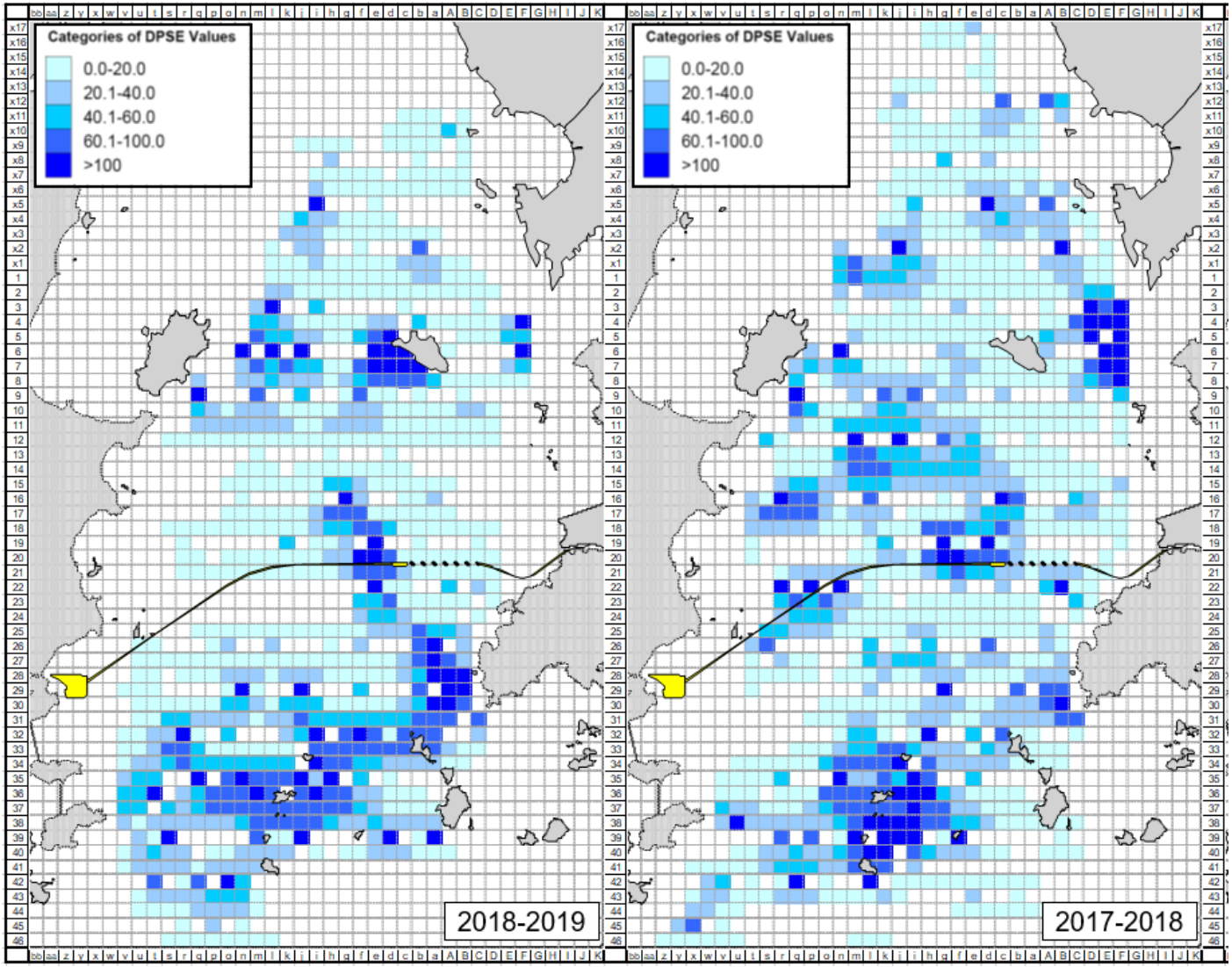

Figure 20. Comparison of Chinese White Dolphin densities with corrected survey effort per km^2 in Lingding Bay during 2018-19 and 2017-18 monitoring periods (number within grids represent "DPSE" = no. of dolphins per 100 units of survey effort)

