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Preliminary Studies on Site Fidelity, Residence Index, and Population Size of Irrawaddy Dolphins in West Penang, Malaysia

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Abstract: The Irrawaddy dolphin is found in the coastal and estuarine areas of West Penang, Malaysia. Studies were conducted to estimate the site fidelity, residence index, and population size of Irrawaddy dolphins in West Penang. Photo-identification studies were conducted using boat surveys from 2019 to 2021. Thirty-nine marked Irrawaddy dolphins were identified, with thirty-six newly identified individuals and three individuals observed in 2013. Resightings of four individuals indicated that they were found north of Sungai Burung and Sungai Pinang in West Penang. The majority of individuals had low sighting rates, ranging from 2.6 to 7.7%, with three individuals having medium sighting rates, the highest being 15.4%. The residence index was 0.01 for all 36 individuals, and the highest value of 0.36 was recorded for one individual. Using open population models and closed models, the population size was determined to be 64 or and 52, respectively. The results suggest that although there is a population present, it is probably open, as the residence index is low. The population size appeared to be stable from 2013 to 2021. This information will inform conservation managers of the best way forward for the conservation of Irrawaddy dolphins in Penang.

Keywords: Irrawaddy dolphin; Penang; population size; site fidelity; residence index

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1. Introduction

The Irrawaddy dolphin (*Orcaella brevirostris*) is an inshore cetacean species found in small patchy populations in coastal, estuarine, and riverine habitats [1]. In Malaysia they have been found in Penang [2,3], Cowie Bay, Sandakan and Kinabatangan (Sabah) [4,5], Kuching Bay, Sarawak [6], and Matang, Perak [7]. Irrawaddy dolphin population size have generally been estimated to be small, e.g., in Cowie Bay, Sabah, in 2010, with a population of 28 individuals (95% confidence limits (CL) = 28–34) [4]; Kuching Bay, Sarawak, with 149 individuals (95% CL = 151–360 with CV = 22.5%) [6]; and Penang Island (32 to 52 individuals) [3], as have other populations in its range. Irrawaddy dolphins are classified as endangered (EN) under the IUCN Red List of Threatened Species for coastal species but are critically endangered for river species and in the Malampaya Sound subpopulation in the Philippines [1,8]. The patchy and fragmented distribution of Irrawaddy dolphins in both coastal waters and rivers renders them particularly vulnerable to threats from human activities concentrated in the same areas [1]. An increase in the number of mortalities among Irrawaddy dolphins has largely been due to threats such as gillnets, which cause incidental mortality in small-scale fisheries [1,9,10]. Habitat loss—particularly from dams in riverine populations and degradation from declining or altered freshwater flows affecting estuarine populations—is a looming conservation threat with the potential to extirpate subpopulations and further fragment the already patchy distribution of the species [1].

The west coast of Penang, Malaysia, is known to host at least three species of inshore cetaceans, namely, the Irrawaddy dolphin (*Orcaella brevirostris*), the Indo-Pacific finless

porpoise (*Neophocaena phocaenoides*), and the Indo-Pacific humpback dolphin (*Sousa chinensis*) [2]. These three species have been observed since the beginning of 2013 when formal boat surveys for cetaceans were initiated. Notably, the Irrawaddy dolphin has been predominantly observed. Using photo-identification techniques, a catalog for the Irrawaddy dolphin was created with 30 individuals that were identified regardless of their right dorsal fins or left dorsal fins [11]. Since then, an initial population for Irrawaddy dolphins using mark–recapture techniques is estimated to include 31 to 52 individuals for both the closed and open population models [3]. Further investigations need to be conducted to analyze the current population status of Irrawaddy dolphins in Penang. In this paper, we will discuss the site fidelity and residence index and provide a new estimate of the population size based on photo-identification studies conducted from 2019 to 2021. This information is important, as it provides us with information on how often the Irrawaddy dolphin is present in the western part of Sungai Pinang, the degree of residency, and population size, which will enable us to determine what kind of conservation measures are needed for this species in this region.

2. Materials and Methods

2.1. Study Area

Penang Island is approximately 293 km^2 in area and located on the western seaboard of Peninsular Malaysia in the Northern Malacca Strait (within latitudes 5°12′ N to 5°30′ N and longitudes 100°09′ E to 100° 26′ E). The exact study area was on the western coastline of Penang Island. It comprises 14 km of mangrove coastline with a shallow, mesotidal estuarine habitat where freshwater comes from six different rivers, including the two largest rivers, Sungai Pinang and Sungai Burung [12,13].

2.2. Boat-Based Surveys and Photo-Identification Studies

Boat-based surveys using transects were used to conduct photo-identification studies and population size estimation, as well as to determine the residency index and site fidelity.

2.2.1. Data Collection

Surveys were conducted from a small fiberglass boat (7.6 m size) between 07:30 am to 2:00 pm (weather permitting) for 5 days every month. The study area covered approximately 17.3 km × 6.0 km (103.8 km^2) and included water depths (0.5 m > depth > 29.5 m). Two survey routes were used to ensure complete coverage of the study site and avoid potential bias, one parallel to the shore and the other at a 45° angle in a zigzag pattern.

When both the parallel line and zigzag routes were completed, we considered one survey to be completed (Figure 1). During the survey, two observers, with the aid of binoculars, usually stood at the front of the boat, alternating shifts every 20 min and checking for the presence of animals. At the start of each survey, effort status and environmental conditions were recorded, such as sea state, wave height, visibility, and glare. These conditions were recorded every 20 min or when dolphins or porpoises were encountered. In addition, the position of the vessel was constantly logged, using a GPS Garmin Montana 360 (Garmin Inc., Olathe, Kansas, KS, USA). Surveys were conducted at sea conditions of Beaufort ≤ 3.

A dolphin sighting is when the occurrence of a dolphin happens during the search effort and ends when 15 min have elapsed since the last surface of the cetacean [3].

2.2.2. Photo-Identification and Population Size Estimation

Photos were taken with a Nikon D3200 DSLR camera with a 70–300 mm lens, and the images were graded according to their quality, with only those of sufficient quality used to identify individual dolphins [14]. While the boat traveled alongside the dolphins, attempts were made to photograph the left and right sides of the dorsal fins of individual dolphins.

