



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

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**Completion Report**



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## Executive summary

The 2025–26 project represents the fourth stage of the long-term monitoring programme for Chinese White Dolphins (CWD; *Sousa chinensis*) in Lingding Bay of the Pearl River Delta region, extending the 2017–18, 2018–19 and 2024–25 monitoring cycles. Using comparable vessel-based line-transect surveys, photo-identification and GIS-based habitat-use analyses, the project updated key information on dolphin distribution, density, abundance, individual ranging patterns and fine-scale habitat use. As in the previous monitoring cycle, the survey covered four principal strata: Central Lingding Bay (CLDB), South Lingding Bay (SLDB), the Macau sector (MA), and Southwest Macau (SWMA), thereby ensuring consistency with earlier datasets and supporting inter-annual comparisons of population dynamics and habitat-use patterns.

During the 2025–26 monitoring period, a total of ten vessel-based line-transect survey trips were conducted from July 2025 to April 2026. Across all Beaufort sea states, the surveys accumulated 3,762.3 km of transect effort and recorded 138 group encounters of CWDs, comprising 683 individuals. For encounter-rate and line-transect analyses, only data collected under favourable sea conditions of Beaufort 0–3 were used. This analytical subset included 3,494.0 km of on-effort survey coverage, with 136 CWD group encounters and 675 individuals recorded.

Area-specific encounter rates based on Beaufort 0–3 data were highest for group encounters in MA (4.79 groups per 100 km) and SLDB (4.59 groups per 100 km), followed by CLDB (3.40 groups per 100 km) and SWMA (1.62 groups per 100 km). Individual encounter rates were highest in SWMA (27.26 dolphins per 100 km) and MA (26.59 dolphins per 100 km), reflecting the occurrence of relatively large groups in these sectors despite lower or more variable sighting frequency.

The 2025–26 line-transect analysis estimated a total abundance of 536 Chinese White Dolphins across the four common survey strata of Lingding Bay, comprising 168 individuals in CLDB, 142 in SLDB, 151 in MA and 75 in SWMA. Estimated individual

densities varied among areas, with relatively higher values in SWMA and MA, indicating persistent spatial heterogeneity in habitat use. The estimates for CLDB, SLDB and MA were of moderate precision, while the SWMA estimate was associated with greater uncertainty because of the smaller number of sightings. These results suggest that, although dolphin abundance remained lower than in some previous monitoring periods, the southern and southwestern parts of Lingding Bay continued to function as important habitats for the population during 2025–26.

Mean group size during 2025–26 was  $4.94 \pm 5.82$  dolphins per group ( $n = 143$ ), with small groups remaining dominant: 44.06% of groups comprised one or two individuals and 76.22% contained fewer than six dolphins. Young dolphins were relatively prominent in this monitoring cycle, with 12 unspotted calves and 66 unspotted juveniles recorded; together, young calves accounted for 13.68% of age-classified individuals. Feeding groups accounted for 24.5% of sightings, socializing groups for 6.3%, and only 3.5% of sightings were associated with operating fishing vessels, suggesting that direct associations with active fishing operations were infrequently observed during the reporting period.

Photo-identification yielded 24,415 photographs, 305 recognisable individuals, 23 newly identified individuals, and 76 repeatedly sighted individuals with 170 resighting events.

Overall, the project achieved its objectives by providing an updated assessment of abundance, distribution, age composition, fine-scale habitat use and individual ranging patterns of Chinese White Dolphins in Lingding Bay during 2025–26. The results indicate that dolphin abundance remained at a relatively low level compared with earlier high-abundance periods, while habitat use was spatially heterogeneous and increasingly concentrated in the western nearshore waters, bridge-associated waters and island-related habitats. Continued long-term monitoring, strengthened photo-identification matching, prey-resource assessment and targeted management of high-

use areas are recommended to support evidence-based conservation of the Pearl River Estuary CWD population.

## **Project title and brief description of the Project**

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

As a continuation of the Chinese White Dolphin (CWD) monitoring projects conducted during 2017–18, 2018–19 and 2024–25, the 2025–26 fourth-stage project was implemented as a vessel-based monitoring programme in Lingding Bay, with ten systematic line-transect survey trips completed from July 2025 to April 2026. The project aimed to update population parameters, distribution patterns, age composition, individual ranging patterns and fine-scale habitat use, and to compare the new findings with previous monitoring cycles so that conservation and management recommendations could be refined for the Pearl River Estuary CWD population.

## **1 Introduction**

The Pearl River Estuary–Moyang River Estuary (PRE–MRE) population of Chinese White Dolphins (CWD; *Sousa chinensis*) is the largest known population of the species (Li et al., 2019; Chen et al., 2010). Lingding Bay (LDB)—including the territorial waters of Hong Kong and Macao—encompasses the core range of this population and therefore holds exceptional conservation importance. Yet LDB borders one of the most densely populated coastal zones in the world; consequently, dolphins are unavoidably exposed to intense and expanding anthropogenic pressures within their habitat. Large-scale land reclamation, port construction, and offshore wind-farm development have already resulted in direct habitat loss, while fisheries by-catch, vessel collisions, underwater noise, and climate-driven changes in prey availability further threaten population viability (SEE Foundation, 2025). Because such pressures continue to evolve, sustained long-term monitoring of the PRE–MRE population is essential for

detecting temporal changes in abundance, distribution, and habitat use.

Between 2017 and 2019, the South China Sea Fisheries Research Institute (SCSFRI) completed two annual monitoring programmes in LDB, generating baseline information on dolphin distribution, abundance, individual ranging patterns—including cross-boundary movements—and fine-scale habitat use. Although those studies documented a decade-long decline in abundance, the rate of decrease appeared to stabilise in recent years. Nevertheless, cumulative anthropogenic threats—ghost fishing gear, high-speed vessel traffic, underwater noise, coastal development, and climate change—continue to degrade habitat quality and may alter prey availability, movement patterns, and individual home ranges. Two years of monitoring are clearly insufficient to evaluate population dynamics against a backdrop of persistent environmental change; a sustained monitoring effort is therefore indispensable.

The 2024–25 monitoring cycle provided an important recent reference point for evaluating the status of CWD in Lingding Bay. That survey estimated a total abundance of approximately 640 dolphins across the four common survey strata, documented continued spatial heterogeneity in dolphin occurrence, and showed that high-use areas were increasingly concentrated in the western and southern parts of the bay. The 2024–25 results also highlighted the need to continue monitoring abundance, calf occurrence, behaviour and habitat use in order to determine whether observed changes represent short-term variation, spatial redistribution or longer-term shifts in the use of Lingding Bay.

The 2025–26 project therefore represents a further extension of the 2017–18, 2018–19 and 2024–25 monitoring initiatives. Focusing on the principal survey strata of CWD in LDB—namely CLDB, SLDB, MA and SWMA—the project conducted ten vessel-based line-transect surveys from July 2025 to April 2026. Line-transect sampling, photo-identification and GIS-based habitat-use analyses were used to generate new data that can be integrated with historical records, thereby supporting cautious inter-annual

assessment of temporal changes in abundance, habitat use and individual ranging behaviour in the Pearl River Estuary region. Ultimately, the findings are intended to inform evidence-based conservation and management recommendations for governmental and regulatory bodies.

### **Objectives of the 2025–26 project**

- 1. Continue long-term monitoring of population dynamics.** Conduct systematic surveys to track distribution, abundance, and age composition trends of Chinese White Dolphins in Lingding Bay, comparing new findings with historical data for robust long-term analyses.
- 2. Enhance individual ranging and site-fidelity analyses.** Leverage the expanded photo-identification dataset to examine movement patterns, site fidelity, and group associations, detecting any shifts related to environmental or anthropogenic changes.
- 3. Refine understanding of fine-scale habitat use.** Integrate recent spatial and environmental data to map ecological hotspots, identify potential habitat fragmentation, and assess how changing conditions influence habitat-use patterns.
- 4. Conduct strategic long-term comparative analysis.** Synthesize multi-year CWD monitoring data to perform before-and-after comparisons with previous survey cycles (2017–2018, 2018–2019, 2024–2025), identify temporal trends in population distribution and habitat use, and evaluate long-term ecological changes and conservation implications.
- 5. Evaluate and update conservation recommendations.** Build on multi-year monitoring insights to critically review existing conservation measures and propose evidence-based management strategies that address current threats and ensure long-term population viability.

## 2 Work schedule

The project followed the planned fourth-stage monitoring framework. The final reporting dataset covers July 2025–April 2026, with April 2026 confirmed as the last survey month included in this completion report.

| Time           | Proposed activities                                                                                             | Completed activities                                        |
|----------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| July 2025      | Historical data review and first 2025–26 line-transect survey / individual identification.                      | Done accordingly                                            |
| August 2025    | Line-transect vessel survey and individual identification.                                                      | Done accordingly                                            |
| September 2025 | Line-transect vessel Survey and individual identification                                                       | Done accordingly                                            |
| October 2025   | Line-transect vessel Survey and individual identification                                                       | Done accordingly                                            |
| November 2025  | Line-transect vessel survey; individual identification and progress reporting                                   | Done accordingly                                            |
| December 2025  | Line-transect vessel survey and individual identification                                                       | Done accordingly                                            |
| January 2026   | Line-transect vessel survey; individual identification                                                          | Done accordingly                                            |
| February 2026  | Line-transect vessel survey; individual identification                                                          | Done accordingly                                            |
| March 2026     | Line-transect vessel survey; individual identification                                                          | Done accordingly                                            |
| April 2026     | Line-transect vessel survey; individual identification                                                          | Done accordingly                                            |
| May 2026       | Data collation, photo-identification processing and statistical analysis following the final April 2026 survey. | Done accordingly                                            |
| June 2026      | Final density, abundance, age-composition and habitat-use analyses; completion report preparation.              | Completion report finalised for submission on 30 June 2026. |

## 3 Methodology

### 3.1 General approach

Systematic line-transect survey data collected during the 2025–26 project were used to calculate updated encounter rates, density and abundance estimates for CWD in Lingding Bay. Results were compared with earlier survey cycles, including 2017–18, 2018–19 and 2024–25, to assess temporal changes in population dynamics.

Photo-identification was carried out concurrently with the line-transect vessel surveys to document individual dolphins and to track their movements within Lingding Bay. For the 2025–26 season, newly acquired images were matched exclusively against a reference catalogue compiled from Lingding Bay surveys conducted over the past decade; no cross-boundary comparison with Hong Kong photo-ID datasets was undertaken. Consequently, the present analysis focuses on intra-bay ranging patterns, while inferences about trans-boundary movements remain based on earlier, inter-annual studies.

Using the analytical method of fine-scale grid analysis, the habitat use of CWD was examined in detail, which could establish the importance of dolphin habitats at various locations of Lingding Bay, and identify areas of relatively high use and potential conservation importance.

### **3.2 Study areas**

For the purpose of interannual comparison, Lingding Bay in the Pearl River Estuary was divided into four common analytical strata (Figure 1): Central Lingding Bay (CLDB), South Lingding Bay (SLDB), Macau (MA), and Southwest Macau (SWMA). The boundaries and surface areas of these strata were held constant across the 2017–18, 2018–19, 2020–21, 2024–25 and 2025–26 monitoring periods. The respective areas were 463.74 km<sup>2</sup> for CLDB, 515.68 km<sup>2</sup> for SLDB, 267.96 km<sup>2</sup> for MA, and 128.36 km<sup>2</sup> for SWMA, giving a total common analytical area of 1,375.74 km<sup>2</sup>.

The 2025–26 surveys followed the same pre-established nominal transect network used in the earlier monitoring programmes. In this report, the “same transect network” refers to the same planned transect layout and approximate spacing within the four common

strata. It does not imply that the realised vessel GPS tracks or effective on-effort survey distances were identical in every monitoring period. The spatial scope of the abundance comparisons was restricted to these four common strata and did not represent complete coverage of the entire Pearl River Estuary.

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

A series of nominally parallel transect lines, oriented approximately perpendicular to the major coastlines, was established at intervals of approximately 3 km within each of the four survey strata. The same planned transect layout and spacing were retained across the monitoring periods to provide broadly consistent and representative coverage of the common analytical area.

The realised vessel tracks did not necessarily coincide exactly with the nominal transect lines or with the GPS tracks recorded in previous monitoring periods. Weather and sea conditions, navigational safety, temporary obstructions and other operational constraints occasionally required minor deviations from the planned lines. In addition, the effective on-effort distance used in the principal analyses varied among monitoring periods because only data collected under Beaufort sea states 0–3 were retained. Interannual comparisons therefore relied on fixed stratum boundaries, common analytical areas and effort-standardised analyses, rather than on exact identity of the realised vessel tracks or survey distances.

A total of ten sets of line-transect surveys were completed during the 10-month study period, with one survey set conducted each month from July 2025 to April 2026.

A shrimp trawler (*Yuezhongyu* 18181) 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 data collected under Beaufort sea states 0–3 were

used for line-transect analyses of density and abundance, as well as for encounter-rate and habitat-use analyses.

To ensure methodological consistency, the 2025–26 surveys were conducted by the same SCSFRI observer team that carried out the 2017–18, 2018–19 and 2024–25 campaigns. During on-effort operations, a two-person team—comprising a primary observer and a data recorder—searched continuously between 270° and 90° relative to the vessel's bow (0°). The primary observer scanned for marine mammals, chiefly CWD but also Indo-Pacific finless porpoises, using  $7 \times 50$  marine binoculars, while the data recorder searched with the unaided eye and completed the datasheets. Two to three additional observers were available on board to work in rotation; observers switched roles approximately every 30 minutes and were given a break after each hour of effort to minimise 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 were also added to the photo-identification catalogue curated by SCSFRI for the PRE CWD population.

Location data of each individual dolphin identified in the Lingding Bay 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 those identified in past surveys, in a desktop GIS to determine whether individuals were recorded across different survey areas and to examine movements within the study area.

### **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 under Beaufort 0–3 conditions (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.

To quantify interannual changes in spatial heterogeneity at the survey-stratum level, the proportion of the annual abundance estimate occurring in each of the four common strata was calculated as  $p_i = N_i / \sum_{j=1}^4 N_j$ , where ( $N_i$ ) is the estimated abundance in stratum  $i$ . Spatial concentration was then summarised using the Herfindahl–Hirschman concentration index,  $HHI = \sum_{i=1}^4 p_i^2$ , and the coefficient of variation among the four stratum-level abundance estimates. With four strata, HHI ranges from 0.25, indicating an even distribution among strata, to 1.0, indicating complete concentration in one stratum.

Uncertainty in HHI was evaluated using 1,000,000 log-normal parametric bootstrap simulations based on the reported stratum-level abundance estimates and their coefficients of variation. Because covariance estimates among strata were unavailable, strata were treated as independent and the resulting comparisons should be regarded as approximate. Density-based HHI values were also calculated as a sensitivity analysis to account for differences in stratum area.

### **3.8 Habitat use 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<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 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<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

For the interpretation of habitat-use patterns, a 1 km × 1 km grid cell was operationally classified as a high-use grid when SPSE was greater than 20 sightings per 100 survey-effort units or DPSE was greater than 100 dolphins per 100 survey-effort units. Grid cells with DPSE values of 60.1–100 were described as moderately high-use grids. A spatially contiguous cluster of two or more high-use grids was defined as a core-use area. These thresholds correspond to the highest categories used in the SPSE and DPSE map legends and are intended to describe relative habitat-use intensity rather than independently validated ecological thresholds.

SPSE/DPSE values were first derived for grids with recorded survey effort. For grids not directly covered by transect effort, density values were estimated from surrounding grids with known SPSE/DPSE values. For example, if only three surrounding grids had

known values, the average of those three grids was used; if seven surrounding grids had known values, the average of those seven grids was used. The resulting density pattern provides a continuous gradient based on empirical data, improves the spatial resolution of habitat-use patterns, and allows comparison with adjacent monitoring areas. In contrast, adopting a  $3 \times 3$  km grid would be too coarse to examine fine-scale changes in habitat use in areas of conservation interest.

## **4 Results and discussions**

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

#### **4.1.1 Survey effort and Beaufort sea conditions**

From July 2025 to April 2026, ten line-transect vessel survey datasets were available for Lingding Bay (Tables 1-2). Across all sea states, the cumulative transect length was 3,762.3 km. Of this, 3,494.0 km was conducted under Beaufort 0-3 conditions and was therefore suitable for the main encounter-rate and line-transect analyses.

