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A Young Eden's Whale (*Balaenoptera edeni edeni*) Wandering in a Busy International Container Port

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Abstract

Eden's whale (*Balaenoptera edeni edeni*) is one of the least-understood baleen whales, with a global distribution that is almost completely unknown; only a few basic population studies of this species have been reported thus far. On 29 June 2021, a single Eden's whale was sighted in Dapeng Bay, Shenzhen, a busy international container port. This sighting was the first record of a live Eden's whale in the area, and it attracted immediate widespread attention. Our research team monitored the whale, nicknamed "Xiaobu" by Shenzhen citizens, until its disappearance. There were 48 sightings of the whale over a period of 50 days during vessel-based surveys from 2 July to 29 August 2021. Xiaobu was mainly sighted in coastal areas with a depth of 8.70 to 16.30 m; it remained 1 km offshore. The whale moved in a small minimum convex polygon range of 44.67 km^2 and kernel density estimation range of 87.96 km^2. From 2 to 27 July 2021, the whale was sighted near the Liquefied Natural Gas Pier in the eastern part of Dapeng Bay; it moved toward the Yantian International Container Terminal in the western part of Dapeng Bay between 28 July and 25 August, after which it was not sighted again. Its shift from east to west may have been influenced by food distribution and/or a gradual increase in familiarity with the local environment. Aerial vertical photogrammetry estimated a short body length of 7.49 m, indicating a young whale. Based on stranding records from the Chinese coastal area, the Eden's whale population in Beibu Gulf presumably migrates northward to the East China Sea (approximately 2,000 km northeast) in April, and then returns in December. Xiaobu may have become separated from the Eden's whale group when whales reached Shenzhen during the northward migration.

Key Words: Dapeng Bay, Shenzhen, feeding behavior, vessel-based survey, Eden's whale, *Balaenoptera edeni edeni*

Introduction

Shenzhen, a special economic zone in southern China approved by the State Council in 1989, is a national economic center and major international modern metropolis. Dapeng Bay is managed by Shenzhen and Hong Kong. Shenzhen has two international terminals with heavy shipping traffic: (1) the Yantian International Container Terminal (YICT) and (2) the Liquefied Natural Gas (LNG) Pier. The YICT is a modern container deep-water transshipment port, as well as a major international financial trade and shipping center. In the past 20 y, only a few large cetaceans have been sighted in this area. A live female sperm whale (*Physeter macrocephalus*) strayed into Dapeng Bay and became stranded in Daya Bay in 2017. Additionally, a whale stranded at Shatoujiao, Dapeng Bay, Hong Kong, China, in 2005; Wang (2012) did not confirm the subspecies for this stranding, so it was either a Bryde's whale (*Balaenoptera edeni brydei*) or an Eden's whale (*Balaenoptera edeni edeni*).

On 29 June 2021, an Eden's whale (subspecies identified using eDNA; Zhang et al., 2023) was sighted in Dapeng Bay. This sighting was the first record of a live Eden's whale in the area, which attracted immediate widespread attention from citizens, the media, and scientists. The whale was nicknamed "Xiaobu." Eden's whale is a subspecies of Bryde's whale, a smaller coastal form. Although dead Bryde's whales have been recorded in the Yellow Sea, East China Sea, and South China Sea, living Bryde's whales were not reported in these areas until a sighting in 2018 near Weizhou Island in the Beibu Gulf of China (Chen et al., 2019). Most Bryde's whales stranded in

Chinese coastal areas were presumed to be Eden's whales; for example, several dead Bryde's whales in the Beibu Gulf and Zhejiang were molecularly identified as Eden's whales (Li et al., 2019). The global distribution of this subspecies is unclear; other than individuals sighted in the Beibu Gulf, only a few Eden's whale populations inhabit the Gulf of Thailand and the coast of Japan. To our knowledge, there are no comprehensive worldwide population data regarding Eden's whales, a poorly understood species for which minimal basic information is available.