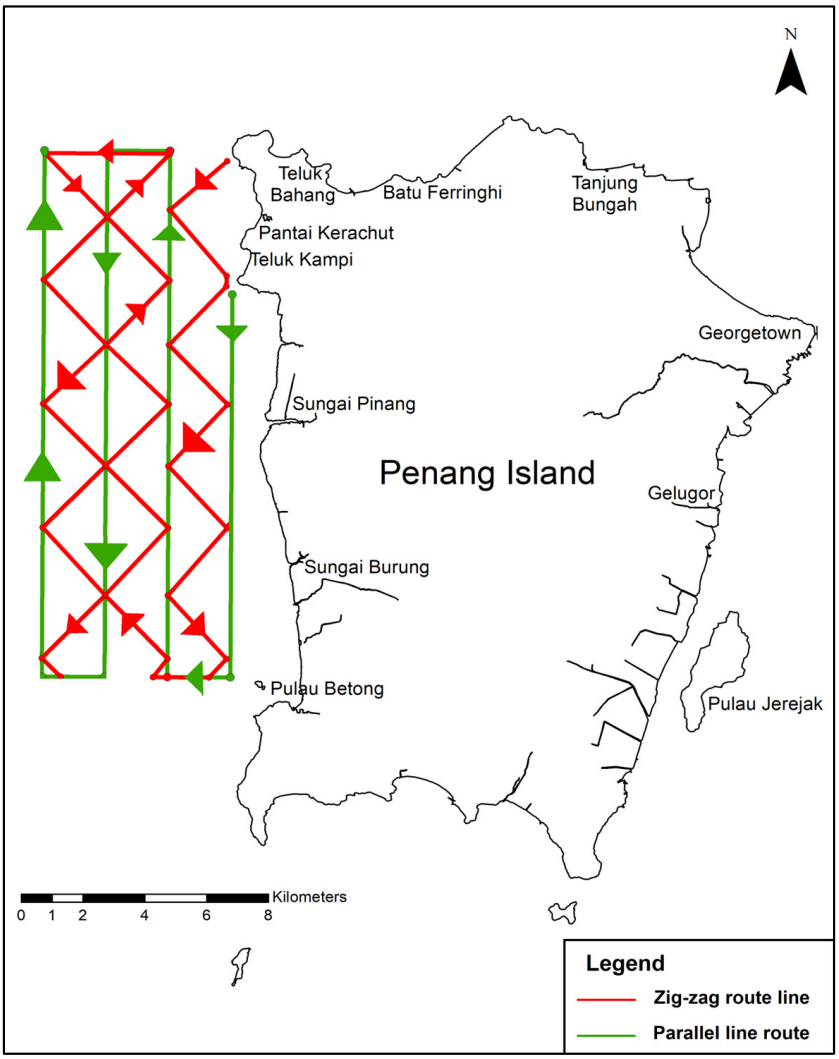

Figure 1. Two types of survey routes where the boat traveled, consisting of a parallel line route and a zigzag route.

Photographs that lacked sufficient markers to be classified as unique were also collected. There were three sets of photo IDs: left dorsal fins (LDFs), right dorsal fins (RDFs), and regardless of the side of the fin (OBP) (see Supplementary Materials).

The dolphin photos were sorted into three folders: Grade 1 (the image of the dolphin or the dorsal fin is less than 10% of the photo's total height; the image is out of focus or blurry); Grade 2 (the photo is in focus, but it does not contain the dorsal fin or the dorsal fin is not properly placed to identify the marks); and Grade 3 (the photo is focused, the dorsal fin is parallel, and the mark is easily recognizable) using the Quality Grading Criteria for Hong Kong HKZMB Photo-Identification Catalog (Lindsay Porter, Southeast Asia Marine Mammal Research, Hong Kong, personal communication). From the photos that we collected and sorted, each dolphin individual was classified based on the fin shape, lesion, scars, and cuts (long-lasting marks). Each unique individual was assigned an ID code with 'OBP' (standing for *Orcaella brevirostris* Penang) as the prefix, followed by the number (e.g., OBP001). Based on the catalog previously created by Rodriguez-Vargas [11], we named the existing individuals, and we provided new names for the new dolphin individuals we discovered.

Two types of population estimates were calculated: closed population and open population. Closed population models were used because it was assumed that there was little change from birth, death, immigration, or emigration during this study period [15].

While open population models consider variation in population size during the study period when assumptions of closure are not met, it can be useful to compare estimates from both open and closed models [16].

Four different models for closed populations were used to determine the best-fit model for population size estimation, which were Mb (behavior-dependent), Mt (time-dependent), Mo (constant), and M(h) (heterogeneity) [17]. The models with the lowest Akaike Information Criterion (AIC) were used to determine the best model for each data set.

The POPAN formulation for Jolly–Seber was used to compare four different models for open populations, where p = capture probabilities, ϕ (phi) = survival probabilities, and PENT = the probability of the entrance of other individuals in the parameterization as a function of time [18].

The four different models are:

- p (t), ϕ (t), PENT (t) = Capture and survival probabilities are time-dependent.
- p (.), ϕ (t), PENT (t) = Capture probabilities are constant, and survival probabilities are time-dependent.
- p (t), ϕ (.), PENT (t) = Capture probabilities are time-dependent, and survival probabilities are constant.
- p (.), ϕ (.), PENT (t) = Capture and survival probabilities are constant.

Since MARK only estimates the number of marked animals, a correction factor that includes the unmarked animals was used to calculate the total population size [6]. The number of identifiable fins per sighting was summed for all sightings and divided by the total sum of both identified and unidentified fins per sighting for all sightings [6]. The resulting mean proportion, p, was used as a correction factor for population estimate estimates (N) that only used the sighting histories of distinctive individuals [19]. The 95% confidence interval, CI, was computed using the following formulas:

$$95\%\ \text{lower interval} = N_{\text{corrected}} \times p, \text{ and} \quad (1)$$

$$95\%\ \text{upper interval} = \frac{N_{\text{corrected}}}{p} \quad (2)$$

2.2.3. Site Fidelity

Information from photo-identification studies during boat-based surveys was analyzed to provide information on site fidelity and residence index [20–22]. The site fidelity patterns of individually identified dolphins were determined based on their resight rate and presence across seasons [22,23].