#### **4.1.2 Sightings of CWD**

Across all sea states, 138 CWD group encounters comprising 683 individuals were recorded in the monthly summary table (Table 1). Under Beaufort 0-3 conditions, the area-by-month table recorded 136 group encounters and 675 individuals, with sightings distributed unevenly among the four survey strata (Figure 2). It should be noted that different analytical components were based on different sighting datasets. Encounter-rate and line-transect abundance analyses used formal on-effort sightings under Beaufort 0–3 conditions, whereas biological analyses, including group-size composition, calf occurrence and behavioural-state assessments, included both formal on-effort sightings and supplementary off-effort or opportunistic sightings. The latter dataset comprised 143 dolphin groups.

#### **4.1.3 Inter-annual comparison with previous survey cycles**

Survey effort in 2025–26 remained broadly comparable with recent monitoring cycles, but the number of group encounters was lower than in 2024–25. The all-state monthly

table recorded 138 groups in 2025–26, compared with 197 groups reported for 2024–25.

SLDB and MA remained important survey strata in terms of group encounter rates, while CLDB contributed a substantial number of sightings and individuals during several months. SWMA recorded few group encounters, but the individual encounter rate was high because several sightings involved larger groups.

These results indicate continued spatial heterogeneity in dolphin occurrence across Lingding Bay and underline the need to interpret encounter rates together with density, abundance and habitat-use outputs.

#### **4.1.4 Incidental records of Indo-Pacific finless porpoises (*Neophocaena phocaenoides*)**

No Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) was recorded during the 2025–26 reporting period.

### **4.2 Dolphin distribution**

#### **4.2.1 Spatial distribution of sightings**

During the 2025–26 monitoring period, Chinese White Dolphins were recorded across much of the surveyed area in Lingding Bay, but their distribution was clearly uneven. Sightings were mainly concentrated along the western coastal waters of Lingding Bay, particularly in the area between Qi’ao Island and Neilingding Island. Additional clusters were observed along and around the Hong Kong–Zhuhai–Macau Bridge (HZMB), in the southwest waters of Lantau Island, and around the Qingzhou–Sanjiao Island waters. These island and infrastructure-associated waters appeared to support relatively frequent dolphin occurrence during the reporting period. In contrast, sightings were comparatively sparse in the outer peripheral waters and in parts of the Southwest Macau sector (Figure 4).

#### **4.2.2 Inter-annual shifts in core areas**

When compared with previous monitoring periods, the 2025–26 sighting pattern

indicates a continued spatial reorganisation of Chinese White Dolphin use within Lingding Bay. In 2005–06 and 2017–18, dolphin sightings were more broadly distributed across the central and eastern parts of Lingding Bay, including waters adjacent to western Lantau and the CLDB–SLDB boundary. In contrast, the 2025–26 records were less evenly distributed and appeared more concentrated along the western and southern sectors of the LDB (Figure 5).

During 2025–26, dolphin sightings were mainly recorded along the western coastal waters of Lingding Bay, particularly between Qi’ao Island and Neilingding Island, around the HZMB, in the southwest waters of Lantau Island, and around the Qingzhou–Sanjiao Island waters. Compared with 2024–25, the general western and southern concentration remained evident, but the 2025–26 distribution appeared more scattered and with fewer records in parts of the central and eastern Bay, suggesting a reduced use of some historically important central habitats.

Overall, the inter-annual comparison suggests that dolphin habitat use in Lingding Bay has shifted from a broader central–eastern distribution in earlier years towards a more localised pattern centred on the western nearshore waters, bridge-associated waters, southwest Lantau waters, and the Qingzhou–Sanjiao Island waters. These spatial changes indicate that habitat importance within Lingding Bay remains dynamic and may be influenced by changing prey availability, vessel traffic, coastal infrastructure, and other anthropogenic or environmental pressures. A quantitative grid-based habitat-use analysis, presented in Section 4.8, further evaluates the relative importance of these sub-regions using effort-corrected SPSE and DPSE metrics.

### **4.3 Encounter rates**

Monthly encounter rates during the 2025–26 monitoring period showed clear temporal and spatial variation among the four survey strata. Based on on-effort data collected under Beaufort 0–3 conditions, group encounter rates varied substantially by month and area (Figure 6A). MA recorded relatively high group encounter rates in July–September

and again in March–April, while SLDB showed a marked peak in October and moderate values in several other months. CLDB had generally lower group encounter rates during the first half of the monitoring period, but higher values were recorded in December, January and especially March. In contrast, SWMA showed intermittent detections, with group encounter rates recorded only in several months.

Individual encounter rates exhibited stronger monthly fluctuations than group encounter rates, indicating that variation in group size contributed substantially to the observed temporal pattern (Figure 6B). Notably, SWMA showed very high individual encounter rates in July and November despite relatively limited monthly occurrence, suggesting that some sightings in this stratum involved large dolphin groups. MA also recorded high individual encounter rates in September, March and April, reflecting relatively intensive dolphin use of this area during these months. CLDB showed elevated individual encounter rates in December, January and March, whereas SLDB reached its highest individual encounter rate in October. Overall, the monthly encounter-rate pattern indicates that dolphin use of Lingding Bay during 2025–26 was temporally dynamic, with the relative importance of different survey strata shifting among months. MA and SLDB supported frequent group encounters in several months, while SWMA occasionally supported large aggregations, and CLDB became more important during winter to early spring.

The spatial comparison of encounter rates across the four monitoring cycles shows clear inter-annual and regional variation in dolphin occurrence within Lingding Bay. In 2025–26, group encounter rates declined in CLDB, SLDB and MA compared with the 2024–25 cycle, with MA and SLDB still showing relatively higher group-based occurrence than CLDB and SWMA (Figure 7). CLDB exhibited a continued decreasing trend in group encounter rate from 2017–18 to 2025–26, suggesting reduced use of the central Bay area over time. In SLDB and MA, both group and individual encounter rates peaked in 2024–25 but decreased markedly in 2025–26, indicating a weakening of the high-use pattern observed in the previous cycle. In contrast, SWMA remained

low in group encounter rate but showed a pronounced increase in individual encounter rate in 2025–26, implying that fewer but larger dolphin groups were recorded in this area. Overall, encounter rates varied among survey strata and monitoring periods, with lower rates in several historically important areas and a notable increase in individual encounter rate in SWMA during 2025–26. The separate stratum-level abundance-concentration analysis presented in Section 4.4.1 did not detect a statistically significant change in inter-stratum spatial heterogeneity after uncertainty in the abundance estimates was taken into account.

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

Using the line-transect analysis method, and following the protocols applied during previous monitoring periods in Lingding Bay, we estimated the density and abundance of Chinese White Dolphins across the four common survey strata: CLDB, SLDB, MA, and SWMA. To ensure comparability with previous monitoring cycles and to minimise the influence of sea-state conditions on detection probability, only data collected under Beaufort sea states 0–3 were used for the analysis. Based on 3,494.0 km of on-effort survey effort under Beaufort 0–3 conditions, 136 dolphin group sightings were available for encounter-rate analyses. After applying the distance truncation and valid-distance criteria, 129 sightings were used for Distance-based density and abundance estimation (Table 3).

A hazard-rate detection function was selected based on minimum AIC. The total abundance of Chinese White Dolphins across the four survey strata during the 2025–26 monitoring period was estimated at 536 individuals. Among the strata, CLDB supported the highest estimated abundance, with 168 dolphins, followed by MA with 151 individuals, SLDB with 142 individuals, and SWMA with 75 individuals. Estimated individual density varied considerably among survey areas, ranging from 27.47 to 58.28 dolphins per 100 km<sup>2</sup>. The highest density estimates were recorded in SWMA and MA, while relatively lower densities were estimated in SLDB and CLDB.

The precision of the estimates differed among strata. Estimates for CLDB, SLDB and MA showed moderate precision, with coefficients of variation ranging from 31.04% to 33.99%. In contrast, the estimate for SWMA was associated with greater uncertainty, with a coefficient of variation of 65.26%, reflecting the smaller number of sightings recorded in this stratum. Therefore, although SWMA showed a relatively high density estimate, this result should be interpreted cautiously. Overall, the 2025–26 abundance and density estimates indicate that dolphin use of Lingding Bay remained spatially heterogeneous, with MA and SWMA showing relatively high individual densities, while CLDB and SLDB continued to contribute substantially to total abundance because of their larger survey areas and more consistent sighting records.

#### **4.4.1 Interannual Comparison of Abundance**

The estimated abundance of Chinese White Dolphins across the four common survey strata of Lingding Bay showed substantial inter-annual variation among the five monitoring periods (Figure 8). Total abundance was estimated at 862 individuals in 2017–18, declined to 611 individuals in 2018–19, increased markedly to approximately 1,160 individuals in 2020–21, and then decreased to approximately 640 individuals in 2024–25 and 536 individuals in 2025–26. The 2025–26 estimate was therefore approximately 16% lower than that in 2024–25 and about 54% lower than the 2020–21 peak.

Because the inter-annual comparisons were based on abundance estimates and their coefficients of variation derived from separate Distance analyses, rather than from a unified multi-year model with shared detection parameters and covariance structure, the statistical tests should be interpreted as approximate pairwise comparisons. These approximate pairwise comparisons indicated that the decrease from 2024–25 to 2025–26 was not statistically significant (log-normal z-test,  $z = -0.81$ ,  $p = 0.417$ ). The 2025–26 estimate was also not significantly different from the 2018–19 estimate ( $z = -0.58$ ,  $p = 0.563$ ). However, abundance in 2025–26 was significantly lower than that in 2017–18 ( $z = -2.08$ ,  $p = 0.037$ ) and markedly lower than the 2020–21 peak ( $z = -3.28$ ,  $p =$

0.001). These results indicate that the 2025–26 abundance estimate remained relatively low compared with earlier high-abundance periods. However, the estimate should be interpreted cautiously because the apparent decrease from 2024–25 was not statistically significant and therefore does not, on its own, provide conclusive evidence of a demographic decline.

The regional pattern also indicates that the overall reduction from 2024–25 to 2025–26 was not uniform across survey strata. Estimated abundance increased in CLDB from 117 to 168 individuals, but this increase was not statistically significant in the approximate log-normal comparison ( $z = 0.87$ ,  $p = 0.382$ ). Estimated abundance also increased in SWMA from 40 to 75 individuals, but this change was associated with high uncertainty and was not statistically significant ( $z = 0.81$ ,  $p = 0.415$ ). By contrast, estimated abundance decreased in SLDB and MA. The most pronounced change occurred in SLDB, where abundance declined from 311 individuals in 2024–25 to 142 individuals in 2025–26, representing a 54.3% reduction; this decrease was nominally significant in the approximate pairwise comparison (log-normal z-test,  $z = -2.18$ ,  $p = 0.030$ ). In MA, abundance decreased from 172 to 151 individuals, but the change was not statistically significant ( $z = -0.34$ ,  $p = 0.736$ ). Therefore, the lower total abundance estimate in 2025–26 was mainly associated with the lower estimate for SLDB, rather than with a consistent decrease across all four survey strata. The proportional distribution of abundance among the four strata also changed between monitoring periods. In 2024–25, SLDB accounted for 48.6% of the total abundance estimate, compared with 18.3% in CLDB, 26.9% in MA and 6.3% in SWMA. In 2025–26, the corresponding proportions were 26.5%, 31.3%, 28.2% and 14.0%, respectively. The distribution of the 2025–26 point estimates was therefore more even among the four strata.

The stratum-level HHI decreased from 0.346 in 2024–25 to 0.267 in 2025–26, while the coefficient of variation among stratum-level abundance estimates decreased from 61.9% to 26.4%. Across the full monitoring series, HHI values were 0.332 in 2017–18,

0.331 in 2018–19, 0.353 in 2020–21, 0.346 in 2024–25 and 0.267 in 2025–26. These point estimates indicate that abundance was less concentrated in a single dominant stratum during 2025–26.

However, after uncertainty in the stratum-level abundance estimates was incorporated using a log-normal parametric bootstrap, the difference in HHI between 2025–26 and 2024–25 was not statistically significant. The median bootstrap difference was  $-0.062$ , with a 95% uncertainty interval of  $-0.154$  to  $0.024$  and an approximate two-sided  $p$ -value of  $0.149$ . A sensitivity analysis using area-standardised density produced HHI values of  $0.286$  for 2024–25 and  $0.272$  for 2025–26 and also found no significant difference ( $p=0.861$ ). Thus, although the point estimates suggest a more even inter-stratum distribution in 2025–26, the available data do not provide sufficient statistical evidence of a significant change in spatial heterogeneity. This spatially uneven pattern is compatible with local redistribution or temporal variation in habitat use, although a local demographic change cannot be excluded.

Overall, the abundance estimates across the four common survey strata showed a dynamic “decline–increase–decline” pattern over the five monitoring periods. The relatively high estimate recorded in 2020–21 was followed by lower estimates in 2024–25 and 2025–26. Nevertheless, the 2025–26 estimate was not significantly different from those of 2018–19 or 2024–25, and should therefore be interpreted as a relatively low estimate within the surveyed strata rather than as definitive evidence of a population-wide decline.

Importantly, these abundance estimates apply only to the four common survey strata—CLDB, SLDB, MA and SWMA—and should not be interpreted as estimates of the total Chinese White Dolphin population throughout the Pearl River Estuary. The northern PRE and other adjacent waters were not systematically surveyed during 2025–26. The available data therefore cannot distinguish conclusively among a real demographic decline, redistribution of dolphins to adjacent unsurveyed waters, temporary variation

in habitat use, sampling and detection variation, or a combination of these processes.

From a local carrying-capacity perspective, prey availability, habitat quality and anthropogenic disturbance may influence the number of dolphins that can be supported within the four surveyed strata. A reduction in prey biomass or prey quality could lower local carrying capacity and result in lower dolphin density, while a spatial shift in prey distribution could cause dolphins to redistribute within or beyond the surveyed area.

Regional studies provide ecological context for this hypothesis. Lin et al. (2021) examined stomach contents from Indo-Pacific humpback dolphins recovered in the Pearl River Delta and reported a recent dietary shift, together with decreases in the size and number of prey items, which the authors interpreted as indicators of declining food resources. Zhou et al. (2019) documented pronounced long-term changes in the Pearl River Estuary fish assemblage, including a reduction of 45 recorded fish species relative to surveys conducted in the 1980s. Ecosystem modelling by Wang et al. (2016) also indicated substantial depletion and restructuring of fishery resources under long-term fishing pressure in the Pearl River Estuary. Nevertheless, these regional findings do not establish that reduced prey availability caused the relatively low 2025–26 dolphin estimate in the present survey area.

Food-resource changes may also involve spatial redistribution rather than a uniform reduction. Pei et al. (2026) found no significant interannual difference in mean catch-resource density in the Jiangmen Chinese White Dolphin habitat, but identified a marked spatial shift in the high-density areas of potential dolphin prey. This finding illustrates how changes in prey distribution could contribute to changes in dolphin habitat use and local abundance without necessarily indicating a decline across the wider population.

No quantitative prey-resource or fisheries-resource data were collected under the present project. Consequently, changes in local carrying capacity remain a plausible hypothesis rather than a demonstrated explanation for the 2025–26 estimate. On the

basis of the available data, the relatively low estimate is most appropriately interpreted as potentially reflecting a combination of demographic change, redistribution to adjacent unsurveyed waters, temporary variation in habitat use, and sampling or detection variation.

Future monitoring should combine synchronised dolphin surveys in the four common strata, North Lingding Bay and other adjacent waters with cross-boundary photo-identification matching and fishery-independent prey-resource surveys. Standardised trawl or hydroacoustic sampling should be used to quantify the biomass, size composition and spatial distribution of principal prey species. Environmental variables, vessel activity and fisheries effort should also be incorporated into an integrated multi-year spatial model. Such an approach would provide a stronger basis for distinguishing population decline from redistribution and for testing whether changes in local dolphin abundance are associated with prey availability or other components of environmental carrying capacity.

#### **4.5 Group size**

Based on all dolphin groups with complete biological records, including both formal on-effort sightings and supplementary off-effort or opportunistic records, group sizes of Chinese White Dolphins in Lingding Bay during the 2025–26 survey period ranged from single individuals to 40 animals, with a mean ( $\pm$  SD) of  $4.94 \pm 5.82$  dolphins per group ( $n = 143$ ). Small groups remained dominant. Groups comprising one or two individuals accounted for 44.06% of all sightings, representing the largest group-size category, while groups of three to four and five to six individuals accounted for 18.18% and 13.99%, respectively (Figure 9). Overall, 76.22% of dolphin groups contained fewer than six individuals, indicating that small aggregations continued to be the prevailing social grouping pattern during the 2025–26 monitoring period. In contrast, large groups of more than ten dolphins accounted for 13.29% of all observed groups ( $n = 19$ ), showing that large aggregations still occurred but were relatively infrequent.