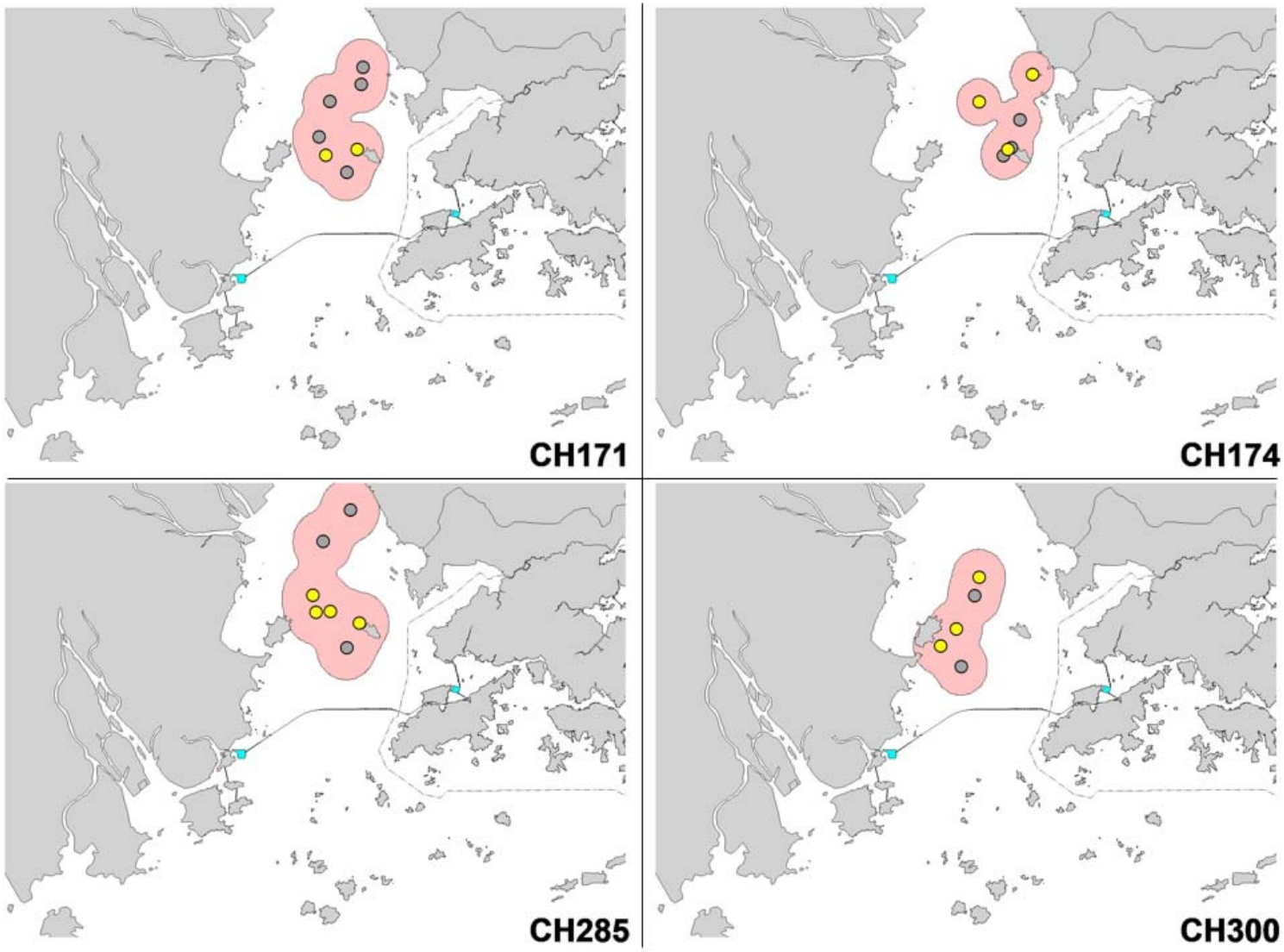

Figure 21. Examples of four individuals sighted during the 2018-19 surveys in Lingding Bay that have ranged mostly in northern part of Lingding Bay (yellow dots: sightings made in August 2018-May 2019)

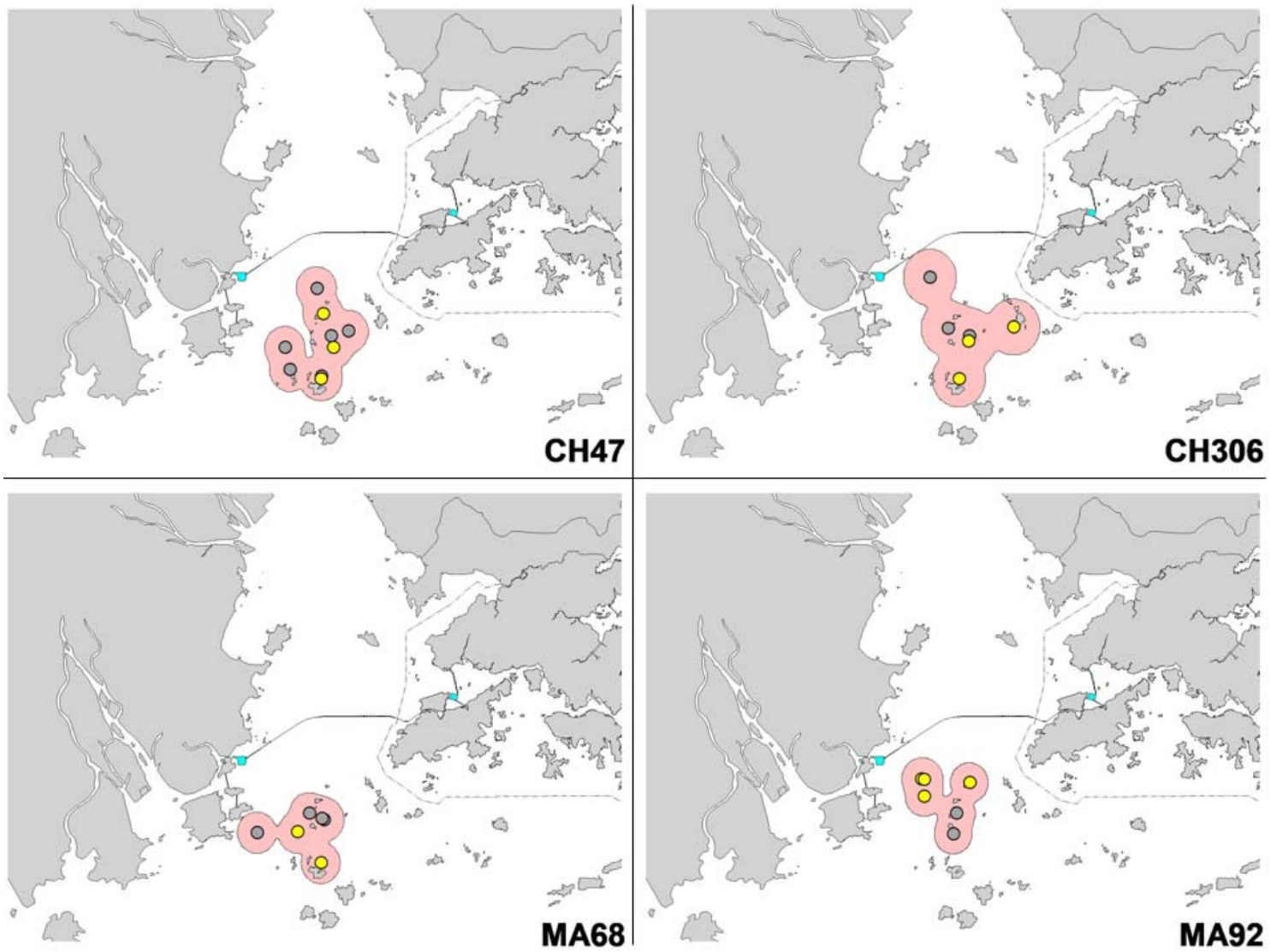

Figure 22. Examples of four individuals sighted during the 2018-19 surveys in Lingding Bay that have ranged mostly in southern part of Lingding Bay (yellow dots: sightings made in August 2018-May 2019)