Sighting rates were classified into three categories according to the proportion of the number of sightings of an identified dolphin to the total number of surveys, which was, in this case, 39 surveys. Sighting rates less than 10% were classified as low sighting rates (LSR), 10–30% as moderate sighting rates (MSR), and more than 30% as high sighting rates (HSR). Dolphins were considered residents if they had moderate to high sighting frequencies throughout the year (i.e., northeast monsoon and southwest monsoon) [22]. Dolphins identified during the same season in consecutive years but not during intervening seasons were defined as seasonal residents [23]. Occasional visitors were dolphins that had low sighting rates but were present in all seasons [22]. Transients were dolphins that had low sighting rates and were only observed in one season [22].

The residence index (RI) was calculated to quantify the occurrences of each individual of *Orcaella brevirostris* [20] by determining the total number of sightings of the individual with the number of months it was seen. The formula is

$$RI = S \times M/100,$$

where RI = residence index, S = total number of sightings of an individual, and M = total number of months in which this particular individual was seen.

3. Results

A total of 39 surveys in 87 days were completed covering 3745 km, with a daily average of 39.43 km + 1.54 SE (see Figure 2, Table A1). The total survey time was 280.4 h, with 7.5 h dedicated to photo identification. Off-effort sightings took up a total of 41 min. Fifty-two Irrawaddy dolphins were sighted during the survey (Figure 3).

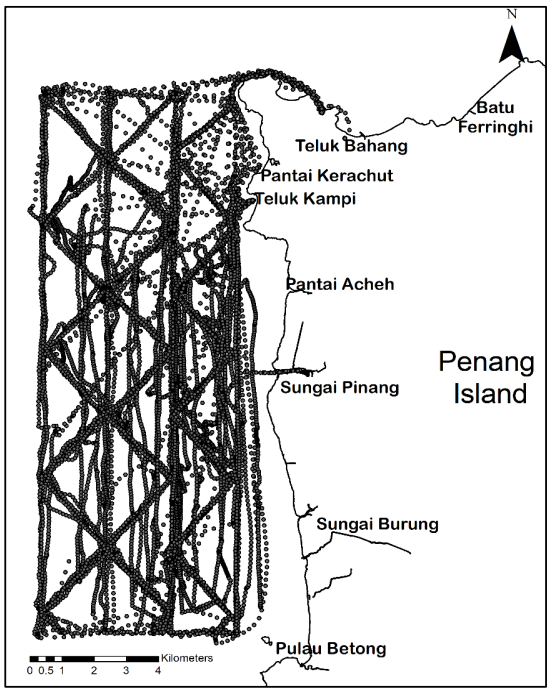

Figure 2. Actual survey path followed by the boat during all the surveys in West Penang.

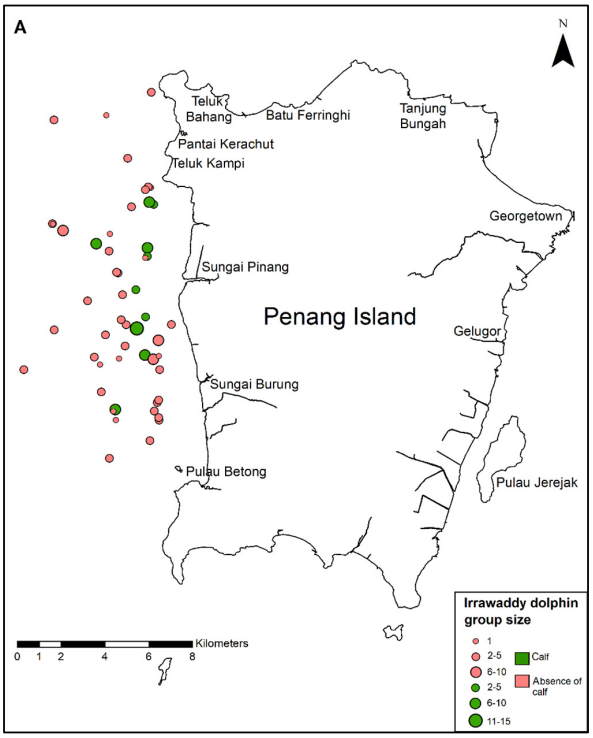

Figure 3. Irrawaddy dolphin encounters in the western coastal waters of Penang Island (February 2019 to April 2021) during on-effort surveys [13] (Permission was granted by the publisher, the Lee Kong Chian Natural History Museum.).

3.1. Photo-Identification Studies and Discovery of New Animals

We obtained a total of 11,056 photos of Irrawaddy dolphins. From these photos, 30.7% (3398 photos) contained images without dolphins, 66.5% (7347 photos) contained Grade 1 photos, 1.56% (173 photos) contained Grade 2 photos, and 1.25% (138 photos) contained Grade 3 photos.

Based on the results of the discovery curve, it appears that most of the individuals were discovered in February (14 animals), April (7), and May (5) of 2019, amounting to a total of 26 individuals (Figure 4). Fewer individuals were discovered in July (4), September (3), and November (2), amounting to a total of nine individuals discovered in the second half of 2019 (Figure 4). No new individuals were found in June, August, or December. In the year 2020, two new individuals were discovered in March, and one new individual was discovered in November. Most of the dolphin individuals sighted in February, March, July, and November 2020 were the resighted individuals from the year 2019. No dolphins were found in January, June, September, or October 2020. In 2021, one new individual was discovered in March. No new individual dolphins were found in January, February, or April.