Compared with previous monitoring periods, the 2025–26 group-size composition was broadly consistent with the long-term pattern in Lingding Bay, where small groups have consistently represented the majority of sightings (Figure 10). However, the proportion of one- to two-individual groups in 2025–26 was slightly higher than in the recent survey cycles of 2017–18, 2018–19, 2020–21 and 2024–25, suggesting a modest increase in the dominance of small groups. The proportion of large groups (>10 individuals) was similar to that recorded in 2024–25 and remained within the range observed in earlier years. These results indicate that although the overall group-size structure remained relatively stable, dolphin groups during 2025–26 were more strongly skewed towards small aggregations, while occasional large groups continued to contribute to the social and spatial dynamics of the population.

#### **4.6 Calf occurrence**

During the 2025–26 monitoring period, age-composition analysis was based on 143 Chinese White Dolphin groups with complete biological records, including formal on-effort sightings and supplementary off-effort or opportunistic records. Among these, eight groups contained unspotted calves (UCs), while 30 groups contained either UCs or unspotted juveniles (UJs). In total, 12 UCs and 66 UJs were identified during the surveys, indicating that young calves continued to occur within the study area during this monitoring cycle. At the individual level, among dolphins for which age class could be determined, UCs accounted for 2.11% and UJs accounted for 11.58%; together, young calves represented 13.68% of age-classified individuals (Figure 14).

The spatial distribution of young calves showed that calf occurrence was not restricted to a single area, but was mainly associated with the western and southern parts of Lingding Bay. Young calves were recorded along the western coastal waters of Lingding Bay, around the Qi’ao–Neilingding sector, near the HZMB, in waters adjacent to southwest Lantau, and around the Qingzhou–Sanjiao Island waters (Figure 12). Compared with earlier monitoring periods, the 2025–26 distribution appeared less broadly dispersed across the central and eastern bay than in 2005–06 and 2017–18, but

calf records remained evident in several important dolphin-use areas. This suggests that the western nearshore waters and island-associated waters continued to provide important habitats for young dolphins.

Regional encounter rates of young calves also varied among survey strata. MA recorded the highest young-calf encounter rate, at 1.60 groups per 100 km, followed by SWMA at 0.81 groups per 100 km and CLDB at 0.72 groups per 100 km. SLDB had the lowest young-calf encounter rate, at 0.50 groups per 100 km (Figure 13). These results indicate that MA was the most important area for calf occurrence during the 2025–26 monitoring period, while SWMA and CLDB also supported young dolphins to a lesser extent.

Inter-annual comparisons showed that the combined percentage of young calves (including UCs and UJs) reached 13.68% in 2025–26, exceeding those recorded in 2024–25, 2018–19 and 2017–18, and slightly higher than the level observed in 2005–06 (Figure 14). Similarly, the proportion of sightings involving young calves was also highest in 2025–26 among the compared monitoring periods. However, this pattern should be interpreted with caution. The relatively high value in 2025–26 was mainly driven by UJs, whereas the UC percentage, which more directly reflects recent birth occurrence, was 2.11% and remained lower than that recorded in 2005–06 (2.90%). Therefore, these results do not necessarily indicate improved calf production or reduced population pressure in recent years, but rather suggest that, despite relatively low overall dolphin abundance, the occurrence of young calves remained comparatively prominent in Lingding Bay during the 2025–26 monitoring period. Continued monitoring of calf occurrence, especially in MA and other western/southern high-use waters, is important for assessing recruitment status and identifying potential nursery habitats within Lingding Bay.

#### **4.7 Behavioral states and association with fishing vessels**

Activity states were recorded for all dolphin groups with complete behavioural information, including both formal on-effort sightings and supplementary off-effort or

opportunistic records, to identify areas used by Chinese White Dolphins for feeding, socializing, travelling and resting. During the 2025–26 monitoring period, 35 of the 143 dolphin groups (24.5%) were observed feeding, while 9 groups (6.3%) were engaged in social interactions. An additional three groups were recorded milling or resting. These results indicate that feeding remained the most frequently recorded behavioural activity, although the proportion of feeding groups was lower than that reported in several previous monitoring periods.

Feeding groups were distributed across much of the surveyed area, but their occurrence was not spatially uniform (Figure 16). During 2025–26, feeding activity was mainly recorded in the western and southern parts of Lingding Bay, including waters between Qi’ao Island and Neilingding Island, the HZMB, and the Qingzhou–Sanjiao Island waters. Compared with 2024–25, 2018–19 and 2017–18, the 2025–26 feeding records appeared less numerous and more spatially restricted, suggesting a weaker and more localised feeding pattern during the reporting period.

Socializing groups were recorded less frequently than feeding groups. The nine social groups observed in 2025–26 were scattered across the study area, with records mainly occurring in the Qingzhou-Sanjiao Island waters and adjacent Neilingding Island waters (Figure 17). Compared with earlier monitoring periods, especially 2017–18 and 2018–19, socializing records in 2025–26 were relatively sparse, indicating that social activity was less commonly observed during the present survey cycle. However, because social behaviour is often episodic and may be affected by observation conditions, this result should be interpreted cautiously.

Associations between dolphin groups and operating fishing vessels were also examined. During 2025–26, five of the 143 dolphin groups, representing 3.5% of all groups with behavioural records, were observed in association with operating fishing vessels. These records were mainly located in the Qingzhou–Sanjiao Island waters and in the waters between Qi’ao Island and Neilingding Island (Figure 18).

Compared with some earlier monitoring periods, fishing-vessel-associated dolphin records appeared less frequent and more spatially localised during 2025–26. However, independent quantitative fisheries-activity data, including the number and distribution of operating fishing vessels, fishing days, fishing tracks, gear deployment, catch data and catch per unit effort, were not available for the present study. The observed pattern therefore cannot be attributed to changes in fishing effort, fishing practices or fishery management. It may also have been influenced by prey distribution, dolphin behaviour, survey effort or other environmental factors.

Overall, the behavioural observations suggest that feeding and social activities continued to occur within the study area during 2025–26, but both were relatively limited in frequency compared with earlier monitoring cycles. Feeding activity was the dominant recorded behaviour and was mainly associated with the western nearshore waters and island-related waters. The low proportion of fishing-vessel-associated sightings indicates only that direct associations with operating fishing vessels were infrequently recorded during the present survey cycle. It does not demonstrate a reduction in fishing activity or an effect of changes in fishery management. Continued behavioural monitoring, together with independent fisheries-effort data, catch records and prey-resource surveys, is required to determine whether the observed pattern is related to fishing activity, prey distribution, dolphin behaviour or other environmental conditions in Lingding Bay.

#### **4.8 Habitat use**

Fine-scale habitat use of Chinese White Dolphins during the 2025–26 monitoring period was examined using effort-corrected sighting density (SPSE) and individual density (DPSE) values calculated for 1 km × 1 km grid cells. The SPSE and DPSE maps showed broadly consistent spatial patterns, indicating that areas with frequent sightings generally also supported higher numbers of dolphins (Figure 19). Based on the operational thresholds defined in Section 3.8, high-use grids, with SPSE greater than 20 or DPSE greater than 100, were mainly distributed in the western and central-

southern parts of Lingding Bay. Moderately high-use grids, with DPSE values of 60.1–100, were also recorded in several southern and southwestern waters. Spatially contiguous clusters of high-use grids were described as core-use areas.

The 2025–26 SPSE map indicated that dolphin sightings were not evenly distributed across the survey area. Instead, sighting density was concentrated in several discrete clusters, with relatively high SPSE values occurring in the western nearshore waters and around island-associated waters. The DPSE map further showed that some of these areas supported high individual densities, especially where grid cells reached DPSE values greater than 60 or 100 dolphins per 100 units of survey effort. These high-density cells suggest that the western nearshore waters, the HZMB-associated waters, and the Qingzhou–Sanjiao Island continued to function as important dolphin-use areas during 2025–26.

Inter-annual comparison of DPSE-based habitat use patterns showed clear temporal changes in the spatial organisation of dolphin habitat use within Lingding Bay (Figure 20). In 2017–18, high-density grids were more widely distributed across the central and southern parts of the bay, with extensive use of waters around the HZMB, western Lantau and the southern islands. In 2018–19, dolphin use remained relatively broad, but high-density areas became more fragmented and showed stronger concentrations around the central-southern bay and island-associated habitats. By 2024–25, high-use areas were more concentrated in the western and southwestern sectors, suggesting an apparent westward and southward shift in the distribution of high-use grids.

Compared with these previous periods, the 2025–26 pattern appeared more spatially restricted and patchier. High DPSE grids persisted in the western nearshore waters and in the Qingzhou–Sanjiao Island area, but the overall extent of moderate- to high-density habitat appeared smaller than in 2017–18 and 2018–19. Some central and eastern parts of Lingding Bay that showed higher dolphin densities in earlier monitoring periods were less intensively used during 2025–26. This visual pattern suggests that dolphin

habitat use may have become more localised; however, the apparent change has not been tested using grid-level spatial autocorrelation statistics.

Overall, the habitat-use analysis indicates that Chinese White Dolphins continued to use Lingding Bay during 2025–26, but their core use areas were spatially heterogeneous and more localised than in earlier monitoring cycles. The persistence of high-density grids in the western nearshore waters, bridge-associated waters and Qingzhou–Sanjiao Island complex highlights the continuing ecological importance of these areas. At the same time, the apparent reduction and fragmentation of high-use habitats suggest that dolphin habitat use in Lingding Bay remains dynamic and may be influenced by changes in prey distribution, vessel traffic, coastal infrastructure, underwater noise and other anthropogenic or environmental pressures. Continued grid-based monitoring is therefore necessary to determine whether the observed pattern represents short-term redistribution or a longer-term change in the distribution of core-use areas. These comparisons describe visual differences among the annual DPSE maps and should not be interpreted as evidence of a statistically demonstrated change in fine-scale spatial aggregation. The quantitative analysis in Section 4.4.1 evaluates the distribution of estimated abundance among the four predefined survey strata and does not test spatial autocorrelation among individual  $1\text{ km} \times 1\text{ km}$  grid cells.

#### **4.9 Photo-identification, Ranging Patterns, and Movements**

Between July 2025 and April 2026, the line-transect surveys in Lingding Bay yielded a total of 24,415 photographs for photo-identification analysis. From these images, 305 individually recognisable Chinese White Dolphins were identified. Among them, 23 individuals were newly identified during the 2025–26 monitoring period, while 76 individuals were resighted on more than one occasion, contributing a total of 170 resighting records. These photo-identification results updated the existing Lingding Bay catalogue by adding newly identified individuals and new sighting records of previously known dolphins. The repeated sightings recorded during the present survey period provide baseline individual-level information that can be used in future analyses

of ranging patterns, movements, and site fidelity within the study area.

Photo-identification records revealed clear inter-individual variation in space use within Lingding Bay. Some individuals were mainly resighted in the central part of Lingding Bay, with their records concentrated around the waters between Qi'ao Island, Neilingding Island and adjacent central Bay areas (Figure 21). These individuals appeared to maintain relatively localised ranging patterns within the central sector of the study area during the reporting period.

In contrast, another group of individuals was mainly recorded in the southern part of Lingding Bay, including waters around the Macau sector, the southern islands, and the Qingzhou–Sanjiao Island complex (Figure 22). These records suggest that the southern and southwestern waters continued to support repeated use by some identifiable dolphins, consistent with the high-use areas indicated by the sighting distribution and DPSE-based habitat-use analyses.

A further set of individuals showed broader ranging patterns, with records spanning different parts of Lingding Bay (Figure 23). These individuals moved across multiple areas within the study region, linking the central, southern and island-associated waters. Such broad-ranging individuals highlight the functional connectivity among different dolphin habitats in Lingding Bay and suggest that conservation planning should consider the bay as an interconnected habitat network rather than a set of isolated survey strata.

Overall, the 2025–26 photo-identification results demonstrate that Chinese White Dolphins in Lingding Bay exhibited diverse ranging patterns, including central-bay residents or frequent users, southern-bay frequent users, and individuals moving across multiple sectors. The identification of 305 recognisable individuals, together with 76 resighted individuals and 170 resighting records, provides an important basis for evaluating individual site fidelity, movement patterns and habitat connectivity. Continued photo-identification monitoring, together with regular matching against

historical catalogues, will be essential for assessing long-term changes in individual ranging behaviour and for detecting potential shifts in habitat use within the Pearl River Estuary.

#### 4.10 References

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## 5 Summary and way forward

The 2025–26 survey provides an updated assessment of CWD in Lingding Bay based on ten vessel-based line-transect surveys conducted from July 2025 to April 2026. The surveys accumulated 3,762.3 km of transect effort across all sea states, of which 3,494.0 km under Beaufort 0–3 conditions was used for encounter-rate and line-transect analyses. A total of 138 CWD groups comprising 683 individuals were recorded across all sea states, and the line-transect analysis estimated an abundance of 536 dolphins across the four common survey strata. Although this estimate was lower than the 2024–25 estimate of approximately 640 individuals, the decrease was not statistically significant; however, abundance remained significantly lower than the 2017–18

estimate and the 2020–21 peak.

The 2025–26 results indicate that dolphin occurrence and habitat use remained spatially heterogeneous. Sightings, feeding records, calf records and high SPSE/DPSE grids were mainly associated with the western nearshore waters between Qi’ao Island and Neilingding Island, the HZMB, southwest Lantau waters, and the Qingzhou–Sanjiao Island complex. Compared with earlier monitoring periods, the distribution and habitat-use pattern appeared more localised and patchier, with reduced use of some central and eastern parts of Lingding Bay that were more widely used in previous cycles.

The group-size, calf and behavioural results provide further evidence of a dynamic population-use pattern during the reporting period. Small groups remained dominant, with a mean group size of 4.94 dolphins, while young calves were relatively prominent, accounting for 13.68% of age-classified individuals. Feeding was the most frequently recorded behavioural activity but accounted for only 24.5% of groups, and fishing-vessel-associated sightings were rare, at 3.5% of all sightings. Photo-identification yielded 24,415 photographs, 305 recognisable individuals, 23 newly identified individuals and 76 repeatedly sighted individuals, providing an important basis for evaluating site fidelity and habitat connectivity.

Long-term monitoring is therefore essential to determine whether the current relatively low abundance estimate within the four surveyed strata reflects short-term fluctuation, redistribution among adjacent habitats or a longer-term decline in the use of Lingding Bay. Future monitoring should continue to integrate vessel line-transects, photo-identification, passive acoustics, prey-resource assessment and fisheries-activity records so that changes in abundance, calf occurrence, behaviour and habitat use can be interpreted within a mechanistic ecological framework.

Cross-boundary collaboration should also be strengthened. Although no systematic cross-boundary matching with Hong Kong photo-identification catalogues was conducted during the 2025–26 reporting period, regular matching with historical and

neighbouring catalogues would improve understanding of individual movements across the Pearl River Estuary and support coordinated risk assessment. Priority attention should be given to the western nearshore waters, bridge-associated waters and Qingzhou–Sanjiao Island complex, where repeated use and high-density grids were observed.

By coupling continued data collection with adaptive, evidence-based management, the monitoring programme can provide a stronger scientific basis for conserving the Pearl River Estuary CWD population under continuing coastal development, vessel traffic, fisheries change and environmental variability.

## **6 Evaluation and benefits**

As the fourth stage of the long-term monitoring programme following the 2017–18, 2018–19 and 2024–25 cycles, the 2025–26 project met its stated objectives. The project fulfilled the five stated objectives by completing systematic surveys, updating abundance and density estimates, expanding the photo-identification catalogue, mapping fine-scale habitat use, comparing results with previous monitoring cycles, and providing updated conservation recommendations. On the basis of ten vessel-based line-transect surveys, 3,494.0 km of Beaufort 0–3 on-effort survey coverage and extensive sighting records, the project updated density and abundance estimates for CWD in the four principal survey strata of Lingding Bay, deriving a total abundance estimate of 536 individuals.

The findings provide an important scientific foundation for regional conservation and management. The 2025–26 results show that dolphin use of Lingding Bay remains spatially heterogeneous and increasingly concentrated in selected western, bridge-associated and island-related waters. The relatively high occurrence of young calves in MA and other western/southern waters, together with repeated use by identifiable individuals, highlights the need to maintain focused monitoring of these areas and to evaluate potential impacts from vessel traffic, fisheries, coastal infrastructure and prey-

resource changes.

Looking ahead, the project supports continued application of adaptive management principles. Routine long-term monitoring, periodic cross-boundary photo-identification matching, passive acoustic monitoring and prey-resource surveys would help clarify the mechanisms driving changes in abundance, behaviour and habitat use. Such evidence will be valuable for informing conservation planning, fisheries management, environmental impact assessment and coordinated protection of the Pearl River Estuary CWD population.