After the Eden's whale, Xiaobu, was first sighted, a research team was formed which conducted monitoring for 50 d until the whale disappeared. Herein, we report basic information regarding the whale, including morphological measurements, movement range, and habitat utilization.

Methods

Vessel-Based Surveys

The Eden's whale was first sighted in Dapeng Bay on 29 June 2021. A team of scientists arrived in Dapeng Bay on 1 July and proceeded to conduct vessel-based surveys between 2 July and 29 August. Surveys were conducted from a vessel (6.15 m) equipped with a 60 hp engine, at a speed of 12 to 20 km/h. At least three investigators participated in each survey. Once the whale was sighted, the vessel slowed or stopped at a distance of ≥ 100 m. The time and location (longitude, latitude) were immediately recorded; and photographs and videos were acquired using a digital camera (Canon 1Dx Mark II; Canon Inc., Tokyo, Japan), video cameras (Sony PXWFS5; Sony Corporation, Minato City, Tokyo, Japan), and unmanned aerial vehicles (DJI Phantom 4 Professional; DJI, Shenzhen, China). Sea environment variables were also recorded; these variables included salinity, water depth, surface water temperature, weather conditions (e.g., wind direction, wind force, wave height), and anthropogenic activities (e.g., number and type of vessels, fishing activities).

External Morphology Measurements

It was difficult to measure the external morphology of the live Eden's whale when it was moving. Aerial vertical photogrammetry from an unmanned aerial vehicle offered a relatively successful method for collecting measurements. In the present study, only aerial vertical photographs of the whale were used to calculate body length and width (lateral distance), based on the formula established by Pitman et al. (2007): $L = l \times scale = (n \times \mu) \times (H/f)$, where n is whale pixel number, μ is pixel size, H is altitude (m), and f is lens focal length (m).

Habitat Use

Basic measurements of habitat use by marine animals—for example, gray whales (*Eschrichtius robustus*), bowhead whales (*Balaena mysticetus*), and humpback whales (*Megaptera novaeangliae*)—are occurrence density and home range size (Quakenbush et al., 2009; Smultea et al., 2012; Martins et al., 2013). Distribution core area was calculated using the density tool in *ArcGIS*, Version 10.4.1. The minimum convex polygon (MCP) and kernel density estimation (KDE) home ranges were also estimated using *ArcGIS*.

Results

From 2 July to 29 August 2021, the Eden's whale in Dapeng Bay was monitored for 50 d along a total of 1,164 km for 172.32 survey hours (mean = 3.45 h/d; Figure 1). Photographic identification was used to confirm sightings of the same Eden's whale, Xiaobu, each day during the surveys. Based on aerial vertical photographs of the whale, body length and maximum body width were estimated to be 7.49 and 0.88 m, respectively. Xiaobu was sighted on 37 of the 50 d (mean = 0.74 sightings/d). The mean duration of each sighting was 1.80 h (range: 0.08 to 5.43 h). Excessive wind or rain, including three typhoons (In-fa on 19 July, Cempaka on 23 July, and Lupit on 4 August), interrupted field observations for several days and led to gaps in the data (Figure 1). The encounter rate (hours whale present/total hours of field observation) with Xiaobu considerably decreased from 2 July (0.98) to 8 July (0); it then increased and remained as a stable high encounter rate during the next 8 d. After the three typhoons, the encounter rate generally remained lower than 0.3 until 10 August when it was 0.46 to 0.82 (Figure 1). The whale was not sighted again after 25 August.

Spatiotemporal Distribution

Generally, Xiaobu was sighted in coastal waters from the YICT in the west to Guanhu in the east (Figure 2). The MCP and 95% KDE home range sizes were 44.67 and 87.96 km^2, respectively. The 50% KDE core range was 16.40 km^2: 10.38 km^2 concentrated in the east and 6.02 km^2 concentrated in the west. During diurnal monitoring, the whale's mean range was 0.292 km^2 (0.005 to 0.921 km^2).