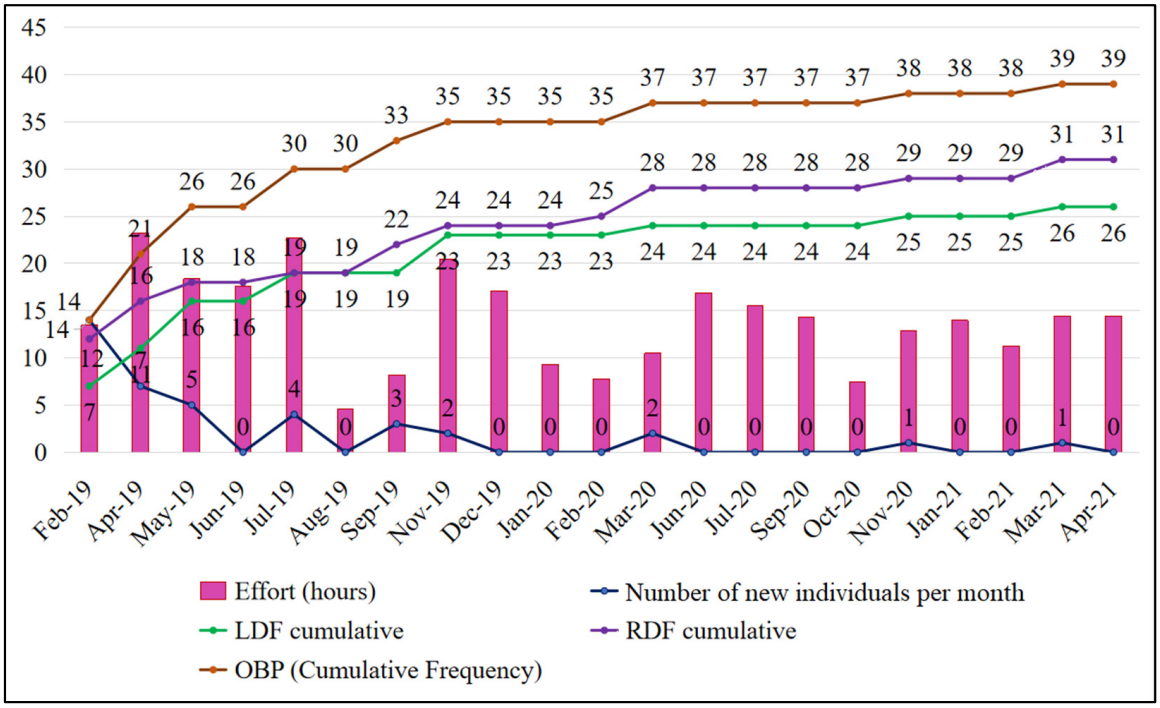

Figure 4. Discovery curve showing the accumulation of newly identified individual Irrawaddy dolphins during the period of study from February 2019 to April 2021, related to the effort in hours per month when sightings were recorded. LDF = left dorsal fin; RDF = right dorsal fin; OBP = regardless of side.

In the surveys conducted between February 2019 and April 2021, a total of 39 new individuals were identified based on either the left dorsal fin or the right dorsal fin. Upon checking the first catalog developed for Irrawaddy dolphins in West Penang for thirty individuals [11], only three individuals, namely, OBP003, OBP010, and OBP016, were rediscovered at this time. A new catalog will be developed using the current data from 2019, 2020, and 2021. From the current data, it appears that recaptures were only seen for 15 individual Irrawaddy dolphins (Table 1).

Adverse weather conditions led to the cancelation of several field days either halfway through a survey day or a whole day before the survey. Photo identification became increasingly difficult because of the decreased sighting ability of the observers during bad

weather and avoidance behavior from the dolphins, which were only sighted once or twice and did not surface again.

Table 1. Individual Irrawaddy dolphins that were recaptured during the field surveys in 2019, 2020, and 2021.

No	Individual's Name	Months They Were Encountered					
		First Encounter	Second Encounter	Third Encounter	Fourth Encounter	Fifth Encounter	Sixth Encounter
1	OBP044	February 2019	April 2019				
2	OBP047	February 2019	May 2019				
3	OBP051	February 2019	March 2020				
4	OBP053	April 2019	May 2019				
5	OBP054	April 2019	November 2019	July 2020	November 2020		
6	OBP057	April 2019	March 2020				
7	OBP061	May 2019	March 2020				
8	OBP062	May 2019	November 2020				
9	OBP064	May 2019	March 2020				
10	OBP066	July 2019	February 2020				
11	OBP067	July 2019	November 2019				
12	OBP068	November 2019	March 2020	March 2021			
13	OBP070	September 2019	November 2019	November 2020	March 2021		
14	OBP003	July 2019	September 2019	November 2019	March 2020	November 2020	March 2021
15	OBP016	March 2020	March 2021				

3.2. Resighting Pattern

Data on the resighting patterns of Irrawaddy dolphins were limited because few recaptures were obtained throughout the survey period; however, the information so far indicates that the common areas where the Irrawaddy dolphin can be observed appear to be in Sungai Pinang and Sungai Burung (Figure 5).

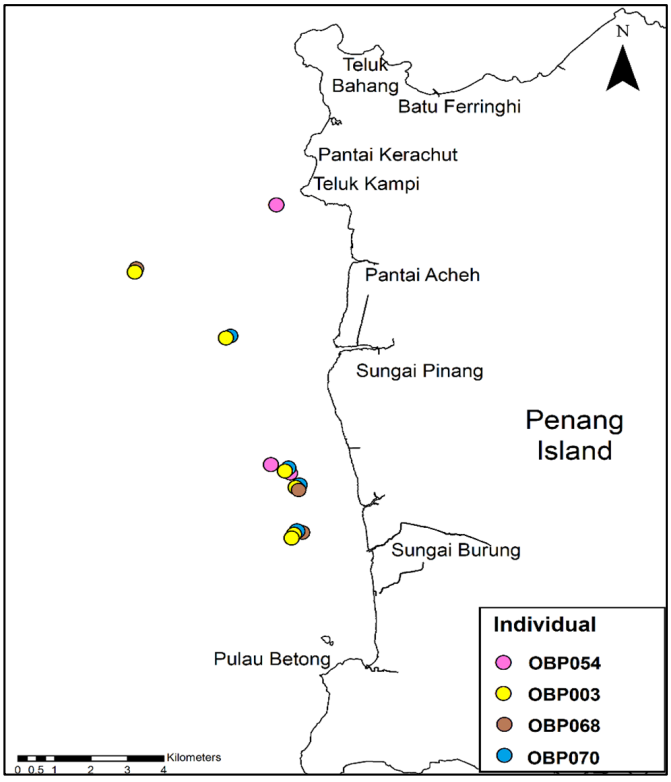

Figure 5. Resighting patterns of Irrawaddy dolphins OBP054, OBP003, OBP068, and OBP070.

Irrawaddy dolphins named OBP054, OBP068, OBP003 and OBP070 were observed more than once (see Table 1). OBP068 was seen three times, while OBP054 and OBP070 were seen four times. There were six occasions of sightings of OBP003 (Table 1), while the rest of the individuals were resighted only once during the survey (Table 1).

3.3. Minimal Distances Traveled by Individual Dolphins

The Irrawaddy dolphin individuals that were resighted more than once (OBP003, OBP054, OBP068, and OBP070) were seen between Sungai Burung, Sungai Pinang, Pantai Acheh, and Teluk Kampi (Figure 5). OBP054 traveled a greater distance, where it was observed in Teluk Kampi, 10.1 km away from the Sungai Burung region (Figure 6a, Table 2). This individual was seen first in Sungai Pinang in April 2019, then in Sungai Burung (November 2019), Teluk Kampi (July 2020), and then back in Sungai Pinang again in November 2020 (Figure 6a, Table 1).