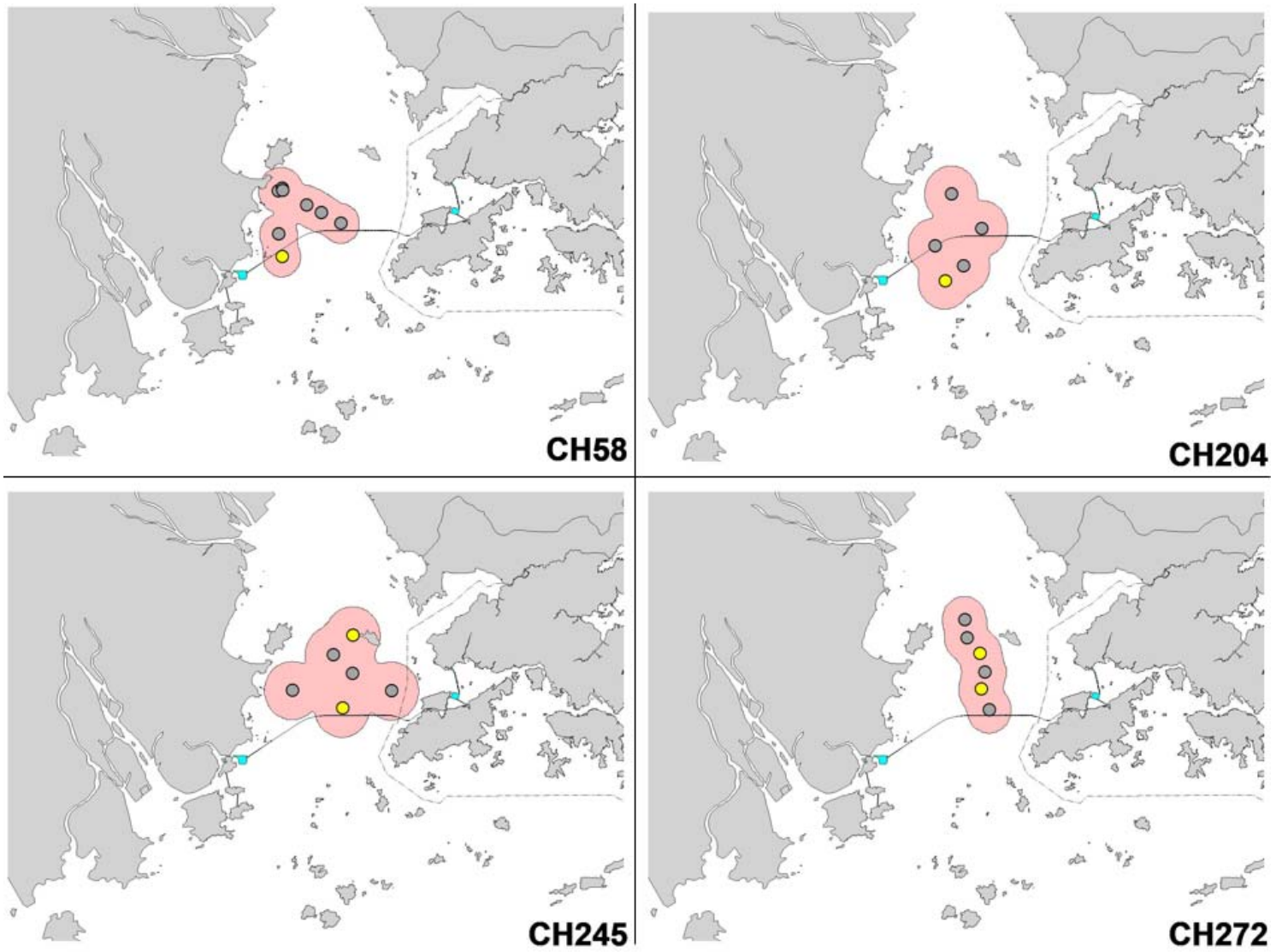

Figure 23. Examples of four individuals sighted during the 2018-19 surveys in Lingding Bay that have ranged mostly in central part of Lingding Bay (yellow dots: sightings made in August 2018-May 2019)

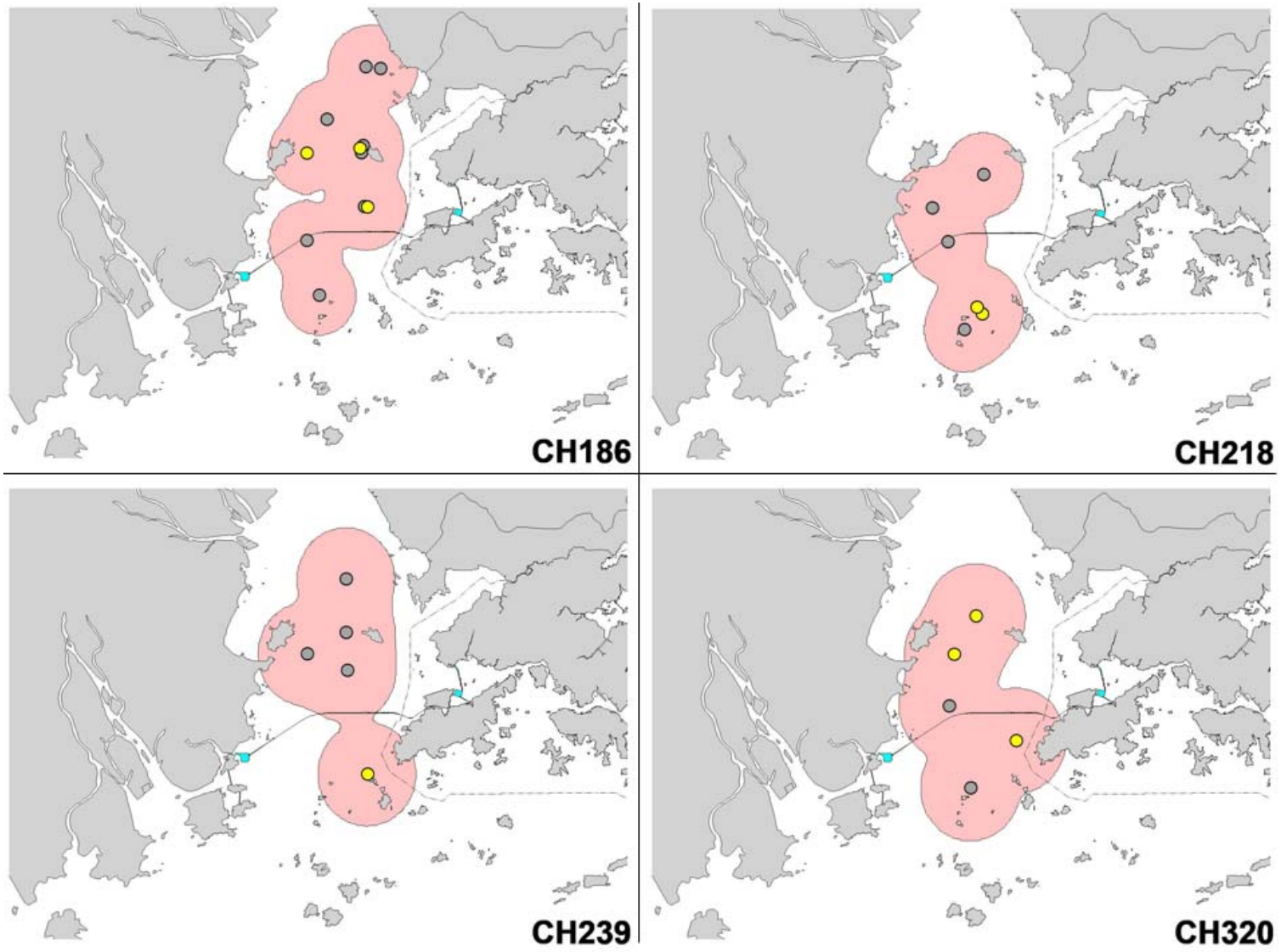

Figure 24. Examples of four individuals sighted during the 2018-19 surveys in Lingding Bay that have spanned across different parts of Lingding Bay (yellow dots: sightings made in August 2018-May 2019)