## 7 Disclaimer

*Any opinions, findings, conclusions or recommendations expressed in this report do not necessarily reflect the views of the Marine Ecology Enhancement Fund or the Trustee.*

## 8 Declaration

*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, Prof. Chen Tao

Date: 2026.6.30

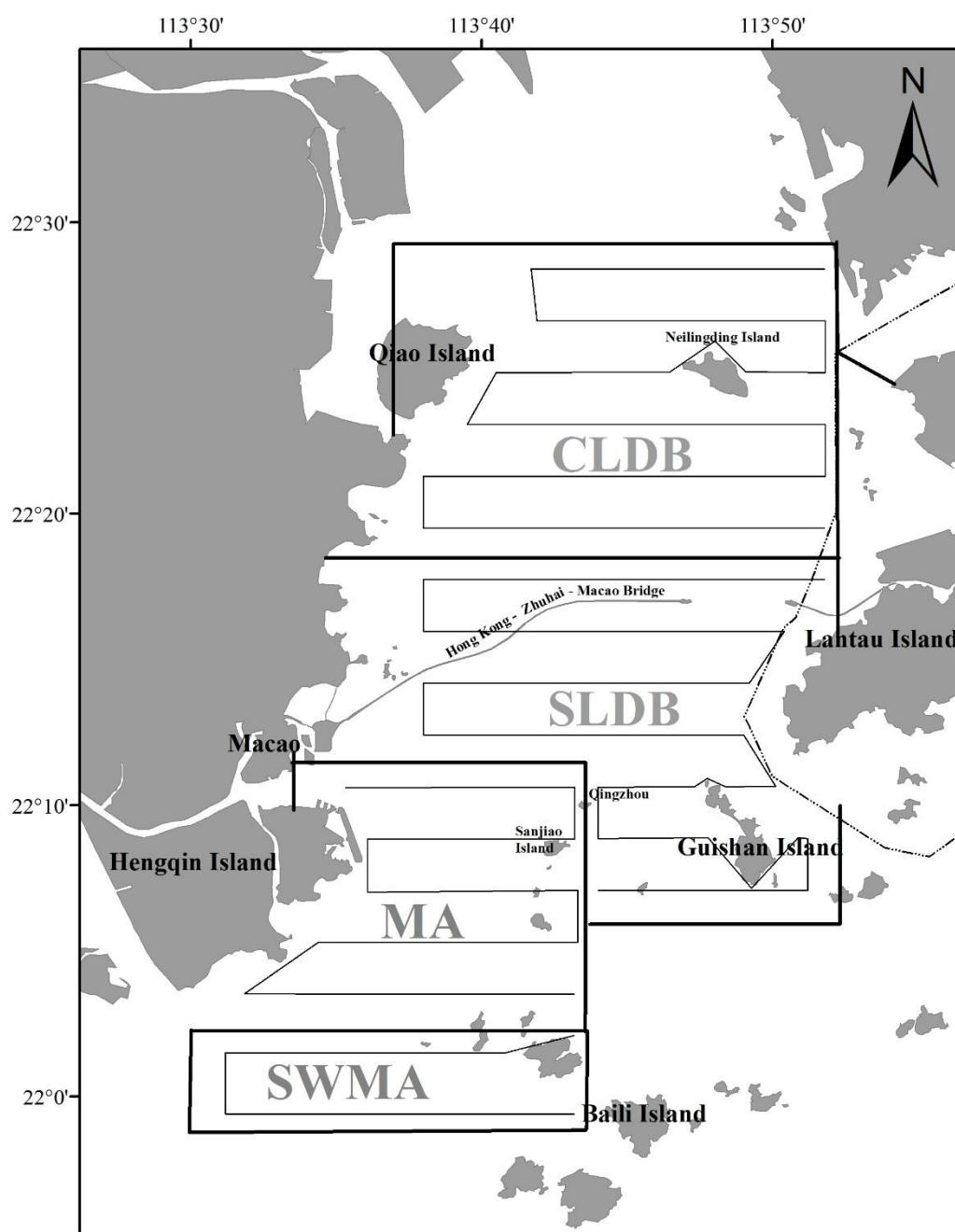


Figure 1. Survey areas and transect lines in Lingding Bay (2025–26)

CLDB, Central Lingding Bay; SLDB, South Lingding Bay; MA, Waters around Macau;  
SWMA, Waters southwest of Macau

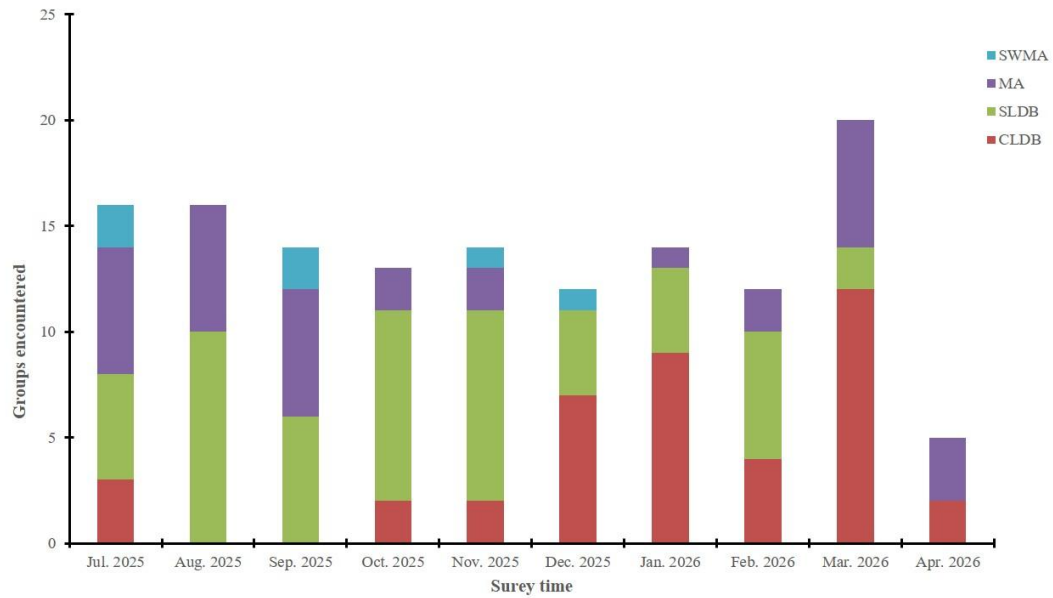


Figure 2. Monthly on-effort sightings of Chinese White Dolphin groups in the four survey areas in Lingding Bay (2025–26)

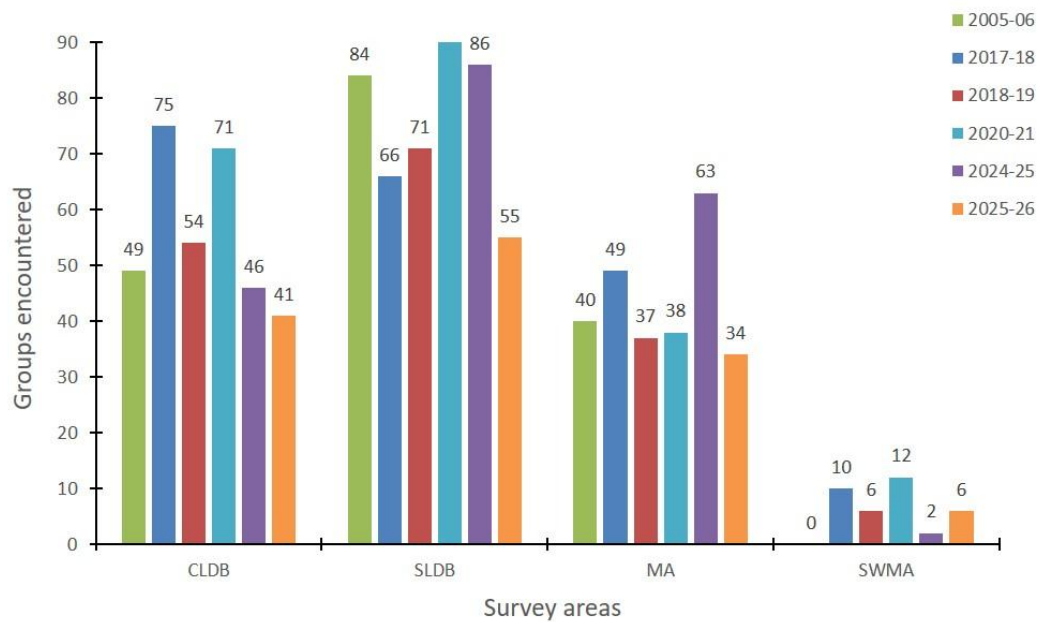


Figure 3. Comparison of the on-effort sightings of Chinese White Dolphin groups in the four survey areas in Lingding Bay between 2025–26, 2024–25, 2018–19, 2017–18 and 2005–06 monitoring periods

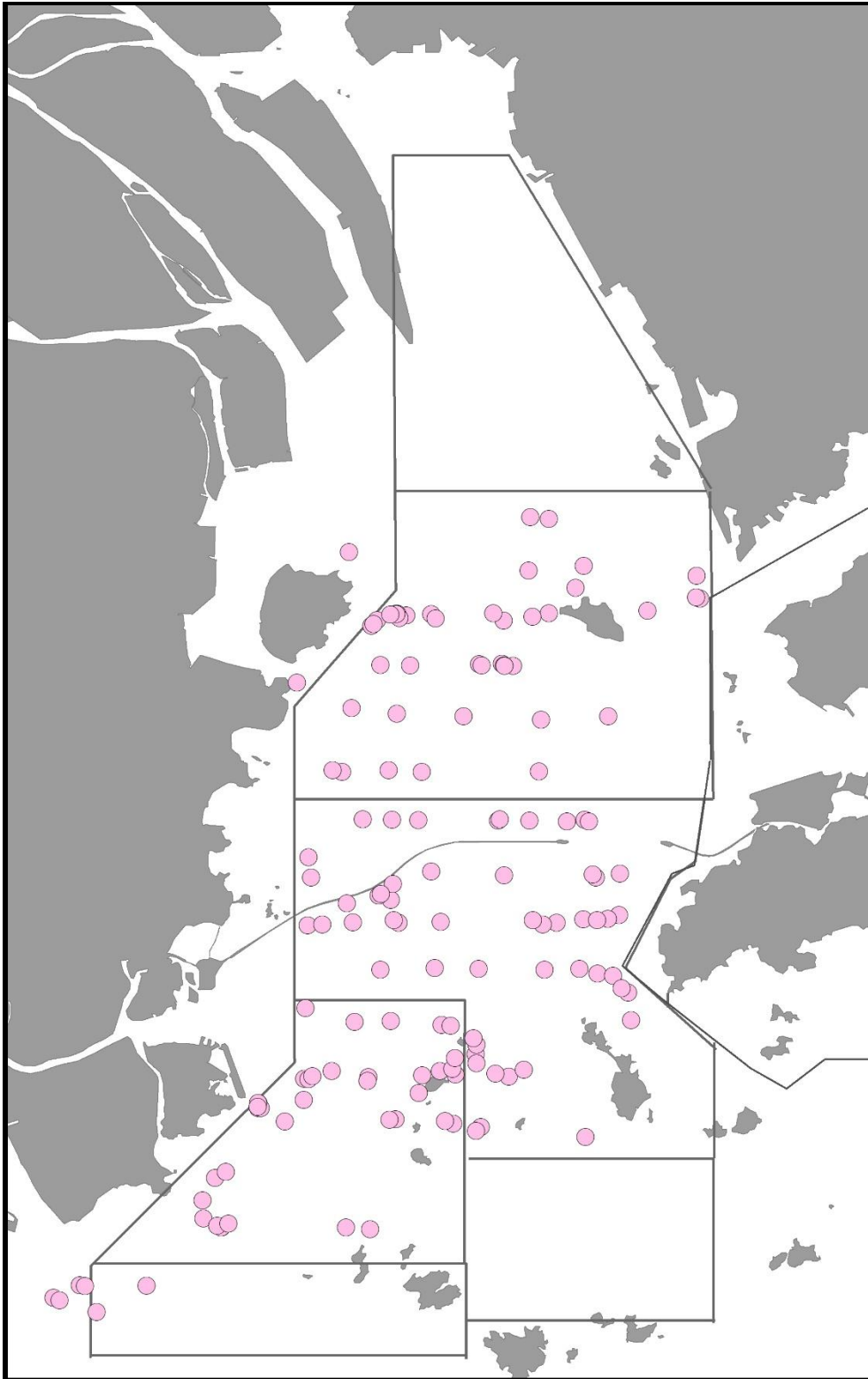


Figure 4. Distribution of Chinese White Dolphin sightings in Lingding Bay (2025–26)

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

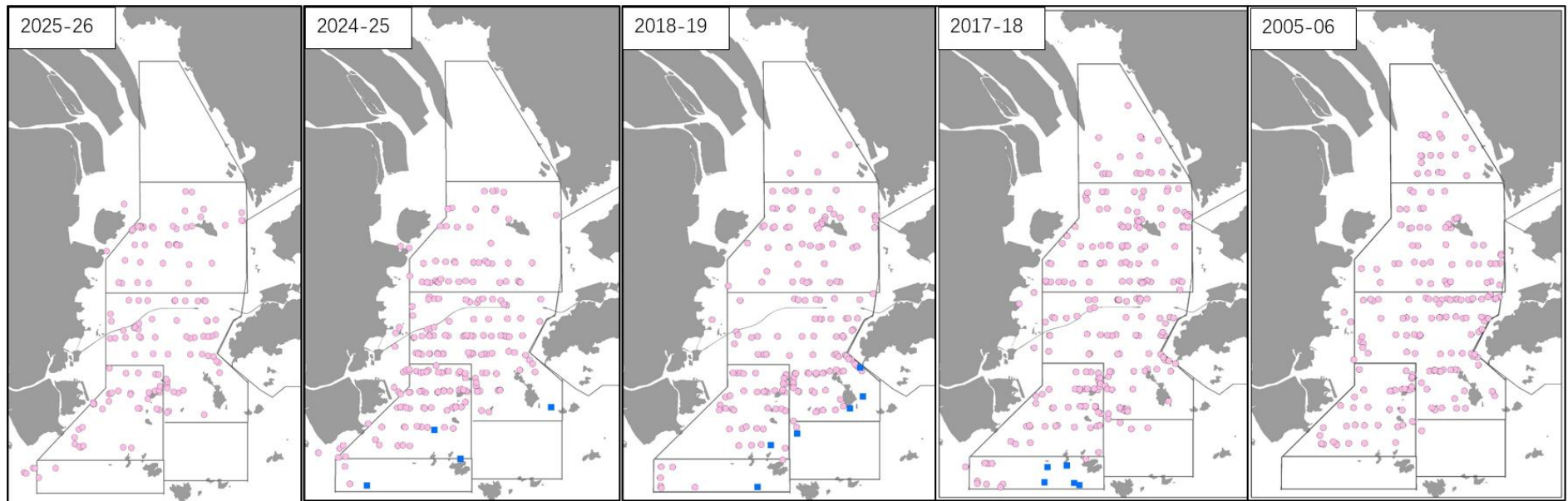


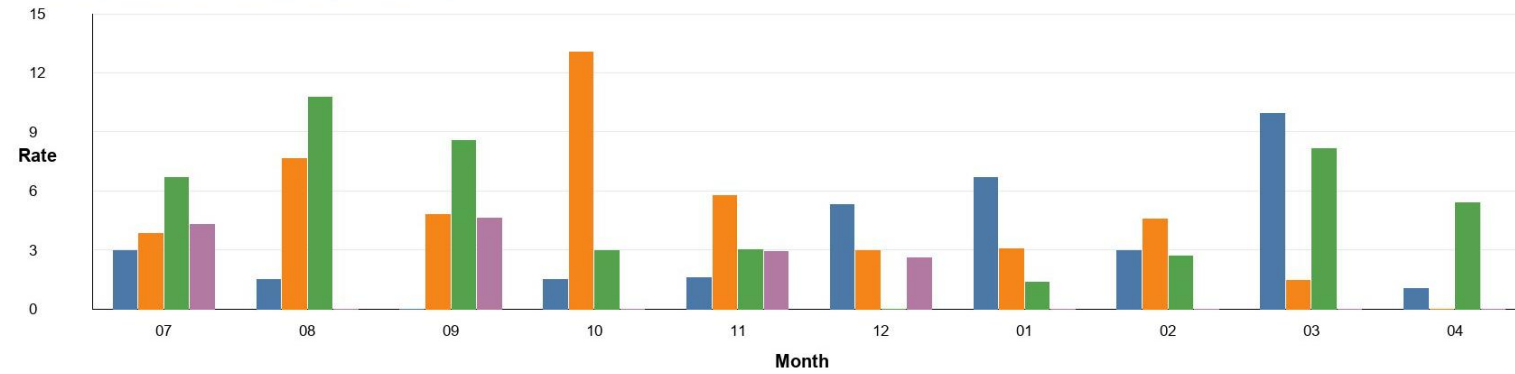
Figure 5. Comparison of the distribution patterns of Chinese White Dolphins in Lingding Bay between 2025–26, 2024–25, 2018–19, 2017–18 and 2005–06 monitoring periods.