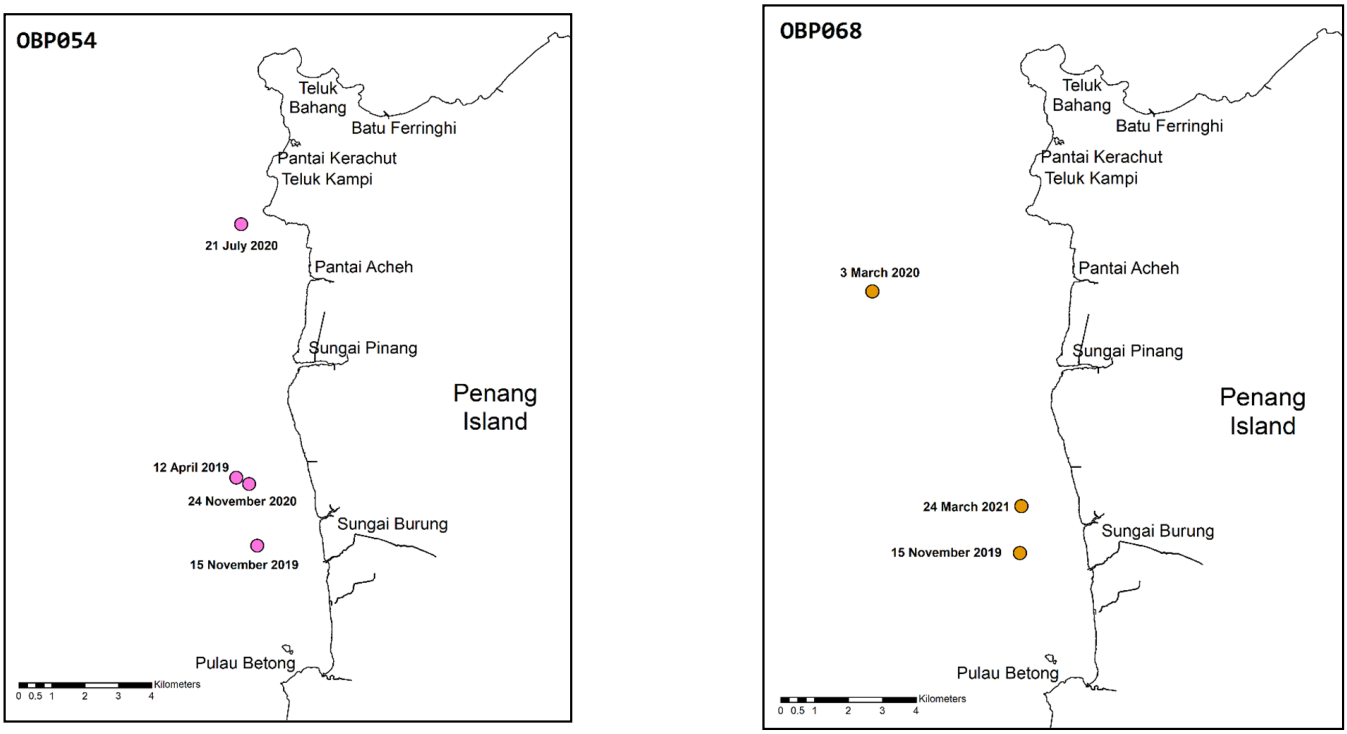

Figure 6. Repeat sightings of the (**a**) Irrawaddy dolphin named OBP054 and (**b**) the Irrawaddy dolphin named OBP068 throughout the survey period from February 2019 to April 2021.

Table 2. Range of distance for each Irrawaddy dolphin individual along West Penang Island waters based on resighting data from February 2019 to April 2021.

Orcaella brevirostris Individual	Range of Distance (km)	Regions Traveled
OBP054	10.1 km	Teluk Kampi, South Sungai Pinang, and Sungai Burung
OBP068	9.2 km	Pantai Acheh, Sungai Pinang, and Sungai Burung
OBP070	6.3 km	Sungai Pinang and Sungai Burung
OBP003	9.5 km	Pantai Acheh, Sungai Pinang, and Sungai Burung

The Irrawaddy dolphin named OBP068 had a slightly shorter moving distance of 9.2 km and traveled from Pantai Acheh to the Sungai Burung region (Figure 6b, Table 2). It was sighted in Sungai Burung in November 2019 and then in Pantai Acheh in March 2020, followed by Sungai Pinang in March 2021 (Figure 6b, Table 2).

Individual OBP070, which was seen four times, had the shortest range of movement, which totaled up to 6.3 km from Sungai Pinang to Sungai Burung (Figure 7a, Table 2). This dolphin was seen in the Sungai Pinang region in September 2019, followed by the Sungai Burung region in November 2019, November 2020, and March 2021.