Xiaobu exhibited significant variation in spatiotemporal distribution (Figure 2, right). From 2 to 21 July, it was mainly sighted in eastern waters near Guanhu Beach. Between 22 July and 2 August, sightings began to occur in Da-Xiaomeisha. After 7 August, sightings were mainly concentrated in

Da-Xiaomeisha and the YICT. The whale was not sighted again after 25 August. The MCP ranges for the three periods were 4.09, 20.18, and 1.25 km^2, respectively.

More often, Xiaobu was sighted farther away from the Guanhu-LNG at high tide than at low tide, but there was no obvious variation in distribution between the two tide periods around the YICT (Figure 2, left).

Xiaobu was often sighted in coastal waters—77.08% of sightings were within 1 km offshore, and the whale often appeared within 500 m offshore (37.50%) in depths ranging from 8.69 to 24.26 m (mean = 11.87 m). In these locations, the salinity ranged from 28.8 to 32.0‰, and the sea surface temperature ranged from 26.6° to 32.0°C. Because of administrative limitations, only waters belonging to Shenzhen were investigated, but the whale also utilized Hong Kong waters—for example, the whale swam toward Hong Kong waters in the east, and then moved back and forth within the boundary of Shenzhen and Hong Kong

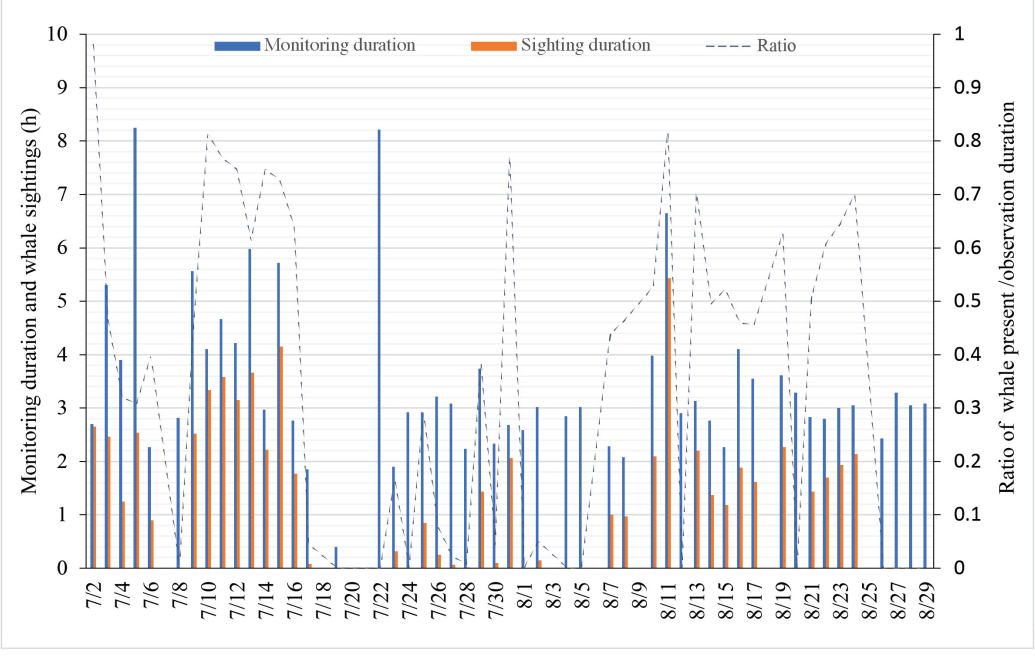

Figure 1. Monitoring duration, Xiaobu sighting duration, and the ration between these two (sighting duration/observation duration) of the Eden's whale (*Balaenoptera edeni edeni*) in Dapeng Bay, Shenzhen, China, between 2 July and 29 August 2021, near a Liquefied Natural Gas (LNG) facility in the Yantian International Container Terminal (YICT)