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

Rates are calculated from Beaufort 0-3 effective effort: on-effort groups or dolphins per 100 km.

CLDB SLDB MA SWMA

#### A. Group encounter rate (groups / 100 km)



#### B. Individual encounter rate (dolphins / 100 km)

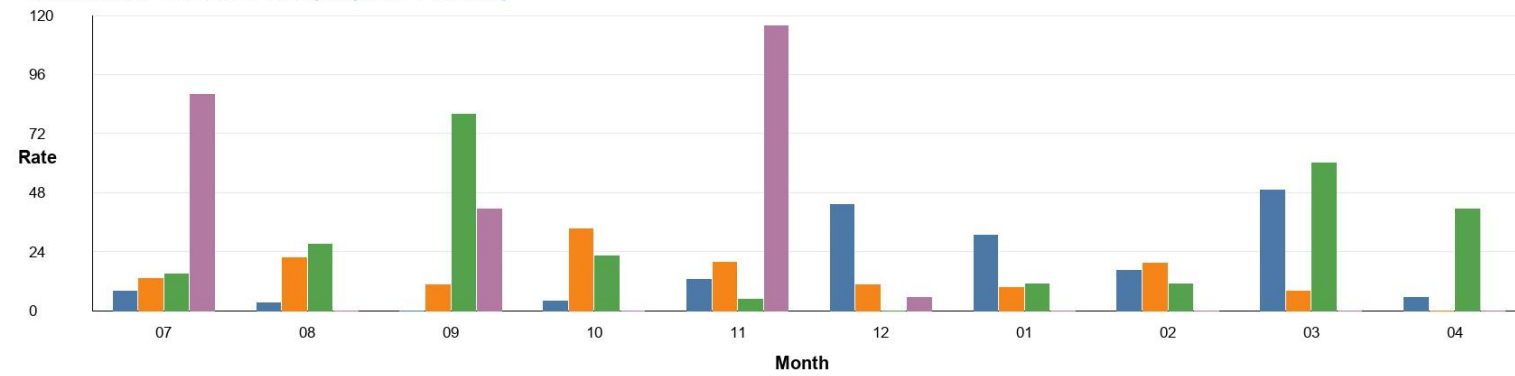


Figure 6. Monthly group and individual encounter rates of Chinese White Dolphins in Lingding Bay during 2025–26.

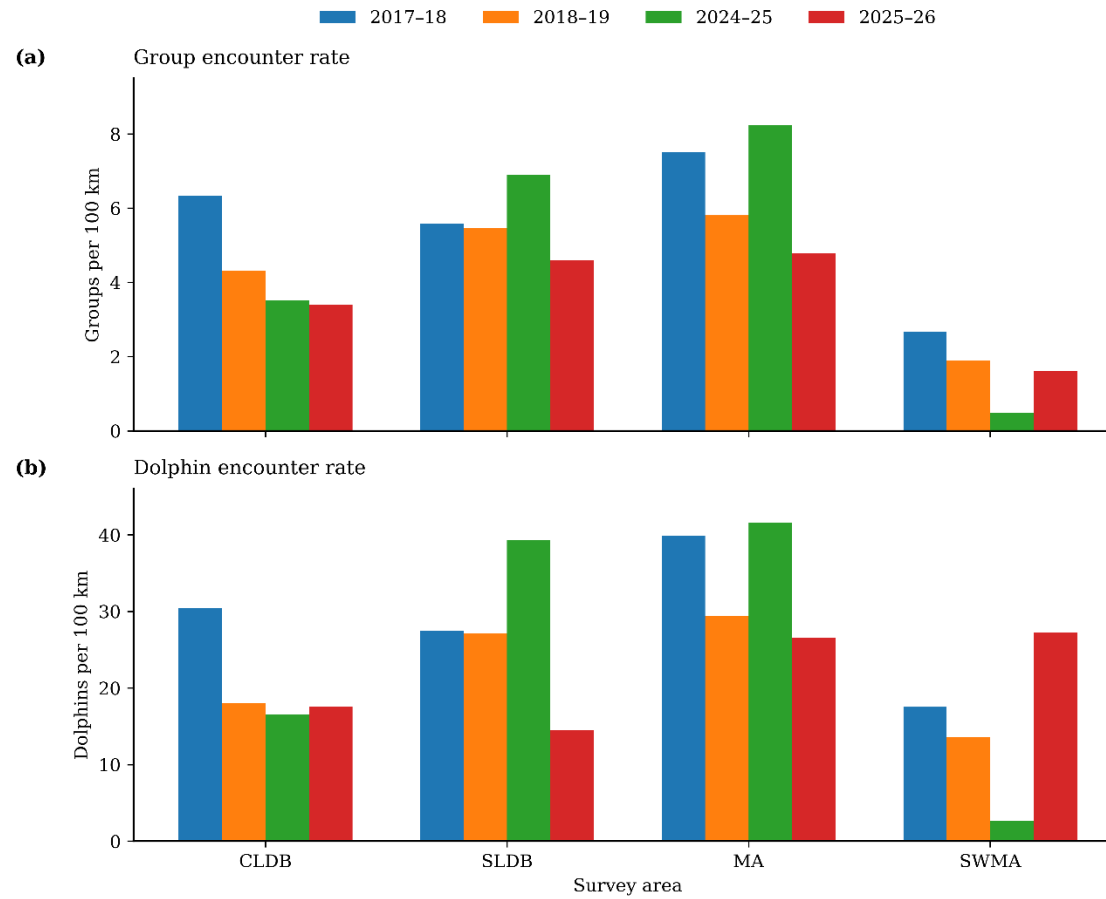


Figure 7. Spatial comparison of group and dolphin encounter rates across the four survey areas in Lingding Bay during four survey cycles (2017–18, 2018–19, 2024–25, and 2025–26). (a) Group encounter rate, expressed as groups per 100 km; (b) dolphin encounter rate, expressed as dolphins per 100 km.

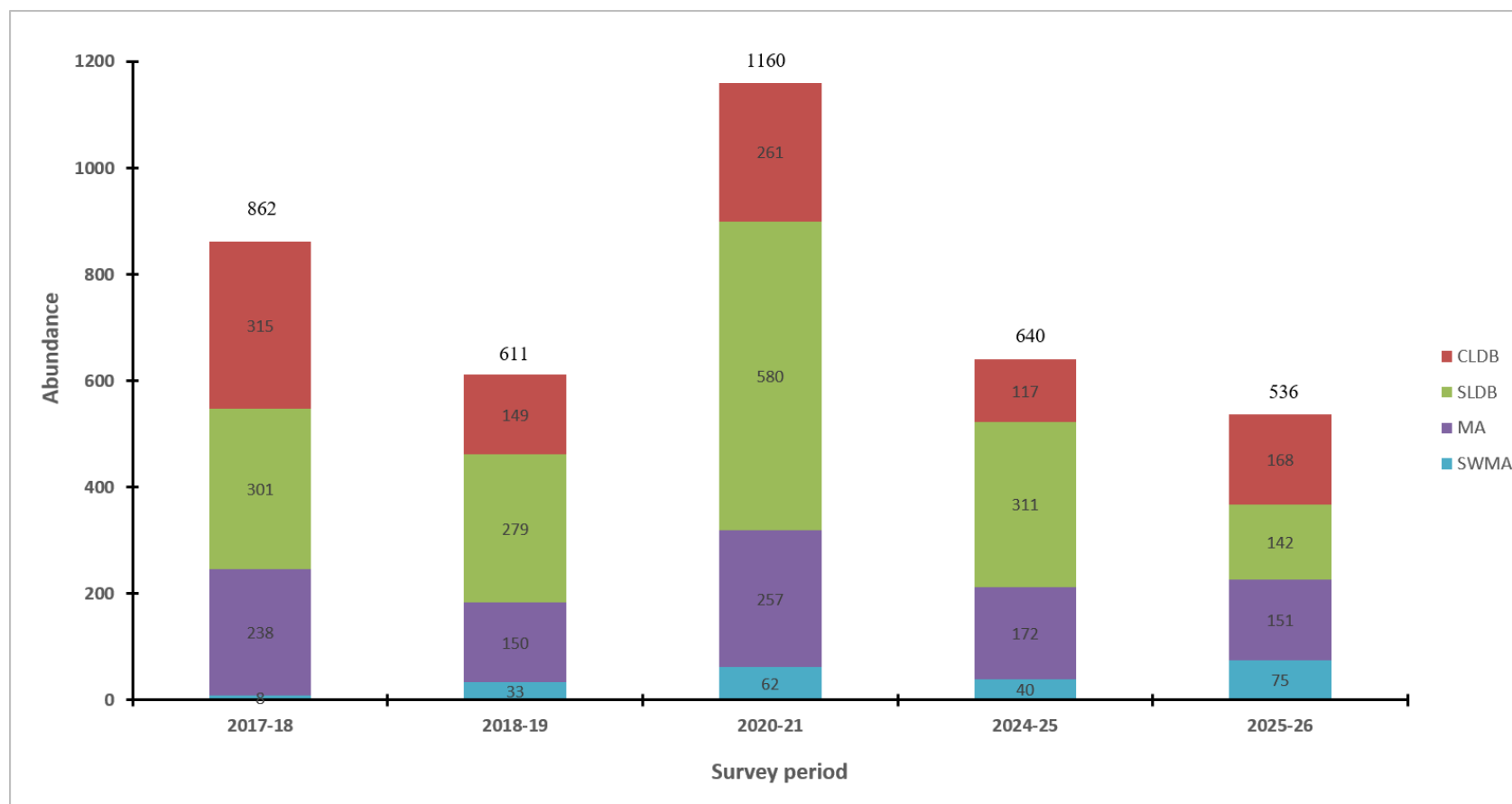


Figure 8. Interannual comparison of Chinese White Dolphin abundance estimates within the four common survey strata of Lingding Bay. The estimates refer to CLDB, SLDB, MA and SWMA; North Lingding Bay and other adjacent waters were not included in the analysis. The estimates should therefore not be interpreted as total population estimates for the entire Pearl River Estuary.

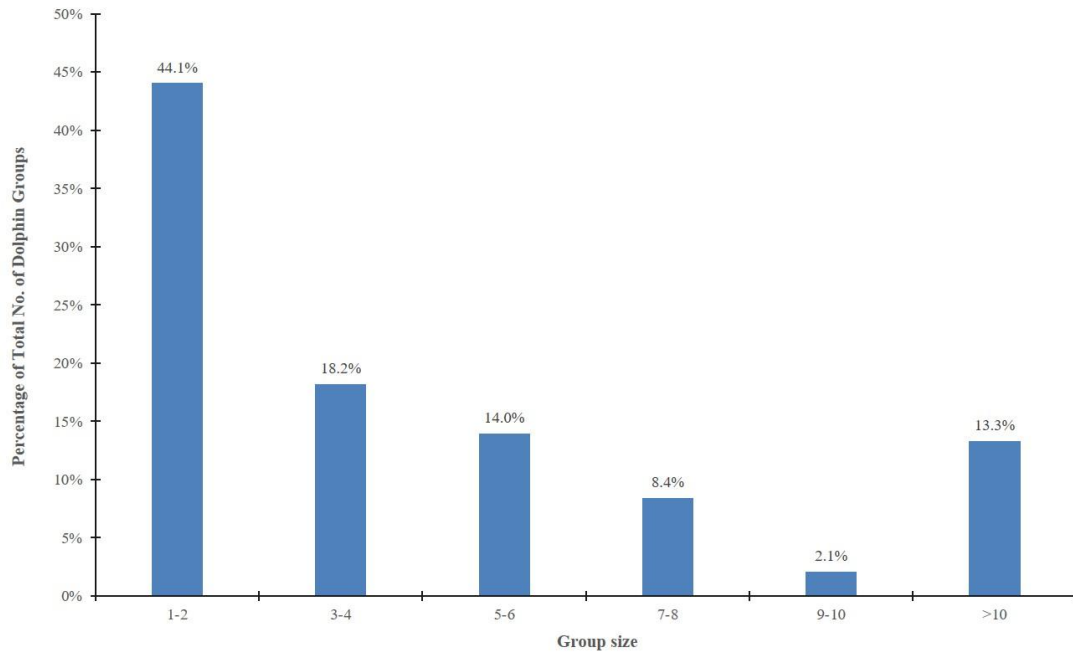


Figure 9. Percentages of different group sizes of Chinese White Dolphins in Lingding Bay (2025–26)

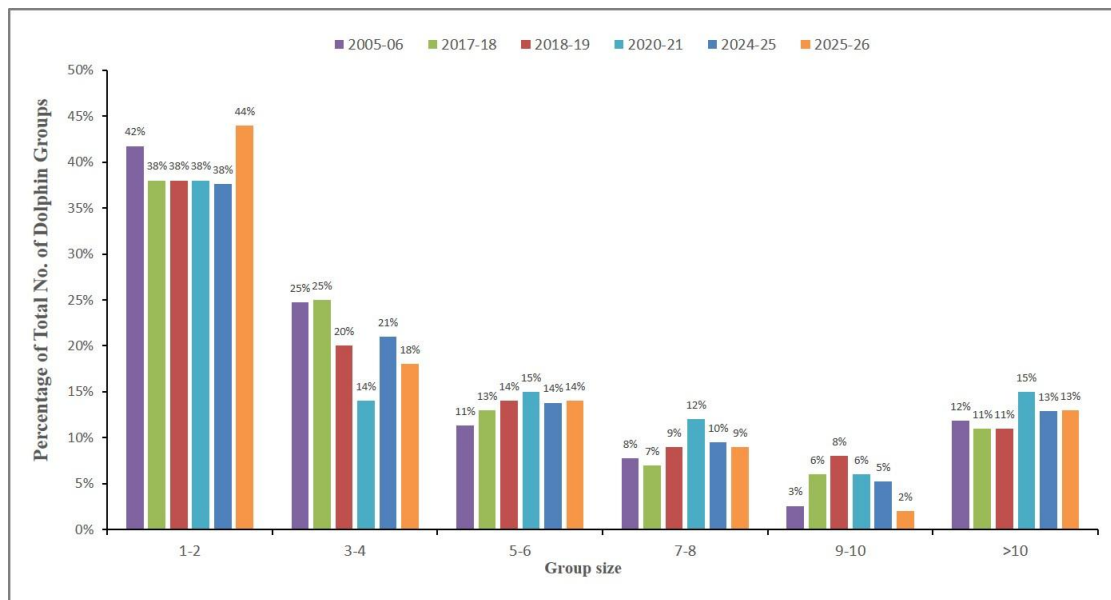


Figure 10. Composition of group size of Chinese White Dolphins in Lingding Bay during 2025–26, 2024–25, 2020–21, 2018–19, 2017–18 and 2005–06 monitoring periods

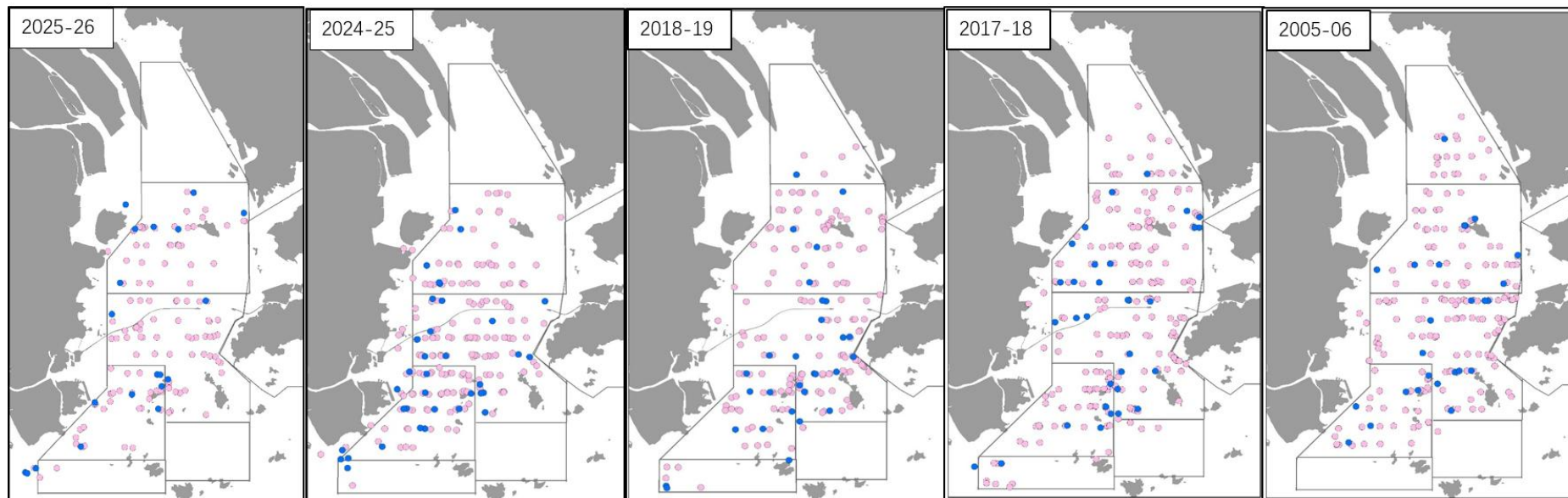


Figure 11. Distribution of dolphin sightings of large groups with more than 10 individuals (blue dots) in Lingding Bay during 2025–26, 2024–25, 2018–19, 2017–18 and 2005–06 monitoring periods