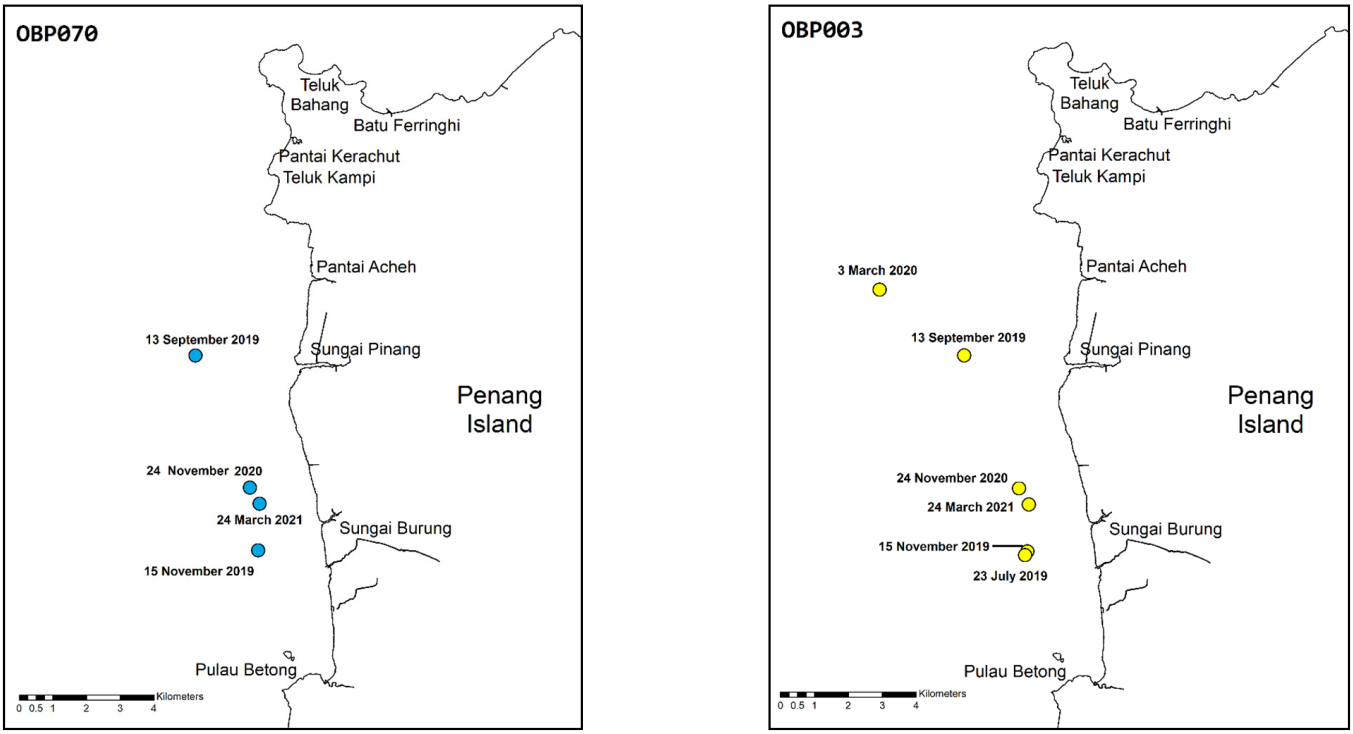

Figure 7. Repeat sightings of the (**a**) Irrawaddy dolphin named OBP070 and (**b**) the Irrawaddy dolphin named OBP003 throughout the survey period from February 2019 to April 2021.

The Irrawaddy dolphin named OBP003 traveled 9.5 km (Figure 7b, Table 2). This dolphin was first spotted in July 2019 in Sungai Burung, in Sungai Pinang in September, in Sungai Burung in November, in Pantai Acheh in March, and then again in Sungai Burung in November 2020 and March 2021.

3.4. Sighting Rates and Residence Index (RI)

Among the 39 individually identified dolphins, 24 individuals had a sighting rate of 2.56%, followed by 11 individuals with a sighting rate of 5.13% (see Table 3, Table A2). One individual (OBP068) had a sighting rate of 7.69%, two (OBP054 and OBP070) had a rate of 10.26%, and one (OBP003) had a sighting rate of 15.38% (Figure 8). This result shows that only three individuals had moderate sighting rates, while the majority (36 of the individuals) had low sighting rates.

The majority of the individuals were transients (32 out of 39, 82.1%), followed by occasional individuals (4 out of 39, 10.3%), namely, OBP016, OBP062, OBP066, and OBP068. Only three individuals (OBP054, OBP070, and OBP003) accounted for all the residents (3 out of 39, or 7.7%).

The majority of the identified individuals (24 animals) had a low residence index of 0.01 (Table 4). Eleven individuals had an RI of 0.04 (individuals were found in two occasions in two months), one individual had an RI of 0.09 (discovered in three sightings in three months), two individuals had an RI of 0.16 (found in four sightings in four months), and one individual had an RI 0.36 (found in six sightings in six months).

Table 3. Number of marked Irrawaddy dolphins, percentage, sighting rates, and category of sightings of the 39 marked Irrawaddy dolphins.

Sighting Rate (%)	Category of Sighting Rate (LSR, MSR, and HSR *)	No. of Individual Marked Irrawaddy Dolphin	Percentage (%)
2.56	LSR	24	61.54
5.13	LSR	11	28.21
7.69	LSR	1	2.56
10.26	MSR	2	5.13
15.38	MSR	1	2.56
	Total	39	100.00

* LSR = low sighting rate, MSR = medium sighting rate, HSR = high sighting rate.

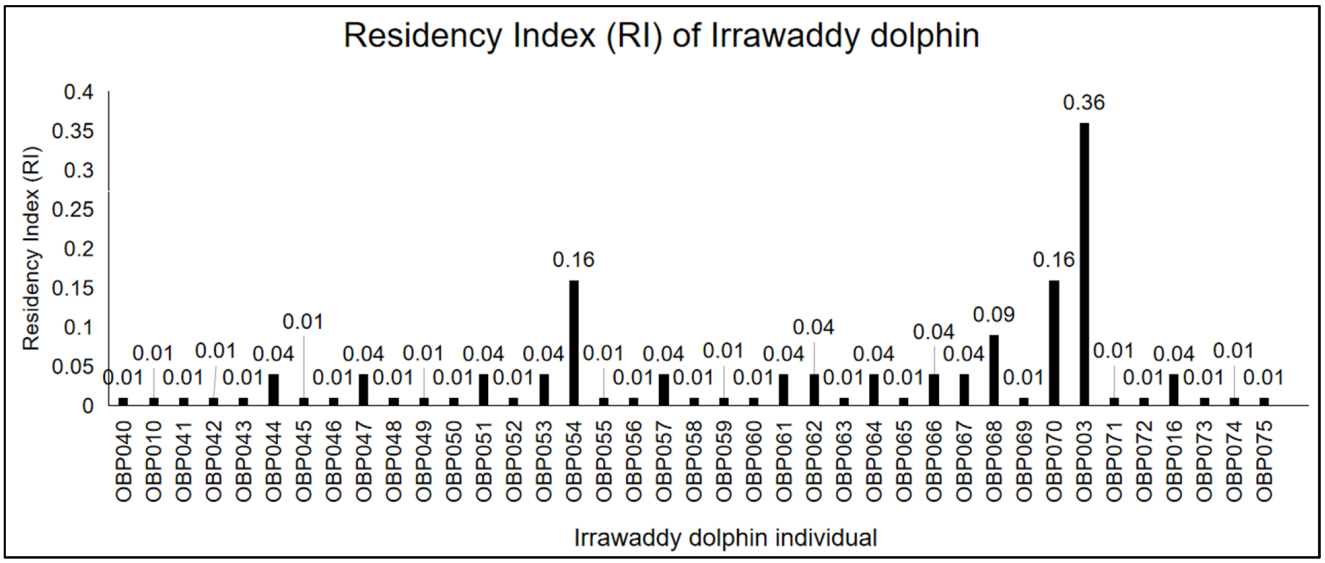

Figure 8. Residence indexes calculated for *Orcaella brevirostris* individuals discovered in 2019, 2020, and 2021 in West Penang Island.