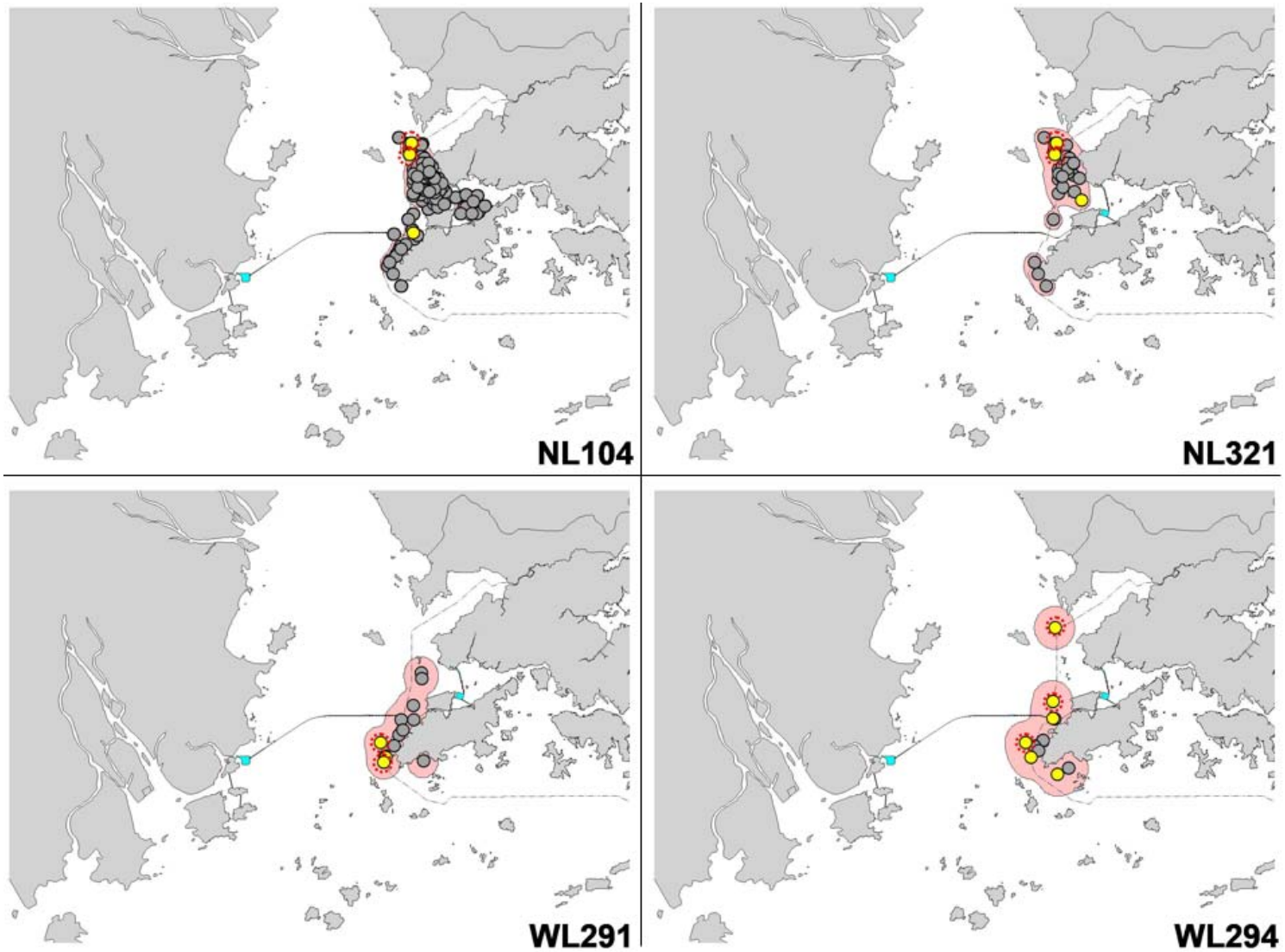

Figure 25. Examples of four individuals sighted during the 2018-19 surveys in Lingding Bay that have ranged mostly in HK waters and occurred only close to the western territorial boundary (yellow dots: sightings made in August 2018-May 2019; red circle: sightings made during 2018-19 EPRE surveys in Lingding Bay)