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

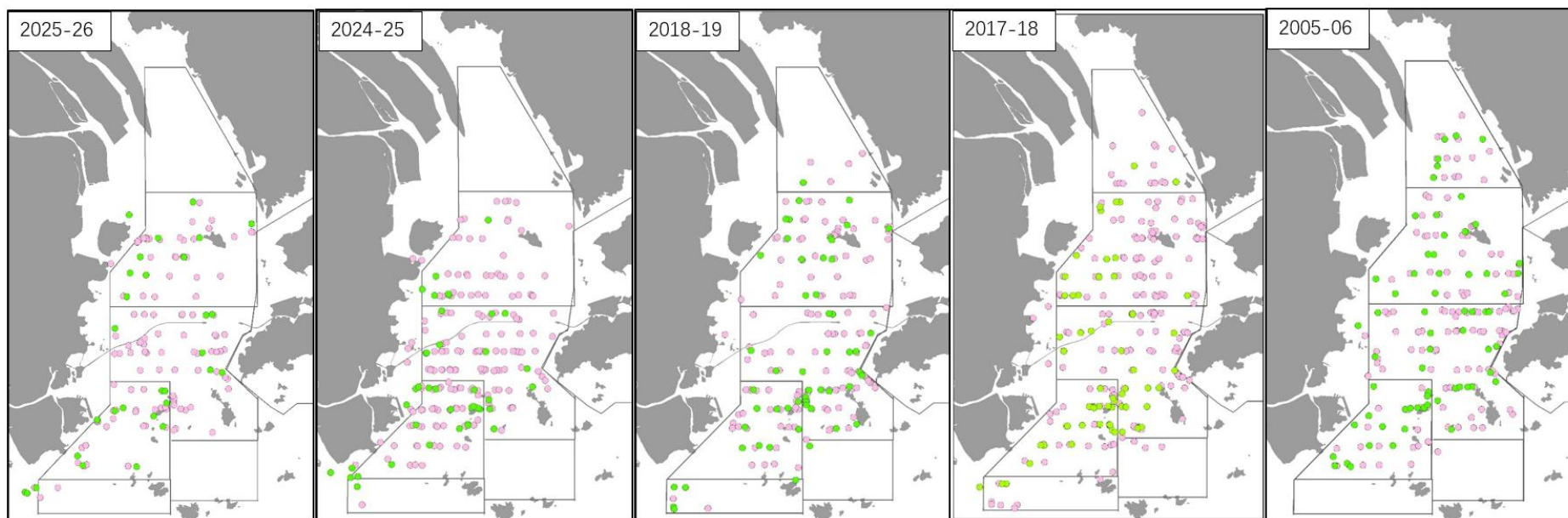


Figure 12. Distribution of young calves, including unspotted calves and unspotted juveniles, in Lingding Bay during 2025–26, 2024–25, 2018–19, 2017–18 and 2005–06 monitoring periods.

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

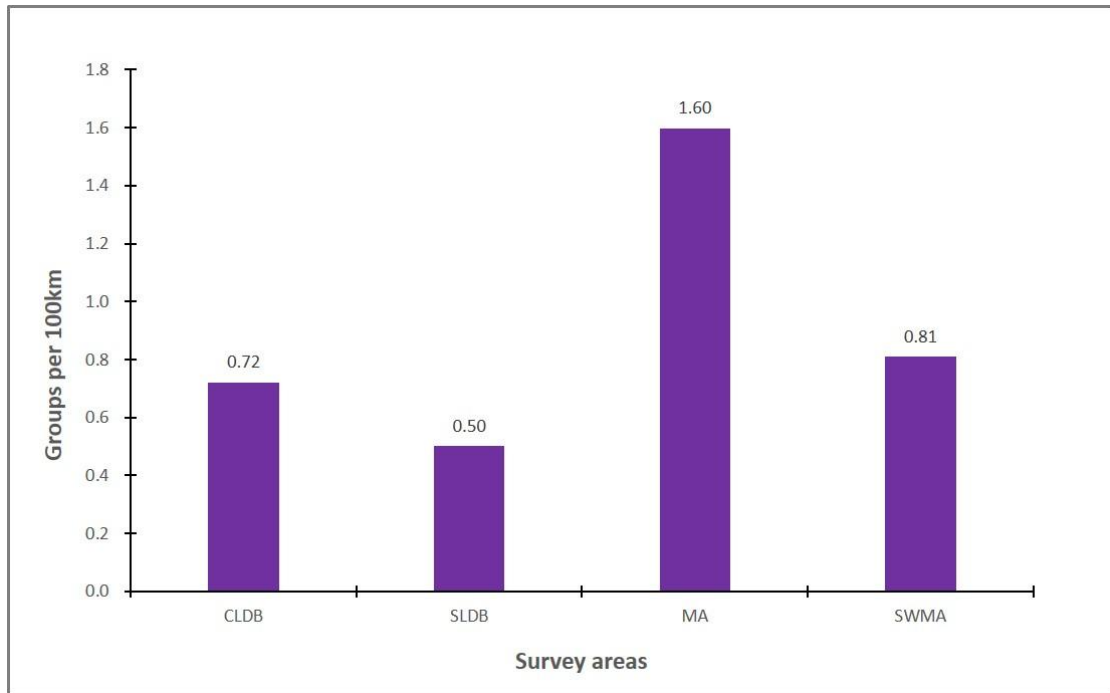


Figure 13. Encounter rates of young calves (Unspotted Calves and Unspotted Juveniles) in the four survey areas in Lingding Bay (2025–26)

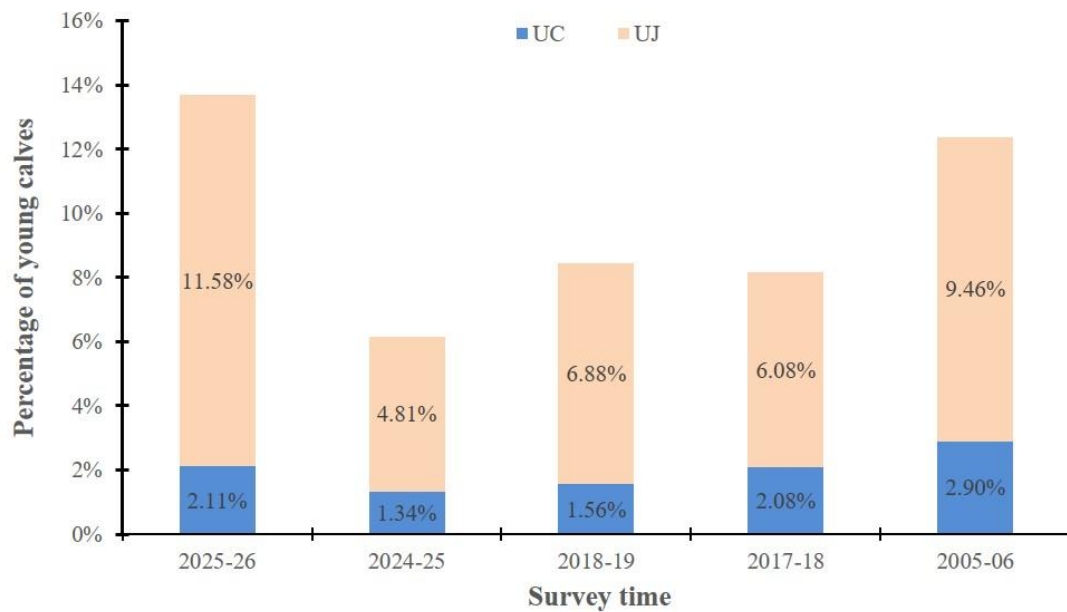


Figure 14. Percentages of unspotted calves (UCs) and unspotted juveniles (UJs) among age-classified Chinese White Dolphin individuals in Lingding Bay during selected monitoring periods.

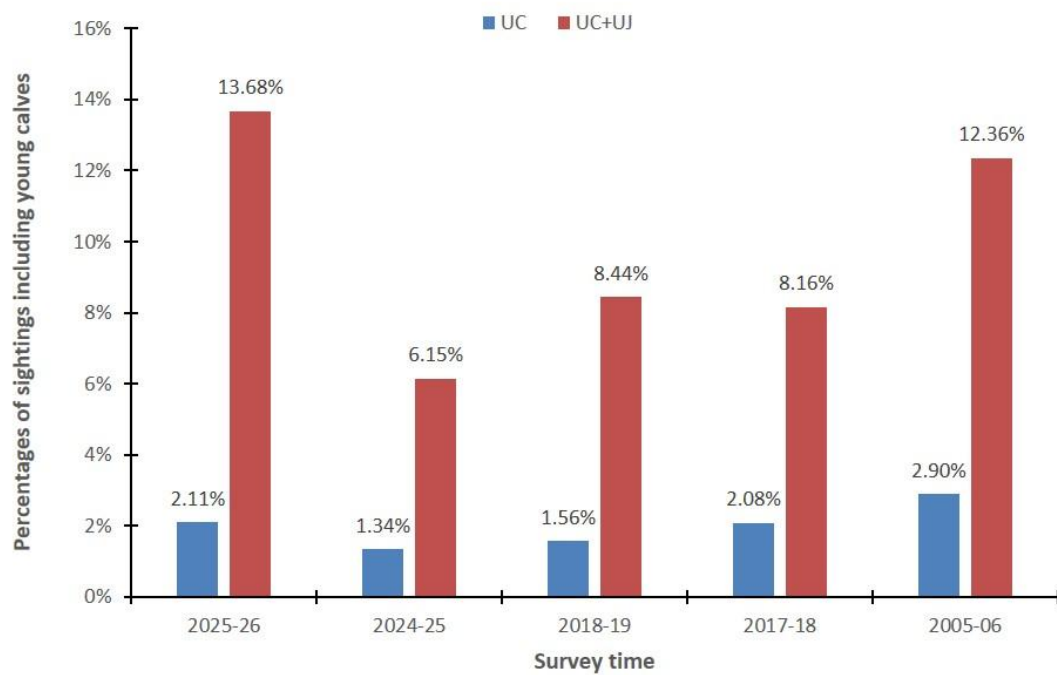


Figure 15. Percentages of sightings including young calves (Unspotted Calves and Unspotted Juveniles) in Lingding Bay during 2025–26, 2024–25, 2018–19, 2017–18 and 2005–06 monitoring periods

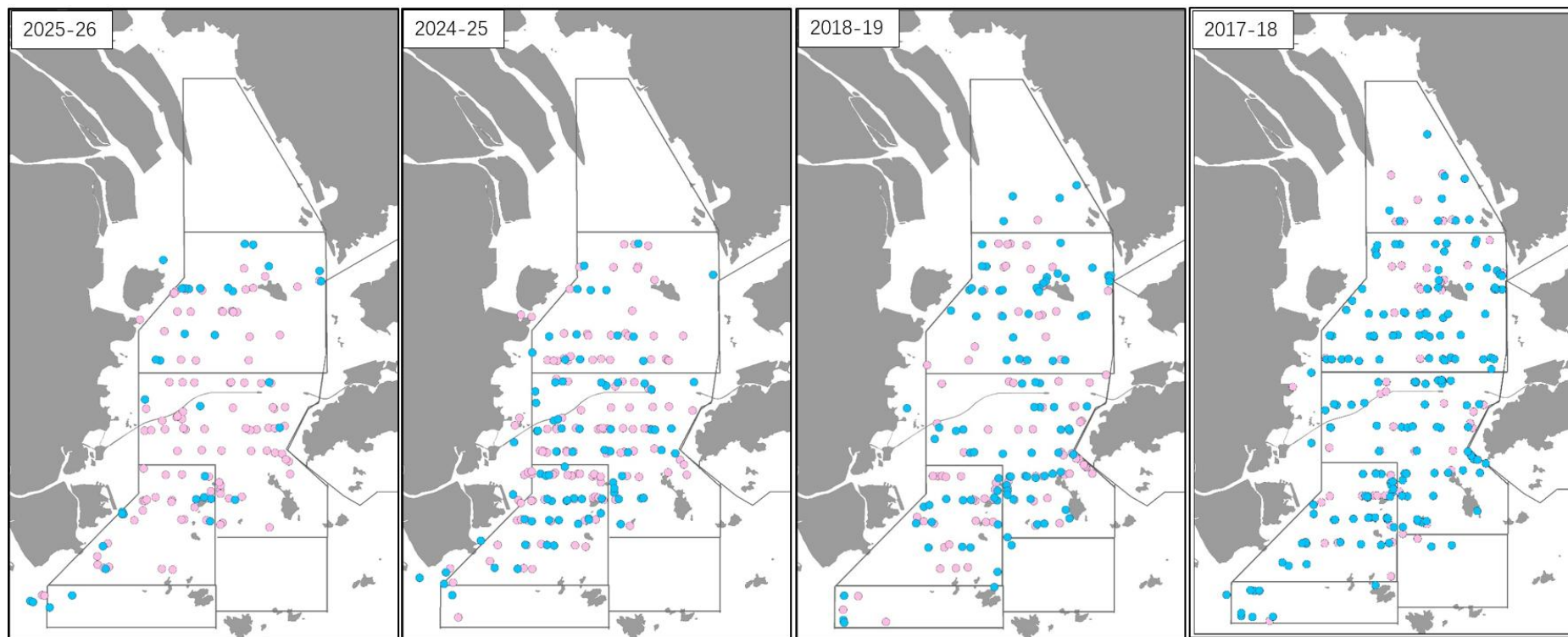


Figure 16. Distribution of Chinese White Dolphins engaged in feeding activities (cyan dots) in Lingding Bay during 2025–26, 2024–25, 2018–19 and 2017–18 monitoring periods

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

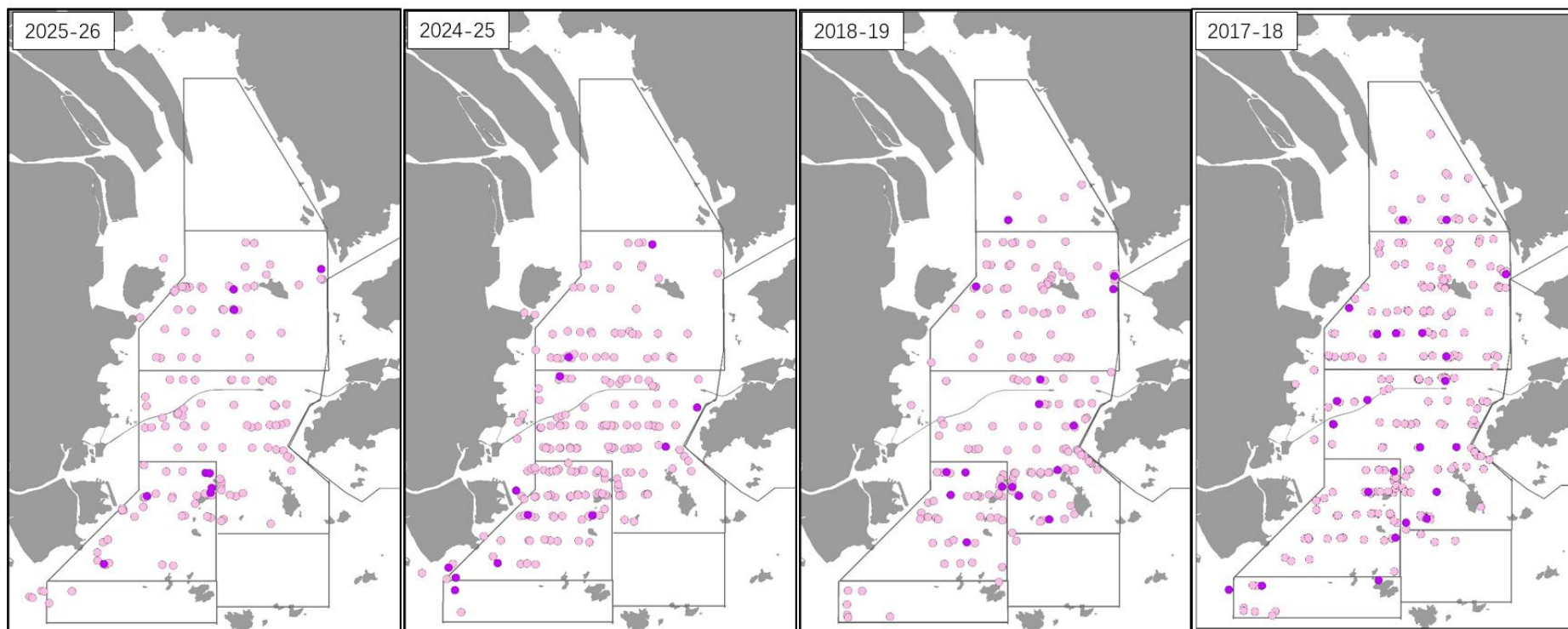


Figure 17. Distribution of Chinese White Dolphins engaged in socializing activities (purple dots) in Lingding Bay during 2025–26, 2024–25, 2018–19 and 2017–18 monitoring periods