Table 4. Number and percentage of Irrawaddy dolphins and their respective residence index (RI) values.

Residence Index (RI)	No. of Marked Individual Irrawaddy Dolphins	Percentage (%)
0.01	24	61.54
0.04	11	28.21
0.09	1	2.56
0.16	2	5.13
0.36	1	2.56

3.5. Population Size

We estimated the population size using mark–recapture analyses of photo-identified dorsal fins using the MARK software (version 10.1), which has been successfully used by researchers to estimate Irrawaddy dolphin population sizes [16,19,24].

3.6. Mark–Recapture Analysis

Based on the discovery curve (Figure 4), we discovered 39 marked Irrawaddy dolphins and 40 dolphins with unmarked fins (Grade 3). The proportion of marked individual photos was 0.706.

The MARK software was used to analyse OBP, LDF and RDF in a close population model. The selected model M(b) which describes the capture probabilities that varied with the dolphin's behaviour in response to being captured is the best fit model for OBP because it had the lowest AIC value (Akaike's Information Criterion). This model provided an estimate of 37 individuals (3.88 SE) (95% CI = 36 to 55). For the LDF site, with a population estimate of N-hat = 30 individuals (8.88 SE, 95% CI = 24 to 70), M(b) was the best fit. The RDF's population estimate, N-hat = 37 individuals (2.12 SE, 95% CI = 24 to 36), also identified M(b) as the most fit model. Meanwhile, in the open-population POPAN formulation for Jolly–Seber estimations, the phi(.), p(t), pent(N) model was the most fit model for OBP (Table 5). The population was estimated to be 45 individuals, with a standard error of 4.55 (95% CI: 45 to 190). For the LDF side, the best-fitting model for the open population estimated was phi(.), p(.), pent(N). The population estimate for LDF was 81 $\pm$ 34.94 SE (95% confidence interval = 36 to 182). In the case of RDFs, the phi(.), p(.), pent(N) model had the lowest AIC value. The model estimated 67 individuals $\pm$ 17.93 SE (95% CI: 40 to 112) (see Table 5).

The corrected population estimates ($N_{corrected}$), which included the unmarked individuals, were calculated using the OBP, LDF, and RDF N-hat results from mark–recapture analyses (Table 5). For the closed population, the corrected population estimated for OBP was 52 individuals (95% CI: 37 to 74). For the left fin side photos (LDF), adjusted for proportion, the estimated population ($N_{corrected}$) was 40 individuals (95% CI = 30 to 53). The corrected population estimate for RDF was 37 individuals, with a 95% CI of 25 to 54 (Table 5). Meanwhile, for the open population, the corrected population estimate for OBP was 64 (95% CI = 45 to 90). For LDF, the $N_{corrected}$ population estimate was 107 individuals (95% CI = 81 to 142), while for RDF, the $N_{corrected}$ was 99 individuals (95% CI = 67 to 146) (Table 5).

Table 5. Best model for closed and open populations for left dorsal fin side, right dorsal fin side, and regardless of side (OBP).

Closed Population Model														
	Model	**AICc**	**Delta AICc**	**AICc Weight**	**Model Likelihood**	**Parameter**	**Deviance**	**−2log(L)**	**N-hat**	**$N_{corrected}$**	**SE**	**CV**	**95% CI**	**95% CI Corrected**
OBP	M(b)	−46.2429	0.0315	0.47198	0.9844	3	18.5972	−52.419	37	52	3.879	0.07	36 to 55	37 to 74
LDF	M(b)	−33.5257	0	0.64613	1	2	5.7949	−37.661	30	40	8.881	0.22	24 to 70	30 to 53
RDF	M(b)	−26.2571	0	0.87046	1	3	7.2159	−32.518	25	37	2.119	0.06	24 to 36	25 to 54
Open population model														
	Model	**AICc**	**Delta AICc**	**AICc Weight**	**Model Likelihood**	**Parameter**	**Deviance**	**−2log(L)**	**N-hat**	**$N_{corrected}$**	**SE**	**CV**	**95% CI**	**95% CI corrected**
OBP	phi(.) p(t) pent(N)	117.8479	0	0.95366	1	8	−36.1515	99.8197	45	64	4.554	0.07	37 to 54	45 to 90
LDF	phi(.) p(.) pent(N)	62.9629	0	0.74121	1	6	−27.0058	47.3108	81	107	34.938	0.33	36 to 182	81 to 142
RDF	phi(.) p(.) pent(N)	86.2406	0	0.90352	1	5	−33.9626	74.4759	67	99	17.931	0.18	40 to 112	67 to 146

4. Discussion

The current results indicate that there is a small population of Irrawaddy dolphins that is probably transient in West Penang.

Out of a total of 39 individuals, there were resightings of only 15 Irrawaddy dolphins. Out of these fifteen sightings, only five individuals were sighted more than three times, indicating that the general population is not a residential one. Only four individuals were resighted more than once, namely, OBP068, OBP054, OBP070, and OBP003, indicating that these individuals visit West Penang more often.

Individual OBP003 was discovered in 2013 during a previous study [11] with a residency index of 0.04, as compared with now, which was 0.36. This means that previously OBP003 was not resident in West Penang but currently is. On the other hand, OBP010 had a residency index of 0.24 [11] compared with 0.01 currently. Individual OBP016 had a residency index of 0.02 [11] compared with 0.04 currently, indicating that its residency status was the same from 2013 to 2021, as far as the evidence shows. This also indicates that the animal occasionally visits West Penang throughout the year. A residence index was developed to overcome biases when the dolphins were often seen in a short period of time [20], which was not true in our case. However, we calculated the index to show a crude estimate of the degree of dolphin residency.

The fact that the resighting rate and residence index were low indicates that the population does not stay for long periods of time, with the majority of the 39 individuals being transients. They may frequently move in and out of the study area in search of prey. The encounter rate was estimated to be 0.19 sightings per hour (or 1.4 sightings per 100 km), which indicates a low encounter rate [13]. This encounter rate is slightly lower than the 0.25 sightings per hour reported in 2013 [3], which does not indicate any significant changes in relative abundance.