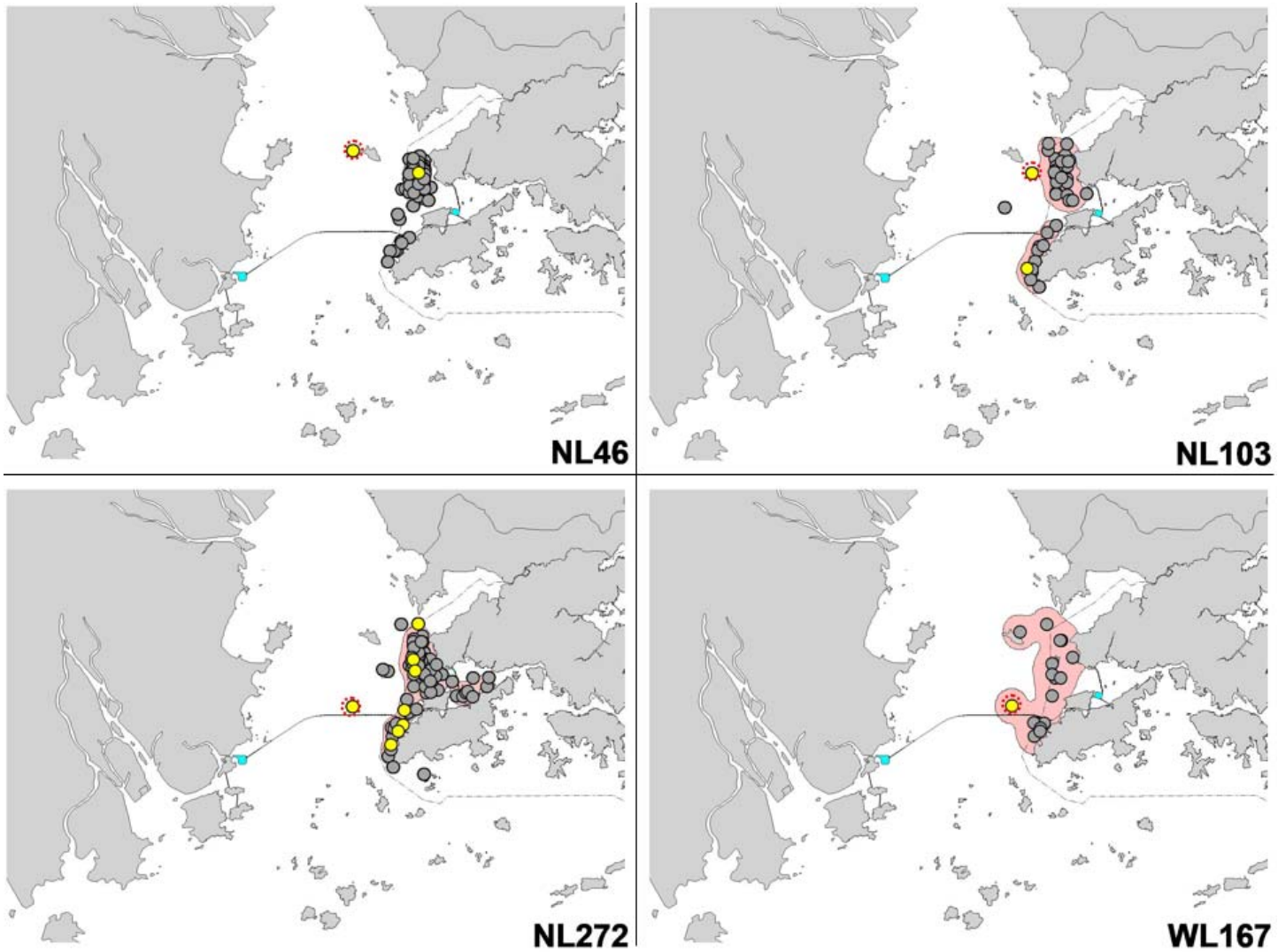

Figure 26. Examples of four individuals sighted during 2018-19 surveys in Lingding Bay that have ranged mostly in North Lantau waters in HK but also showed extensive movements within the northern part of Lingding Bay (yellow dots: sightings made in August 2018-May 2019; red circle: sightings made during 2018-19 EPRE surveys in Lingding Bay)

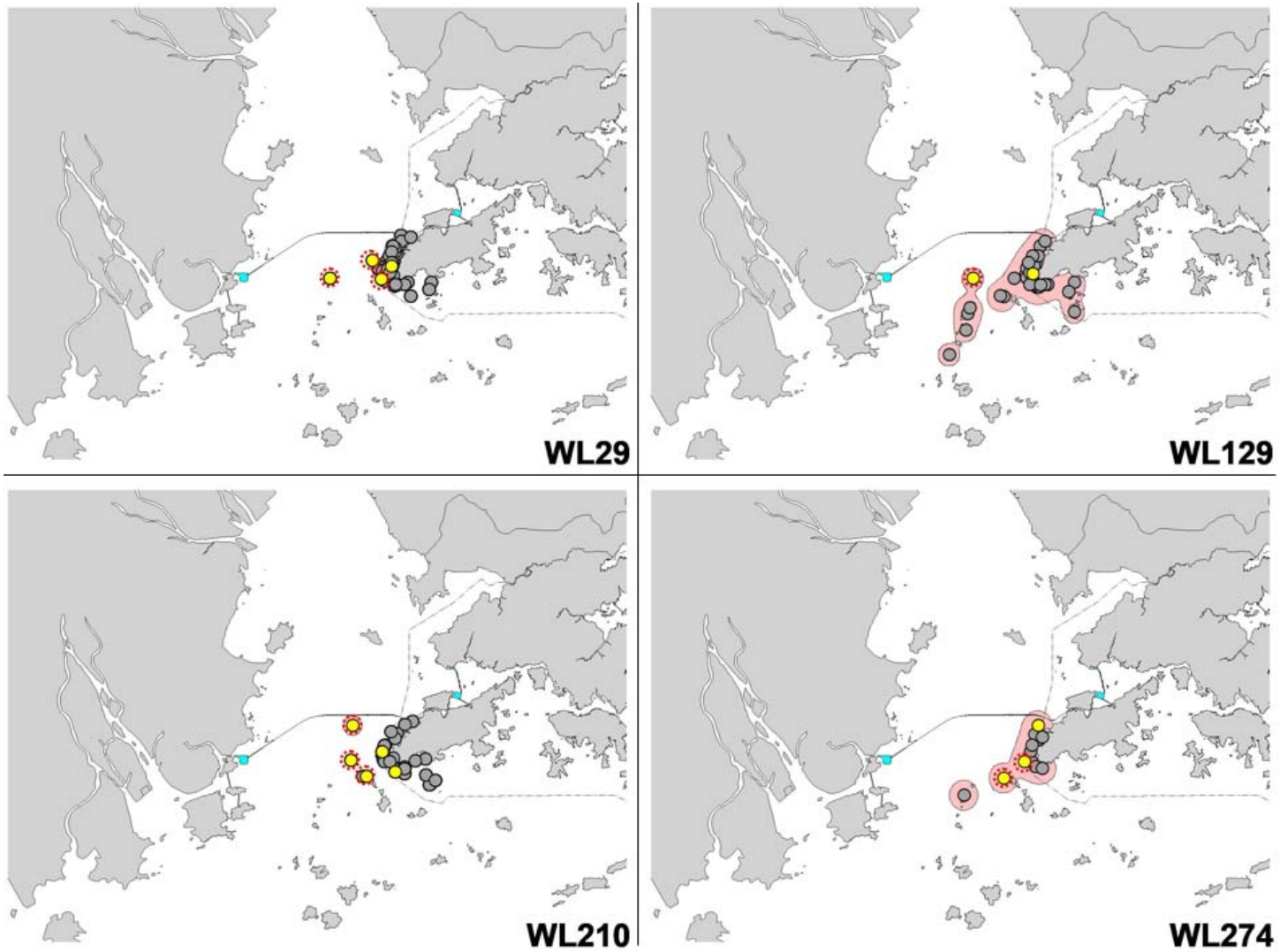

Figure 27. Examples of four individuals sighted during 2018-19 surveys in Lingding Bay that have ranged mostly in West Lantau waters in HK but also showed extensive movements within the southern part of Lingding Bay (yellow dots: sightings made in August 2018-May 2019; red circle: sightings made during 2018-19 EPRE surveys in Lingding Bay