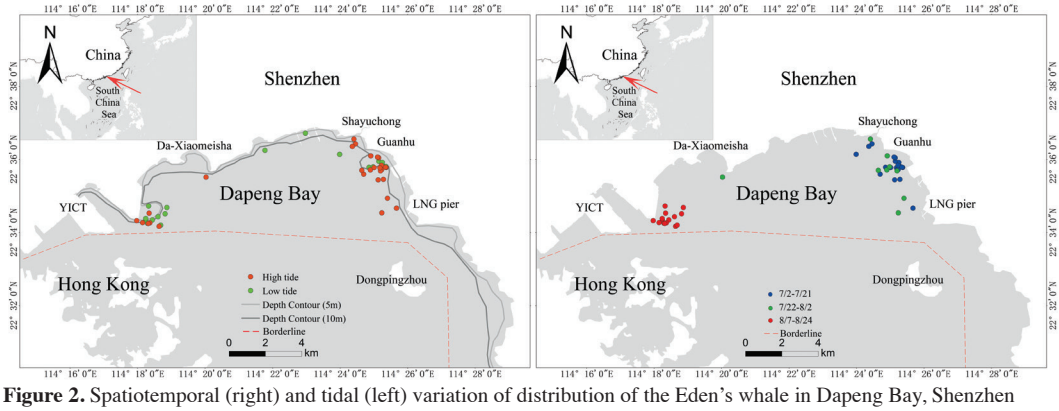

Figure 2. Spatiotemporal (right) and tidal (left) variation of distribution of the Eden's whale in Dapeng Bay, Shenzhen

in the YICT. Therefore, the exact pattern of the whale's range in Hong Kong waters is unknown.

Feeding Behavior

Xiaobu was observed to feed on fish using four predatory behaviors: (1) upright lunge feeding (UPL), (2) right lateral lunge feeding (RLL), (3) trap feeding/tread water feeding (TPF; Figure 3), and (4) pirouette feeding (PIF; Figure 4). The frequencies of UPL and RLL were generally low (once and twice, respectively), whereas PIF (n = 362) and TPF (n = 315) were the dominant feeding patterns. In TPF by Eden's whale, the whale generally rises slowly and vertically out of the water amid a prey swarm at the surface, exposing its head with its mouth opened widely until it is at, or just below, the waterline. After holding this position for some seconds, the whale closes its mouth and rolls forward or sideways, swallowing the prey underwater (Chen et al., 2023). PIF is a newly defined behavior of Eden's whales in Beibu Gulf that was reported by our group (Chen et al., 2023). The whale lifts its head above the water, opens its mouth, and inclines the lower jaw to 90°. After the jaws are extended below the waterline, the whale tilts its head to the right (or possibly to the left), lifting the left jaw edge out of the water and lowering the right edge below the surface. Subsequently, it swings (≥ 90°; Xiaobu reportedly made three circles) to the right (or possibly to the left), scooping up fish at the surface. After approximately 5 to 20 s, the mouth closes, and the whale briefly rolls into the water in an arbitrary direction. It then swings its body upright, swimming forward. The feeding bouts of Xiaobu gradually increased between July and August; they exceeded 15 times/h after 16 August (Figure 5).

Figure 3. Trap feeding by the Eden's whale in Dapeng Bay, Shenzhen, on 5 July 2021 (*Photo credit:* Bingyao Chen)