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

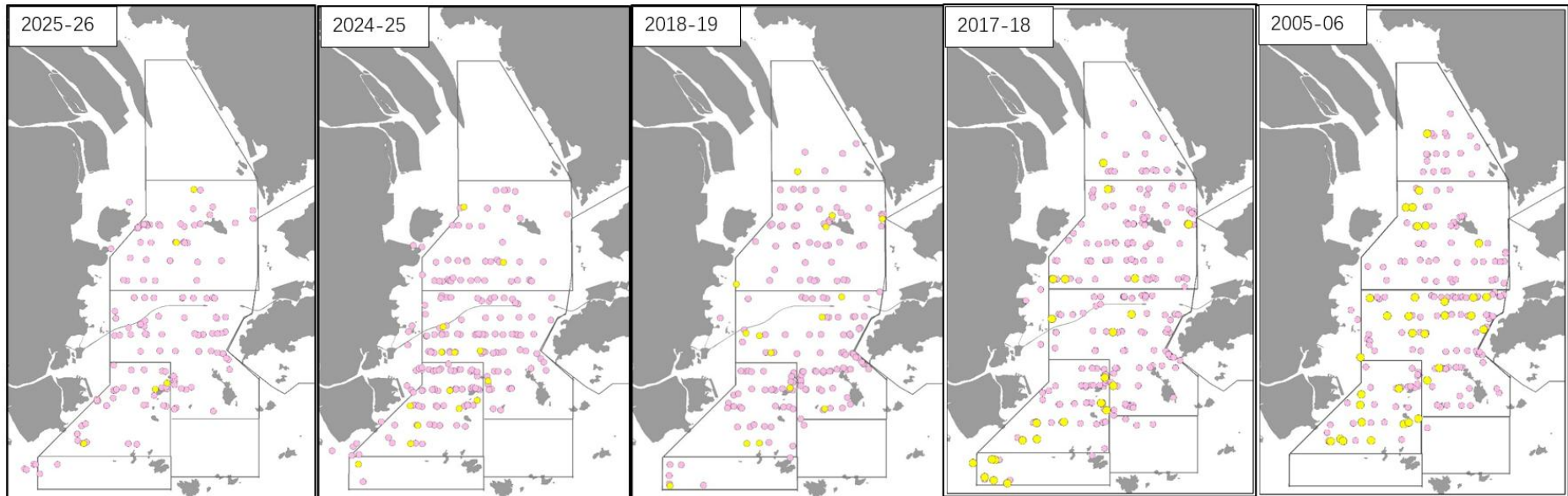


Figure 18. Distribution of observed associations between Chinese White Dolphin groups and operating fishing vessels in Lingding Bay during the 2025–26, 2024–25, 2018–19, 2017–18 and 2005–06 monitoring periods. The mapped records represent observed dolphin–fishing-vessel associations and do not represent the distribution or intensity of fishing effort.

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

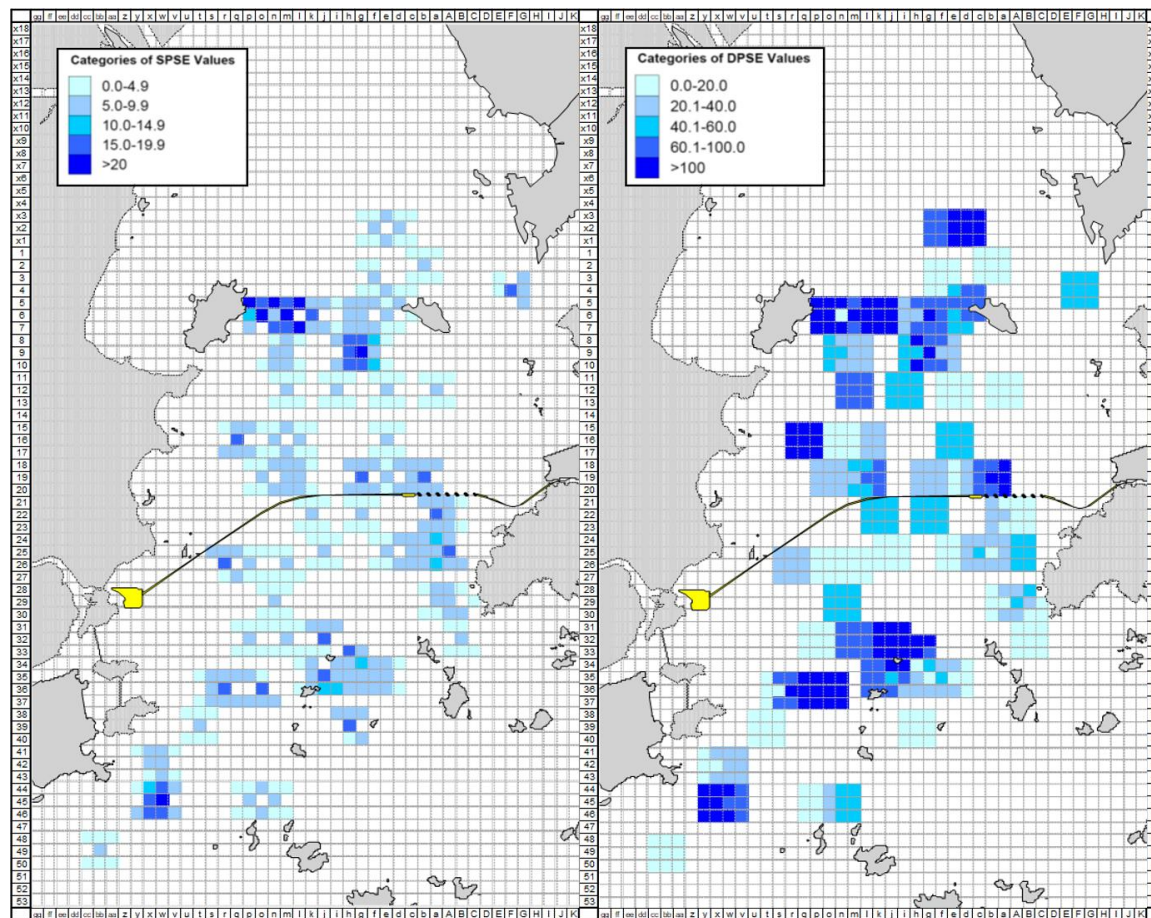


Figure 19. Effort-corrected sighting density (SPSE) and individual density (DPSE) of Chinese white dolphins in the Pearl River Estuary, 2025–26. High-use grids were operationally defined as grid cells with SPSE >20 or DPSE >100 per 100 survey-effort units. Grid cells with DPSE values of 60.1–100 were classified as moderately high-use grids.

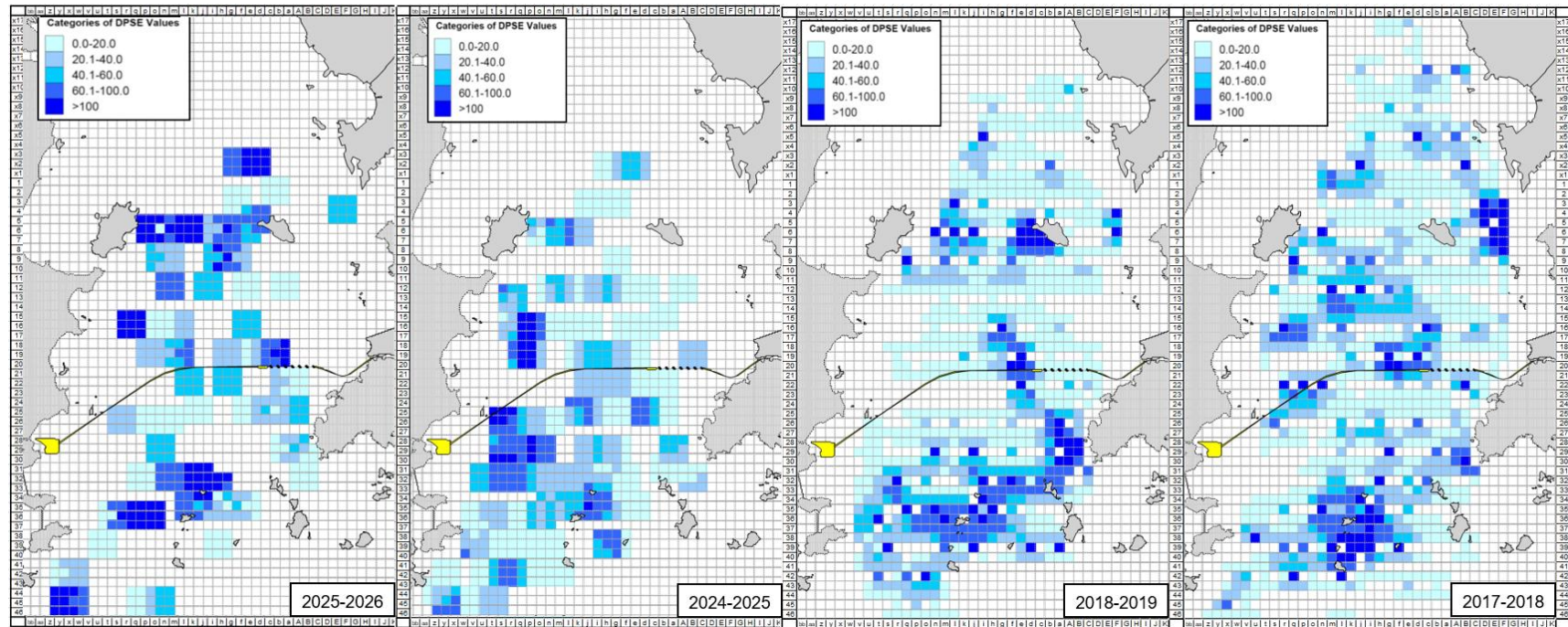


Figure 20. Comparison of effort-corrected Chinese white dolphin (CWD) densities in Lingding Bay across four monitoring periods: 2025–2026, 2024–2025, 2018–2019, and 2017–2018. For these comparisons, DPSE values of 60.1–100 were classified as moderately high-use, while DPSE values greater than 100 were classified as high-use.

Note: North Lingding Bay (NLDB) was not surveyed during the 2024–25 and 2025–26 monitoring periods. The absence of sightings in NLDB during these periods should not be interpreted as evidence of dolphin absence.

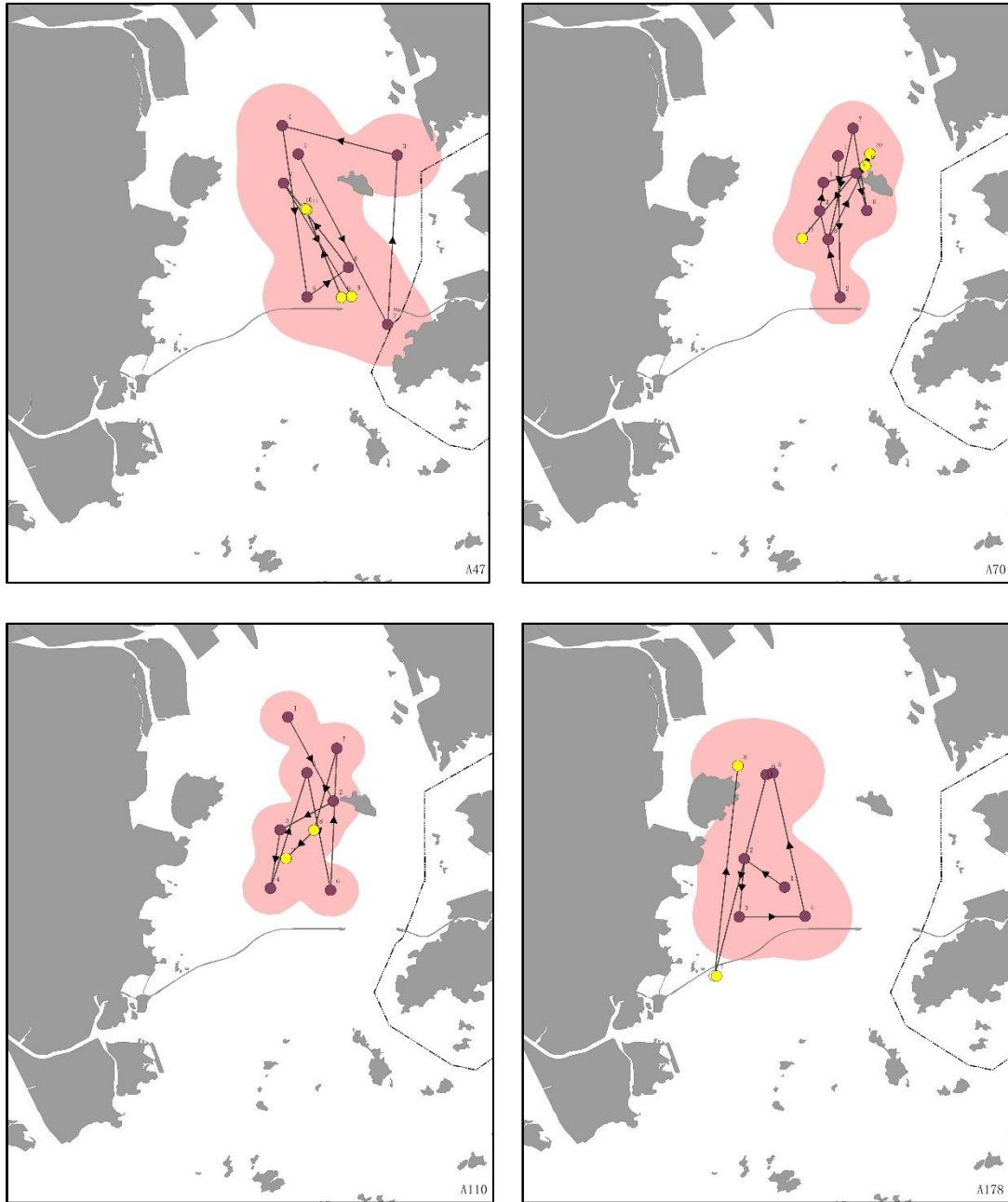


Figure 21. Resighting locations and apparent movement directions of four photo-identified Chinese White Dolphins recorded mainly in central Lingding Bay. Purple points represent historical resighting records in the photo-identification catalogue, whereas yellow points represent sightings recorded between July 2025 and April 2026. Numbered points and arrows indicate the chronological observation sequence. Connecting lines show apparent displacement between discrete resighting events and do not represent actual continuous swimming routes.