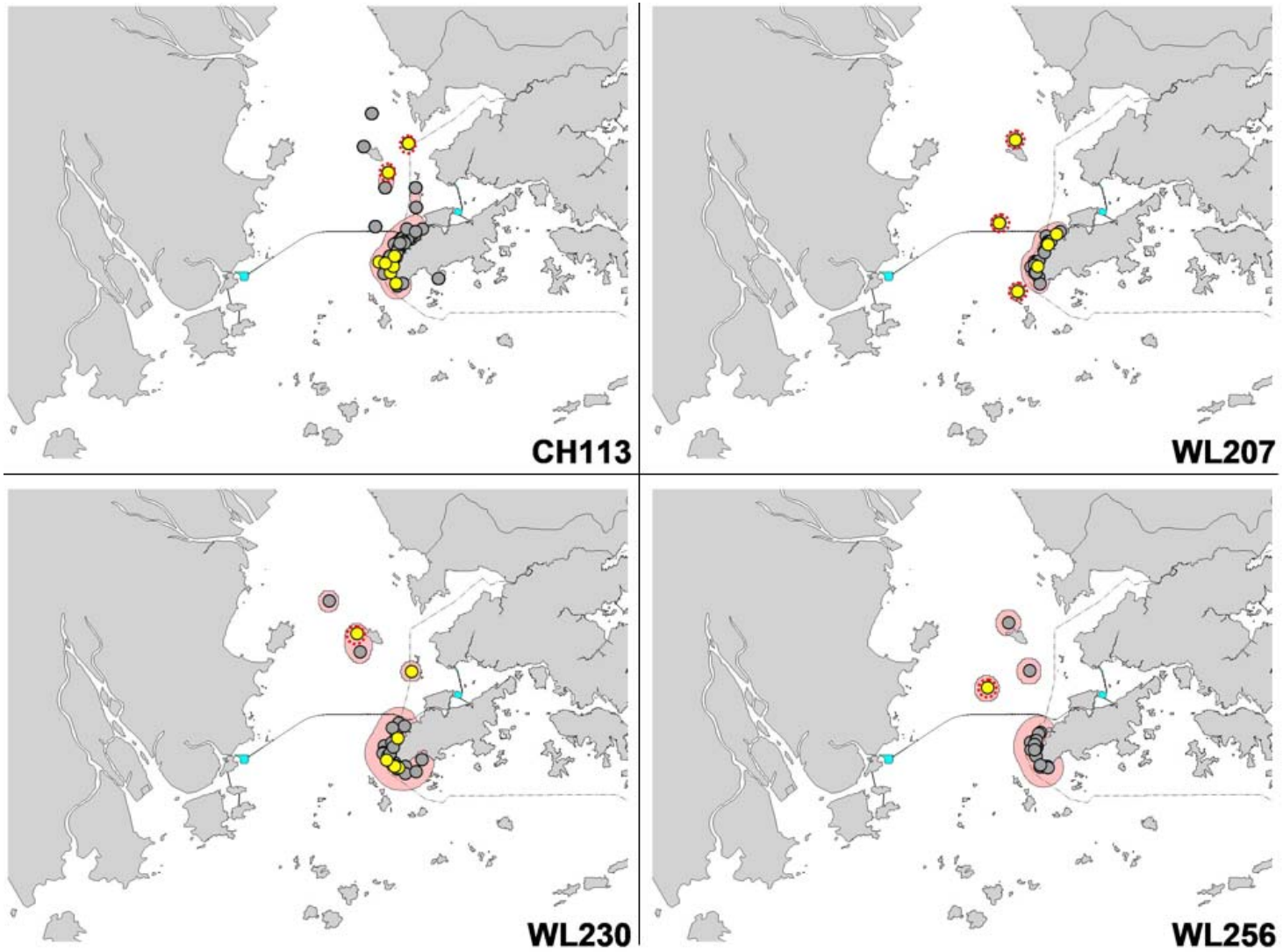

Figure 28. Examples of four individuals sighted during 2018-19 surveys in Lingding Bay that have ranged mostly in West Lantau waters in HK but occurred much further up in northern part of Lingding Bay (yellow dots: sightings made in August 2018-May 2019; red circle: sightings made during 2018-19 EPRE surveys in Lingding Bay)

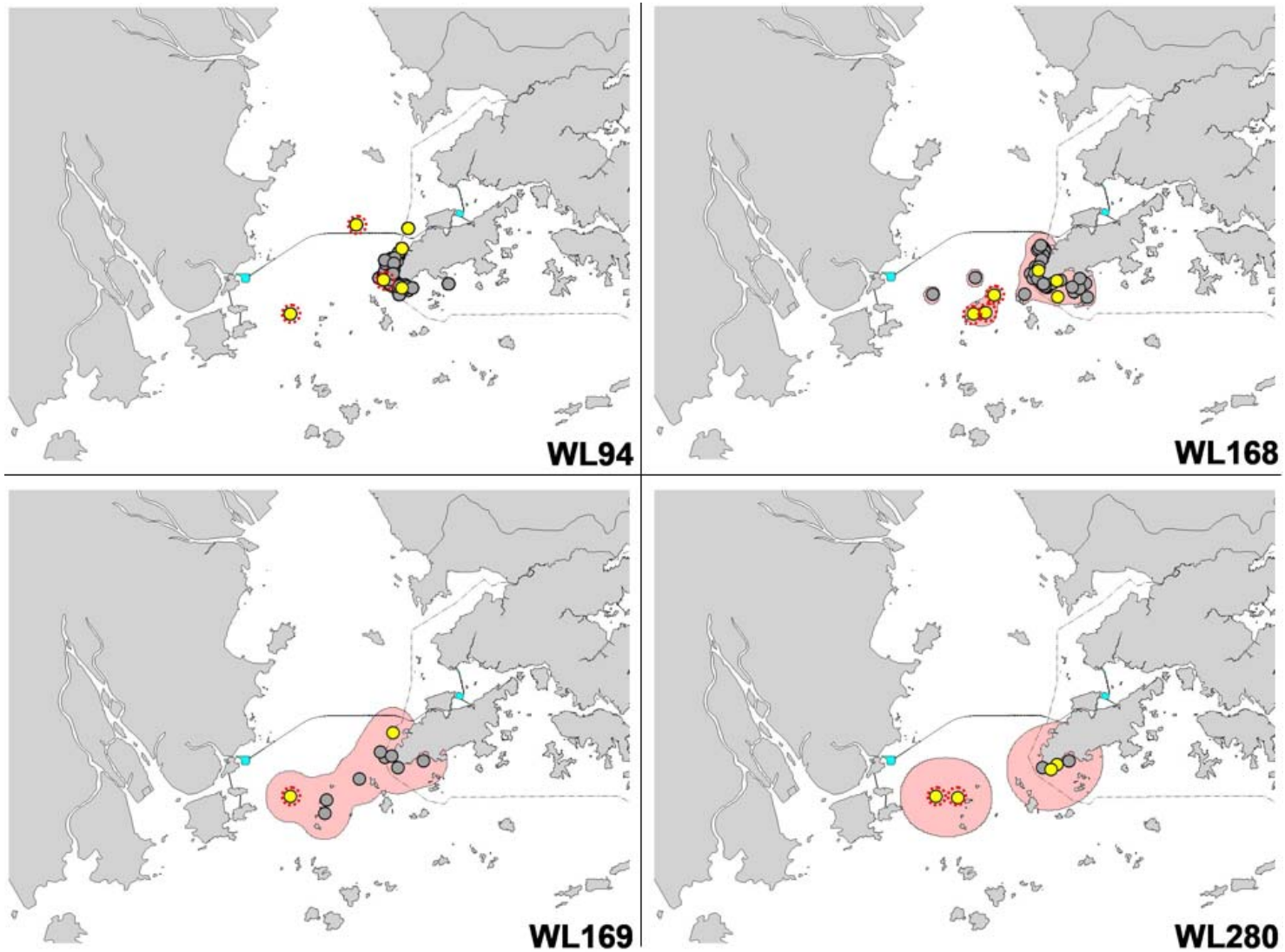

Figure 29. Examples of four individuals sighted during 2018-19 surveys in Lingding Bay that have ranged mostly in West Lantau waters in HK but have extended ranges further into Macau survey area (yellow dots: sightings made in August 2018-May 2019; red circle: sightings made during 2018-19 EPRE surveys in Lingding Bay)