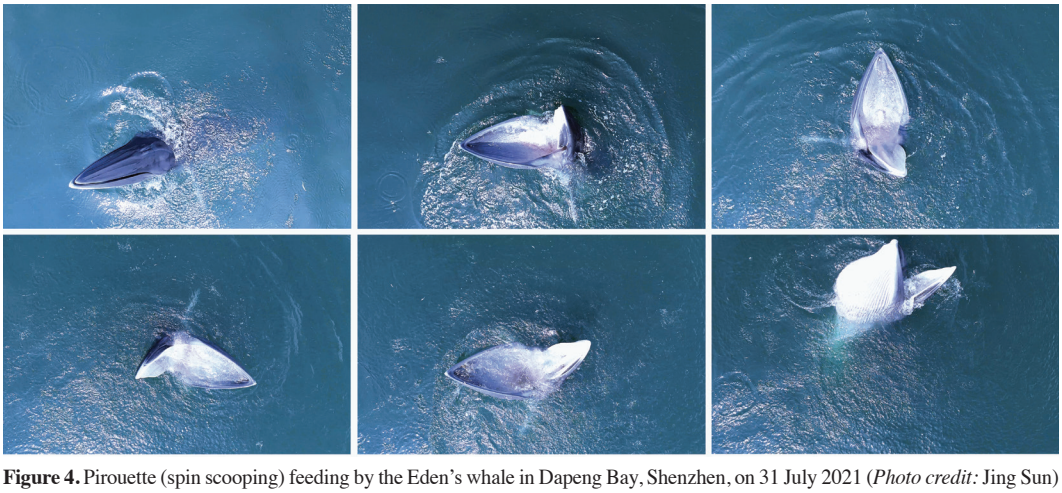

Figure 4. Pirouette (spin scooping) feeding by the Eden's whale in Dapeng Bay, Shenzhen, on 31 July 2021 (*Photo credit:* Jing Sun)

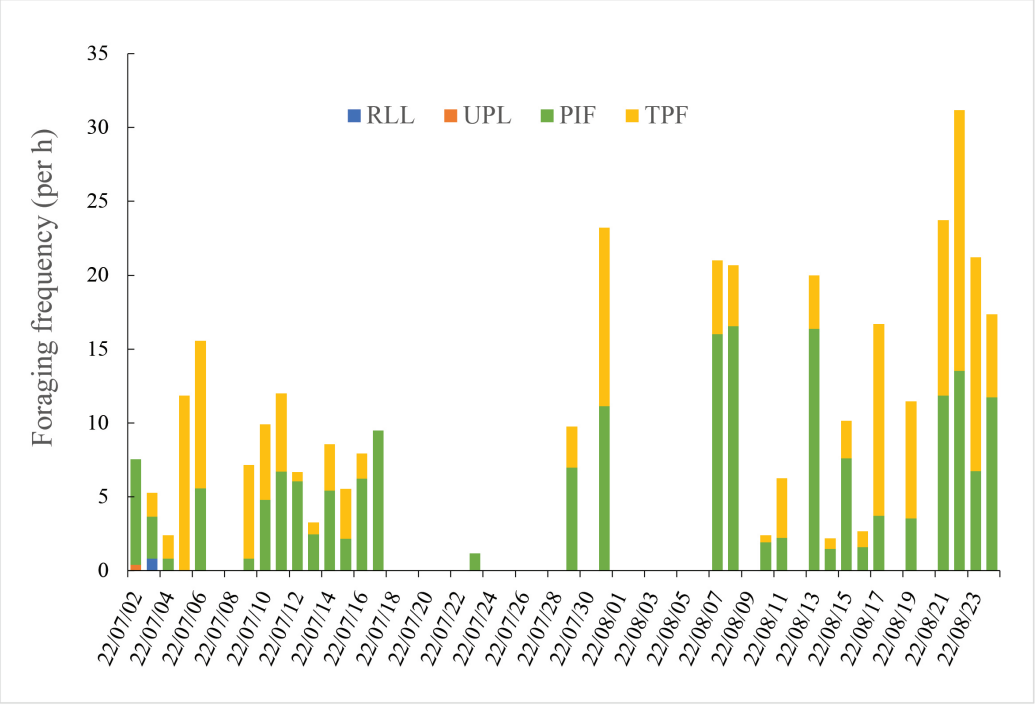

Figure 5. Daily feeding frequency and various behaviors of the Eden's whale in Dapeng Bay, Shenzhen