A study conducted simultaneously with the current study showed that milling [13] was more predominant than feeding behavior for Irrawaddy dolphins, indicating that the current environment is possibly less suitable for finding prey. Compared with recent surveys conducted from 2019 to 2021, feeding was not the predominant behavior for the Irrawaddy dolphin, as opposed to 2013, where feeding was the predominant behavior [3]. Avoidance behavior could also lead to poor resighting rates, as avoidance behavior was recorded 13 times for Irrawaddy dolphins in the period from 2019 to 2021 [13]. However, it is unclear to what extent avoidance behavior affects the resighting of animals.

From marked Irrawaddy dolphins, the estimated population size obtained from both the closed and open population models was 52 and 64 individuals respectively. Even though the population size is slightly higher compared with the year 2013 (32 to 51 individuals) [3], the result is incomparable, as the current survey area size was larger than the previous one even though both studies were in West Penang. However, this still indicates that there is a viable population of Irrawaddy dolphins, and from that, we can observe if the population will increase or decrease in the future. The population is small and comparable to other regions such as in Cowie Bay, Sabah, in 2010, with a population of 28 individuals (95% confidence limits, CL = 28–34) [4]. Large population sizes have been estimated for open estuarine waters in Bangladesh with 5383 individuals (CV = 40%) [25].

Largely, these results indicate that there exists a population of Irrawaddy dolphins that has low site fidelity, i.e., has a low sighting rate and low residence, indicating the population is open rather than closed. The current study probably only investigated a small portion of a larger metapopulation (that is, more or less permanently resident), in which case, it may extend to unknown boundaries and be underestimated in open population estimate modeling. Another factor is that some individuals may show avoidance behavior to boats, thus decreasing the chance of resightings and obtaining Grade 3 photos.

There is no kind of modeling (including one based on behavior) that can assess or explain their absence during a survey. Therefore, the study could have left a portion of the local population unstudied. More survey effort is needed to ascertain population size changes in the years to come. For instance, if the population is indeed open, it may be

necessary to know if these individuals are seen in other estuarine systems close to West Penang, such as Kuala Muda (north of Penang) and Pulau Aman (south of Penang). Further photo-identification studies can be conducted in the future in these areas. Research into the avoidance behavior of Irrawaddy dolphins should also be considered. However, at present, decisions can be made based on the current results for their conservation. Since the region of West Penang is an important area for Irrawaddy dolphins, a suitable management plan that incorporates local fisher and dolphin needs should be established.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/oceans4040029/s1, Dolphin catalogue (LDF and RDF) of each Irrawaddy dolphin individual in west Penang Island.

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Appendix A

Table A1. Months, Dates, Distance, and Hours Traveled on Effort in 2019, 2020, and 2021.

Year	Month	Date of Survey	Distance Traveled on Effort (km)	Effort Hours (h)
2019	February	18, 19 and 20	96	11.38
	April	12, 15, 16, 17 and 18	230	20.64
	May	13, 14, 15 and 16	182	18.75
	June	24, 25, 26, 27 and 28	239	19.23
	July	19, 22, 23, 24 and 25	219	21.49
	August	20, 26 and 27	119	6.17
	September	12, 13 and 18	189	10.56
	November	13, 15, 18 and 19	251	12.84
	December	4, 12, 13 and 15	242	10.88
2020	January	29, 30 and 31	113	9.33
	February	1, 24 and 25	116	7.73
	March	16 and 17	143	10.50
	June	22, 23, 24, 25 and 26	192	16.88
	July	16, 17, 20, 21 and 22	184	15.48
	September	23, 25, 28, 29 and 30	147	14.33
	October	19, 20, 21 and 22	135	7.4
	November	21, 22, 24, 25 and 26	183	12.86
2021	January	25, 26, 27 and 28	167	13.96
	February	22, 23, 24, 25, 26 and 27	255	11.27
	March	24, 25, 26, 27 and 28	198	14.4
	April	22, 26, 28 and 29	145	14.35
		Total	3745	280.43

Appendix B

Table A2. Sighting Rate, Residency Index Value, Category of Sighting Rate, and Category of Residency for Each Irrawaddy Dolphin Individual Discovered.

Irrawaddy Dolphin Individual	Sighting Rate (%)	Residency Index (RI)	Category of Sighting Rate	Category of Residency
OBP040	2.56	0.01	LSR	Transient
OBP010	2.56	0.01	LSR	Transient
OBP041	2.56	0.01	LSR	Transient
OBP042	2.56	0.01	LSR	Transient
OBP043	2.56	0.01	LSR	Transient
OBP044	5.13	0.04	LSR	Transient
OBP045	2.56	0.01	LSR	Transient
OBP046	2.56	0.01	LSR	Transient
OBP047	5.13	0.04	LSR	Transient
OBP048	2.56	0.01	LSR	Transient
OBP049	2.56	0.01	LSR	Transient
OBP050	2.56	0.01	LSR	Transient
OBP051	5.13	0.04	LSR	Transient
OBP052	2.56	0.01	LSR	Transient
OBP053	5.13	0.04	LSR	Transient
OBP054	10.26	0.16	MSR	Seasonal Resident
OBP055	2.56	0.01	LSR	Transient
OBP056	2.56	0.01	LSR	Transient
OBP057	5.13	0.04	LSR	Transient
OBP058	2.56	0.01	LSR	Transient
OBP059	2.56	0.01	LSR	Transient
OBP060	2.56	0.01	LSR	Transient
OBP061	5.13	0.04	LSR	Transient
OBP062	5.13	0.04	LSR	Occasional
OBP063	2.56	0.01	LSR	Transient
OBP064	5.13	0.04	LSR	Transient
OBP065	2.56	0.01	LSR	Transient
OBP066	5.13	0.04	LSR	Occasional
OBP067	5.13	0.04	LSR	Transient
OBP068	7.69	0.09	LSR	Occasional
OBP069	2.56	0.01	LSR	Transient
OBP070	10.26	0.16	MSR	Seasonal Resident
OBP003	15.38	0.36	MSR	Seasonal Resident
OBP071	2.56	0.01	LSR	Transient
OBP072	2.56	0.01	LSR	Transient
OBP016	5.13	0.04	LSR	Occasional

Notes: Some Irrawaddy dolphins are transient, occurring only in one season, while others are occasional, seen in all seasons. Both transient and occasional dolphins have low sighting rates.

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