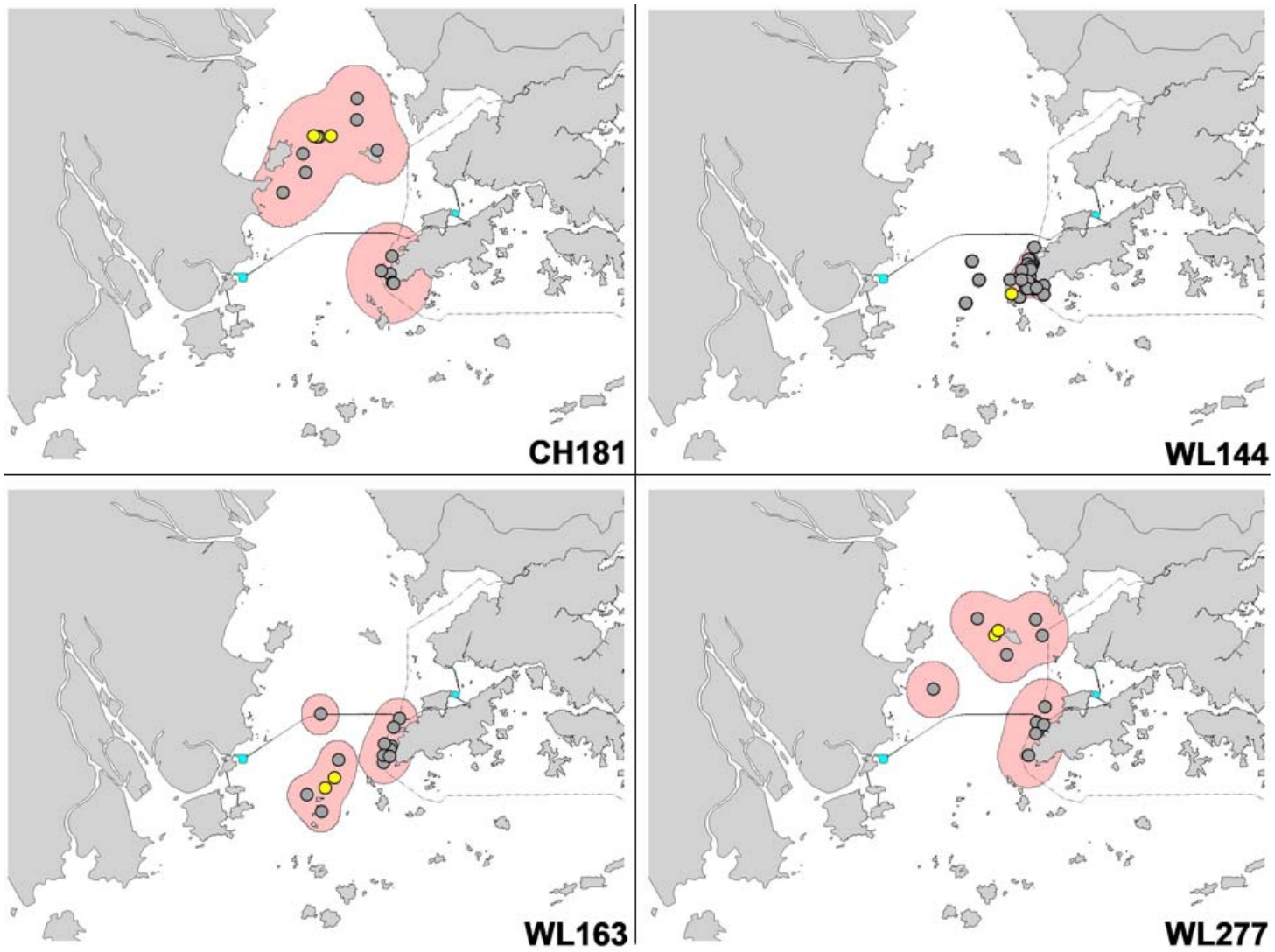

Figure 30. Four individuals being sighted during 2018-19 surveys in Lingding Bay that have disappeared from Hong Kong waters for at least two years (yellow dots: sightings made in August 2018-May 2019)

Table 1. Survey effort and sightings of Chinese White Dolphins in Lingding Bay (August 2018 - May 2019)

Surveys	Length of transect-lines (km)	Encounter groups	Encounter dolphins
Aug. 2018	509.1	17	84
Sep. 2018	494.8	19	92
Oct. 2018	468.5	16	67
Nov. 2018	494.1	16	87
Dec. 2018	501.3	16	98
Jan. 2019	495.2	17	132
Feb. 2019	488.0	24	117
Mar. 2019	499.9	20	90
Apr. 2019	435.6	16	89
May. 2019	424.9	12	49
Total	4804.2	173	905

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 2018 - May 2019)

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.2018	NLDB	71.5	71.5	1	1	4	4
	CLDB	138.4	127	2	2	7	7
	SLDB	146.3	146.3	7	7	30	30
	MA	72.8	72.8	7	7	43	43
	SWMA	46	46	0	0	0	0
	AZ	26.9	26.9	0	0	0	0
	Total	501.9	490.5	17	17	84	84
Sep.2018	NLDB	72.2	72.2	0	0	0	0
	CLDB	137.3	134.2	7	7	31	31
	SLDB	142.4	142.4	9	9	39	39
	MA	69.1	69.1	3	3	22	22
	SWMA	45.2	45.2	0	0	0	0
	AZ	28.6	28.6	0	0	0	0
	Total	494.8	491.7	19	19	92	92
Oct.2018	NLDB	71.4	71.4	0	0	0	0
	CLDB	134.6	134.6	11	11	51	51
	SLDB	125	117.6	5	5	16	16
	MA	73.2	27.6	0	0	0	0
	SWMA	34.8	32.6	0	0	0	0
	AZ	29.5	1.5	0	0	0	0
	Total	468.5	385.3	16	16	67	67
Nov.2018	NLDB	71.5	71.5	0	0	0	0
	CLDB	135.2	135.2	4	4	13	13
	SLDB	141.2	129.2	8	8	60	60
	MA	71.6	63.3	4	3	14	11
	SWMA	45.7	0	0	0	0	0
	AZ	28.9	0	0	0	0	0
	Total	494.1	399.2	16	15	87	84
Dec.2018	NLDB	72.5	72.5	0	0	0	0
	CLDB	140.9	100	4	3	20	12
	SLDB	145.3	94.7	4	4	26	26
	MA	71.6	71.6	6	6	43	43
	SWMA	43	43	2	2	9	9
	AZ	28	28	0	0	0	0
	Total	501.3	409.8	16	15	98	90
Jan.2019	NLDB	72.3	72.3	2	2	17	17