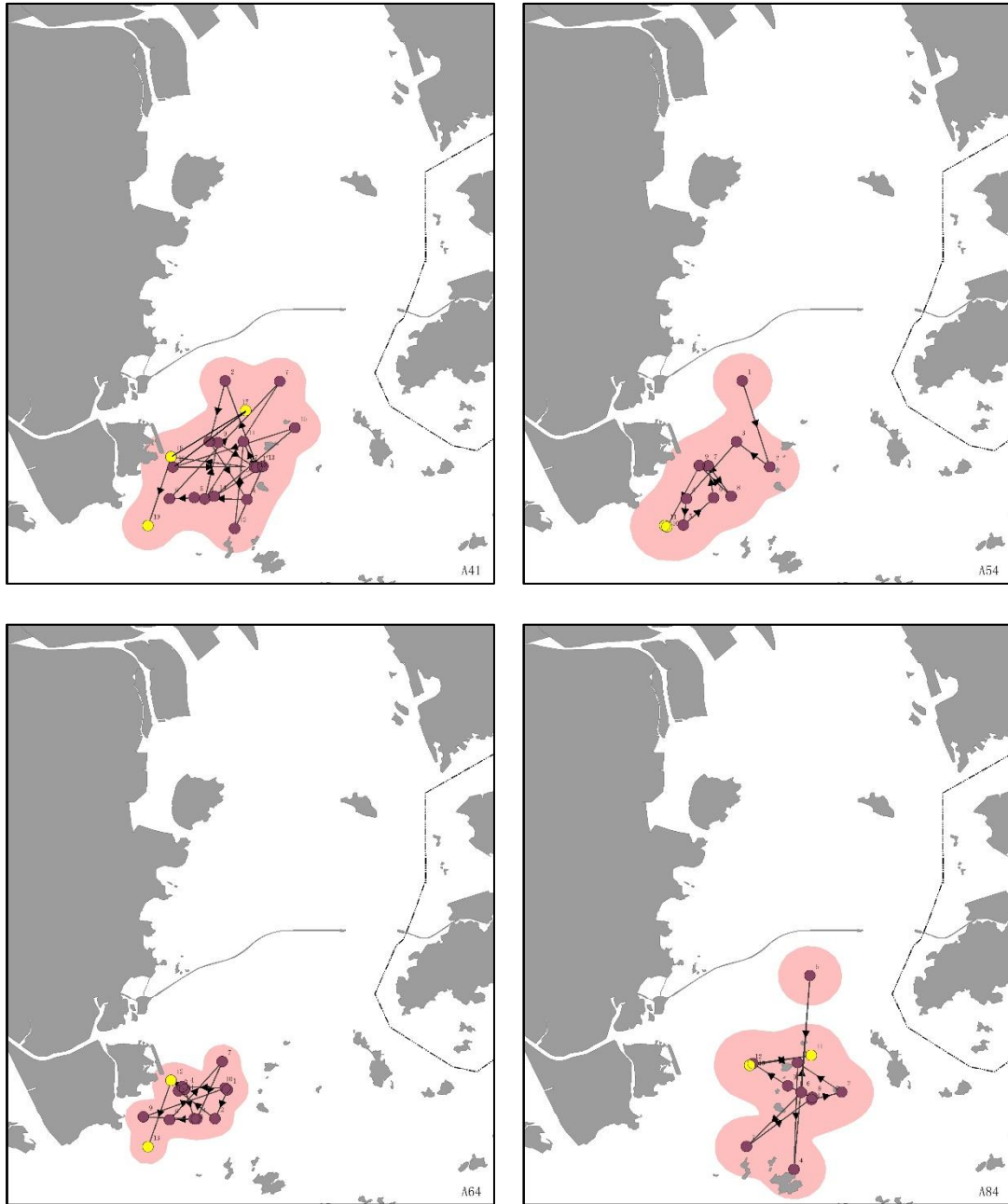


Figure 22. Resighting locations and apparent movement directions of four photo-identified Chinese White Dolphins recorded mainly in southern Lingding Bay. Purple points represent historical resighting records in the photo-identification catalogue, whereas yellow points represent sightings recorded between July 2025 and April 2026. Numbered points and arrows indicate the chronological observation sequence. Connecting lines show apparent displacement between discrete resighting events and do not represent actual continuous swimming routes.

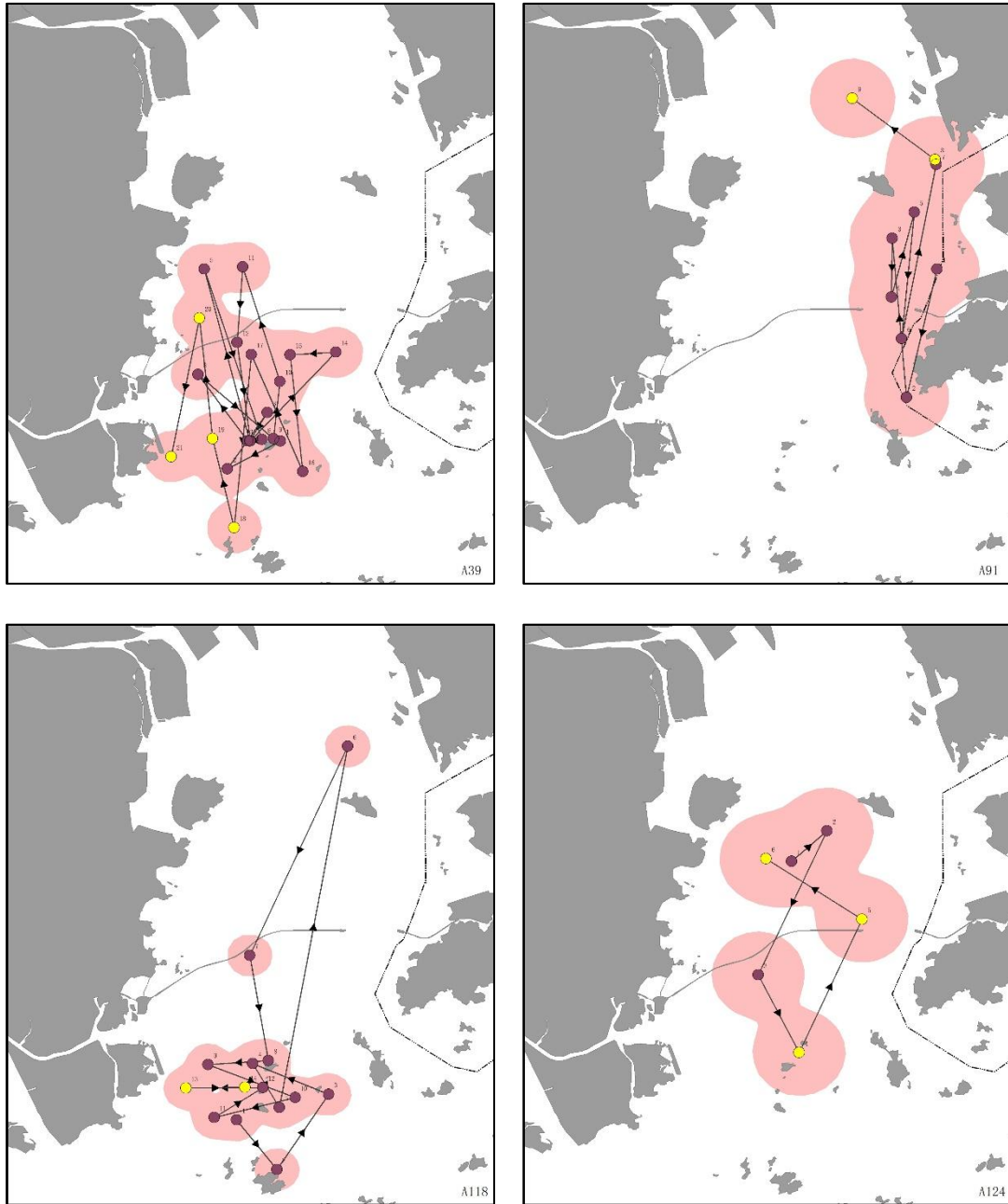


Figure 23. Resighting locations and apparent movement directions of four photo-identified Chinese White Dolphins recorded across multiple parts of Lingding Bay. Purple points represent historical resighting records in the photo-identification catalogue, whereas yellow points represent sightings recorded between July 2025 and April 2026. Numbered points and arrows indicate the chronological observation sequence. Connecting lines show apparent displacement between discrete resighting events and do not represent actual continuous swimming routes.

Table 1. Survey effort and sightings of Chinese White Dolphins in Lingding Bay (July 2025–April 2026)

| Surveys    | Length of<br>transect-lines (km) | Encounter groups | Encounter dolphins |
|------------|----------------------------------|------------------|--------------------|
| July 2025  | 367.3                            | 16               | 80                 |
| Aug. 2025  | 379.6                            | 18               | 47                 |
| Sep. 2025  | 370.8                            | 14               | 87                 |
| Oct. 2025  | 378.0                            | 13               | 43                 |
| Nov. 2025  | 366.8                            | 14               | 90                 |
| Dec. 2025  | 383.2                            | 12               | 73                 |
| Jan. 2026  | 375.5                            | 14               | 61                 |
| Feb. 2026  | 382.6                            | 12               | 55                 |
| March 2026 | 381.7                            | 20               | 114                |
| April 2026 | 376.8                            | 5                | 33                 |
| Total      | 3762.3                           | 138              | 683                |

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 (July 2025–April 2026)

| 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 |
| Jul. 2025   | CLDB         | 114                | 101.9        | 3                  | 3            | 8                    | 8            |
|             | SLDB         | 130.2              | 130.2        | 5                  | 5            | 17                   | 17           |
|             | MA           | 76.4               | 74.8         | 6                  | 5            | 14                   | 11           |
|             | SWMA         | 46.7               | 46.7         | 2                  | 2            | 41                   | 41           |
|             | Total        | 367.3              | 353.6        | 16                 | 15           | 80                   | 77           |
| Aug. 2025   | CLDB         | 135.4              | 135.4        | 2                  | 2            | 4                    | 4            |

|           |       |       |       |    |    |    |    |
|-----------|-------|-------|-------|----|----|----|----|
|           | SLDB  | 131.1 | 131.1 | 10 | 10 | 28 | 28 |
|           | MA    | 73.9  | 55.7  | 6  | 6  | 15 | 15 |
|           | SWMA  | 39.2  | 39.2  | 0  | 0  | 0  | 0  |
|           | Total | 379.6 | 361.4 | 18 | 18 | 47 | 47 |
| Sep. 2025 | CLDB  | 131.6 | 120.8 | 0  | 0  | 0  | 0  |
|           | SLDB  | 125.4 | 125.4 | 6  | 6  | 13 | 13 |
|           | MA    | 70.3  | 70.3  | 6  | 6  | 56 | 56 |
|           | SWMA  | 43.5  | 43.5  | 2  | 2  | 18 | 18 |
|           | Total | 370.8 | 360.0 | 14 | 14 | 87 | 87 |
| Oct. 2025 | CLDB  | 134.1 | 134.1 | 2  | 2  | 5  | 5  |
|           | SLDB  | 124.3 | 100.4 | 9  | 9  | 23 | 23 |
|           | MA    | 74.9  | 67.9  | 2  | 2  | 15 | 15 |
|           | SWMA  | 44.7  | 44.7  | 0  | 0  | 0  | 0  |
|           | Total | 378.0 | 347.1 | 13 | 13 | 43 | 43 |
| Nov. 2025 | CLDB  | 136.7 | 126.1 | 2  | 2  | 16 | 16 |
|           | SLDB  | 125.1 | 125.1 | 9  | 9  | 31 | 31 |
|           | MA    | 70.5  | 66.8  | 2  | 2  | 3  | 3  |
|           | SWMA  | 34.5  | 34.5  | 1  | 1  | 40 | 40 |
|           | Total | 366.8 | 352.5 | 14 | 14 | 90 | 90 |
| Dec. 2025 | CLDB  | 132.4 | 132.4 | 7  | 7  | 57 | 57 |
|           | SLDB  | 135.7 | 135.7 | 4  | 4  | 14 | 14 |
|           | MA    | 76.6  | 76.6  | 0  | 0  | 0  | 0  |
|           | SWMA  | 38.5  | 38.5  | 1  | 1  | 2  | 2  |
|           | Total | 383.2 | 383.2 | 12 | 12 | 73 | 73 |
| Jan. 2026 | CLDB  | 134.6 | 134.6 | 9  | 9  | 41 | 41 |
|           | SLDB  | 130.5 | 130.5 | 4  | 4  | 12 | 12 |
|           | MA    | 72.8  | 72.8  | 1  | 1  | 8  | 8  |
|           | SWMA  | 37.6  | 37.6  | 0  | 0  | 0  | 0  |
|           | Total | 375.5 | 375.5 | 14 | 14 | 61 | 61 |

|           |       |       |       |    |    |     |     |
|-----------|-------|-------|-------|----|----|-----|-----|
| Feb. 2026 | CLDB  | 134.3 | 134.3 | 4  | 4  | 22  | 22  |
|           | SLDB  | 130.9 | 130.9 | 6  | 6  | 25  | 25  |
|           | MA    | 74.3  | 74.3  | 2  | 2  | 8   | 8   |
|           | SWMA  | 43.1  | 43.1  | 0  | 0  | 0   | 0   |
|           | Total | 382.6 | 382.6 | 12 | 12 | 55  | 55  |
| Mar. 2026 | CLDB  | 128.3 | 120.8 | 12 | 12 | 59  | 59  |
|           | SLDB  | 137.2 | 137.2 | 2  | 2  | 11  | 11  |
|           | MA    | 73.5  | 73.5  | 6  | 6  | 44  | 44  |
|           | SWMA  | 42.7  | 42.7  | 0  | 0  | 0   | 0   |
|           | Total | 381.7 | 374.2 | 20 | 20 | 114 | 114 |
| Apr. 2026 | CLDB  | 134.9 | 96.3  | 2  | 1  | 10  | 5   |
|           | SLDB  | 130.2 | 52    | 0  | 0  | 0   | 0   |
|           | MA    | 71.5  | 55.6  | 3  | 3  | 23  | 23  |
|           | SWMA  | 40.2  | 0     | 0  | 0  | 0   | 0   |
|           | Total | 376.8 | 203.9 | 5  | 4  | 33  | 28  |

Table 3. Abundance estimates and associated parameters for Chinese white dolphins in four survey areas of Lingding Bay during different survey periods.

| Survey period     | Survey area | Area(km <sup>2</sup> ) | L(km)  | n  | f(0) (km <sup>-1</sup> ) | E(s)  | D (100 km <sup>-2</sup> ) | N   | CV (%) |
|-------------------|-------------|------------------------|--------|----|--------------------------|-------|---------------------------|-----|--------|
| Jul 2025–Apr 2026 | CLDB        | 463.74                 | 1236.7 | 40 | 4.28                     | 5.23  | 36.13                     | 168 | 32.85  |
|                   | SLDB        | 515.68                 | 1198.5 | 51 | 4.28                     | 3.02  | 27.47                     | 142 | 31.04  |
|                   | MA          | 267.96                 | 688.3  | 32 | 4.28                     | 5.69  | 56.53                     | 151 | 33.99  |
|                   | SWMA        | 128.36                 | 370.5  | 6  | 4.28                     | 16.83 | 58.28                     | 75  | 65.26  |
| Jul 2024–Jun 2025 | CLDB        | 463.74                 | 1305.4 | 45 | 3.17                     | 4.62  | 25.25                     | 117 | 26.73  |
|                   | SLDB        | 515.68                 | 1201.5 | 81 | 3.17                     | 5.64  | 60.27                     | 311 | 19.66  |
|                   | MA          | 267.96                 | 739.1  | 60 | 3.17                     | 5.00  | 64.31                     | 172 | 20.10  |
|                   | SWMA        | 128.36                 | 415.0  | 8  | 3.17                     | 10.25 | 31.31                     | 40  | 52.11  |
| Aug 2018–May 2019 | CLDB        | 463.74                 | 1114.4 | 47 | 3.75                     | 4.06  | 32.12                     | 149 | 22.36  |
|                   | SLDB        | 515.68                 | 1263.9 | 67 | 3.75                     | 5.45  | 54.12                     | 279 | 20.44  |
|                   | MA          | 267.96                 | 619.6  | 33 | 3.75                     | 5.61  | 55.96                     | 150 | 24.87  |
|                   | SWMA        | 128.36                 | 264.8  | 5  | 3.75                     | 7.20  | 25.48                     | 33  | 79.11  |
| Aug 2017–Apr 2018 | CLDB        | 463.74                 | 1103.4 | 70 | 4.46                     | 4.80  | 67.89                     | 315 | 22.06  |
|                   | SLDB        | 515.68                 | 1093.1 | 59 | 4.46                     | 4.85  | 58.33                     | 301 | 20.34  |
|                   | MA          | 267.96                 | 626.7  | 47 | 4.46                     | 5.32  | 88.93                     | 238 | 28.66  |
|                   | SWMA        | 128.36                 | 336.8  | 8  | 4.46                     | 1.13  | 6.01                      | 8   | 70.20  |

**Notes:** L = total transect length; n = number of on-effort sightings;  $f(0)$  = probability density function at zero distance;  $E(s)$  = estimated mean group size; D = individual density; N = abundance estimate; CV = coefficient of variation. CLDB = central Lingding Bay; SLDB = southern Lingding Bay; MA = Macau area; SWMA = southwest Macau area.

All abundance estimates are based on the four common survey areas shown in the table. D is expressed as individuals per 100 km<sup>2</sup>