	CLDB	136.7	48.8	4	2	25	12
	SLDB	145.5	83.5	4	3	41	25
	MA	70	70	6	6	26	26
	SWMA	43.2	43.2	1	1	23	23
	AZ	27.5	27.5	0	0	0	0
	Total	495.2	345.3	17	14	132	103
Feb.2019	NLDB	71.3	71.3	1	1	5	5
	CLDB	133.9	110.7	9	8	45	44
	SLDB	143.8	123.8	12	11	45	44
	MA	73.7	31.5	0	0	0	0
	SWMA	42.3	7	2	1	22	3
	AZ	23	4.9	0	0	0	0
	Total	488	349.2	24	21	117	96
Mar.2019	NLDB	72	72	0	0	0	0
	CLDB	138.5	110.1	7	5	21	14
	SLDB	145.2	145.2	9	9	60	60
	MA	73.3	73.3	3	3	8	8
	SWMA	38.5	38.5	1	1	1	1
	AZ	32.4	32.4	0	0	0	0
	Total	499.9	471.5	20	18	90	83
Apr.2019	NLDB	72.7	62.4	0	0	0	0
	CLDB	140.9	130.2	4	4	17	17
	SLDB	143.5	143.5	7	7	43	43
	MA	72.1	72.1	5	5	29	29
	SWMA	0	0	0	0	0	0
	AZ	6.4	6.4	0	0	0	0
	Total	435.6	414.6	16	16	89	89
May.2019	NLDB	46.2	46.2	1	1	1	1
	CLDB	134.1	83.6	2	2	6	6
	SLDB	143.2	137.7	6	6	25	25
	MA	68.3	68.3	3	3	17	17
	SWMA	9.3	9.3	0	0	0	0
	AZ	23.8	23.8	0	0	0	0
	Total	424.9	368.9	12	12	49	49

Table 3. Estimates of abundance and associated parameters for Chinese White Dolphins in different survey areas in Lingding Bay (August 2018 - May 2019)

Survey area	*L* (km)	*n*	*f*(0) (km^{-1})	*E*(*s*)	*D* (100 km^{-2})	*N*	CV (%)
NLDB (403.81 km^2)	683.3	5	3.75	5.40	7.41	30	69.78
CLDB (463.74 km^2)	1114.4	47	3.75	4.06	32.12	149	22.36
SLDB (515.68 km^2)	1263.9	67	3.75	5.45	54.12	279	20.44
MA (267.96 km^2)	619.6	33	3.75	5.61	55.96	150	24.87
SWMA (128.36 km^2)	264.8	5	3.75	7.20	25.48	33	79.11

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 (August 2017 - April 2018)

Survey area	*L* (km)	*n*	*f*(0) (km^{-1})	*E*(*s*)	*D* (100 km^{-2})	*N*	CV (%)
NLDB (403.81 km^2)	616.07	14	4.46	4.07	20.63	83	43.46
CLDB (463.74 km^2)	1103.4	70	4.46	4.80	67.89	315	22.06
SLDB (515.68 km^2)	1093.1	59	4.46	4.85	58.33	301	20.34
MA (267.96 km^2)	626.7	47	4.46	5.32	88.93	238	28.66
SWMA (128.36 km^2)	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 5. Average precipitation (mm) for Pearl River Basin (consist of Xijing River Basin, Beijiang River Basin and Dongjiang River Basin) in each month during the 2018-19 monitoring period (August 2018- May 2019).

	XRB	BRB	DRB	PRB
Aug.2018	340	249	404	993
Sep.2018	273	104	194	571
Oct.2018	75	99	41	215
Nov.2018	25	67	53	145
Dec.2018	31	40	17	88
Jan.2019	8	16	4	28
Feb.2019	100	151	61	312
Mar.2019	175	304	241	720
Apr.2019	240	374	340	954
May 2019	255	301	267	823
Total	1522	1705	1622	4849

Symbols used: XRB, Xijing River Basin; BRB, Beijiang River Basin; DRB, Dongjiang River Basin; PRB, Pearl River Basin

Table 6. Average precipitation (mm) for Pearl River Basin (consist of Xijing River Basin, Beijiang River Basin and Dongjiang River Basin) in each month during the 2017-18 monitoring period (August 2017 - May 2018).

	XRB	BRB	DRB	PRB
Aug.2017	284	112	214	610
Sep.2017	156	102	109	367
Oct.2017	88	38	74	200
Nov.2017	72	88	27	187
Dec.2017	5.8	14.1	2.8	22.7
Jan.2018	74	151	134	359
Feb.2018	18	37	19	74
Mar.2018	62	94	54	210
Apr.2018	71	103	70	244
May 2018	175	131	98	404
Total	1005.8	870.1	801.8	2677.7

Symbols used: XRB, Xijing River Basin; BRB, Beijiang River Basin; DRB, Dongjiang River Basin; PRB, Pearl River Basin

Table 7. Estimates of abundance and associated parameters for Chinese White Dolphins in different survey areas in Lingding Bay (dry season: October 2018 - March 2019)

Survey area	*L* (km)	*n*	*f*(0) (km^{-1})	*E*(*s*)	*D* (100 km^{-2})	*N*	CV (%)
NLDB (403.81 km^2)	431.0	3	3.10	7.33	7.90	32	92.24
CLDB (463.74 km^2)	639.4	32	3.10	4.06	31.49	146	23.16
SLDB (515.68 km^2)	694.0	39	3.10	5.87	51.10	264	25.21
MA (267.96 km^2)	337.3	15	3.10	4.93	33.97	91	34.87
SWMA (128.36 km^2)	164.3	5	3.10	7.20	33.93	44	74.29

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 8. 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^{-1})	*E*(*s*)	*D* (100 km^{-2})	*N*	CV (%)
NLDB (403.81 km^2)	410.87	13	4.24	4.31	28.92	117	41.32
CLDB (463.74 km^2)	706.85	51	4.24	5.02	76.84	356	26.05
SLDB (515.68 km^2)	753.10	37	4.24	5.00	52.12	269	24.91
MA (267.96 km^2)	479.90	28	4.24	6.14	76.04	204	30.04
SWMA (128.36 km^2)	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