Table 1. Prey species for the Eden's whale in Dapeng Bay, Shenzhen

Date (d/mo/y)	Scientific name	Quantity	Average weight (g)	Average length (cm)
23/7/2021	*Thryssa* spp.	12	1.16	5.5
23/7/2021	*Mugil cephalus*	1	16.60	14.1
25/7/2021	*Sardinella zunasi*	1	9.58	9.1
30/7/2021	*Konosirus punctatus*	4	57.94	17.0
31/7/2021	*Konosirus punctatus*	7	78.54	19.2
17/8/2021	*Thryssa* spp.	14	2.31	7.1
19/8/2021	*Thryssa* spp.	9	3.76	7.8

Using photographs and video for identification, along with fish capture (immediately after the Eden's whale had fed), we determined that Xiaobu preyed on a minimum of four fish species: (1) dotted gizzard shad (*Konosirus punctatus*), (2) sea mullet (*Mugil cephalus*), (3) Japanese sardinella (*Sardinella zunasi*), and (4) anchovy (*Thryssa* spp.) (Table 1).

Discussion

In these sightings, Xiaobu (body length: 7.49 m) fed on fish, indicating that it was not a calf. Based on a previous report of a 7.1 m weaning calf (Wang, 2012), Xiaobu was regarded as a newly weaned juvenile. The Eden's whale is a social animal, and Xiaobu was presumably separated from a group, raising questions regarding the location of the population from which it originated. The global distribution of Eden's whales

is unknown. To our knowledge, only three populations occur around Southeast Asia: (1) in the Gulf of Thailand (Chiu, 2009); (2) in Beibu Gulf, China (Chen et al., 2019); and (3) in Japan/East China Sea (Cherdsukjai et al., 2015). The Eden's whales in the Gulf of Thailand did not match any Eden's whales in the Beibu Gulf by comparison of dorsal fin photos (Zhang Xuelei, pers. comm. with Kongkiat Kittiwatanawong from the Phuket Marine Biological Center, Thailand, December 2018 and March 2020). Therefore, it is unlikely that Xiaobu originated from the Gulf of Thailand. Xiaobu also did not match any identified Eden's whales in the Beibu Gulf (our photo-ID database); however, this does not exclude the possibility that Xiaobu originated from the Beibu Gulf population because some individuals in Beibu Gulf had no identifiable distinct characteristics, just like Xiaobu. We were also unable to determine whether Xiaobu originated from the East China Sea, where basic information regarding Eden's/Bryde's whale populations is extremely sparse.

This species does not make long-distance seasonal migrations, although it may move widely across ocean basins while crossing tropical and warm waters (Kato et al., 2009); short-distance migrations have been documented in some areas (Jefferson et al., 2019). If a short migration occurred, Xiaobu presumably originated from the Beibu Gulf population or East China Sea population; otherwise, Xiaobu may have been separated from a resident population offshore of Hong Kong/Shenzhen. In China, there are some records of dead and stranded Eden's whales along the coastal areas from Nantong to Hainan (Wang, 2012); these indicated that an Eden's whale population may have migrated along the China coast. In 2021, Eden's whales in Beibu Gulf disappeared on 28 April; 2 mo later (29 June), Xiaobu was sighted in Dapeng Bay, Shenzhen, 570 km northeastward. Furthermore, another Eden's whale (not Xiaobu) was stranded in Zhejiang, 940 km northeast of Shenzhen, on 27 July (confirmed from Provincial Bureau of Oceans and Fisheries, 28 July 2021). These locations are consistent with a northeastward migration. Therefore, we speculate that the Beibu Gulf population begins to migrate northeastward along the China coast at the end of April or beginning of May, arriving in Guangdong Province (including Shenzhen) in June and Zhejiang Province in July, and then in Jiangsu Province or Shandong Province in August or September (ultimate destination unknown). It begins to migrate back in September or October, returning to the Beibu Gulf in November to December, where it remains until the following May. Further studies are needed to verify this proposed migration route.

It is unclear why Xiaobu entered and remained in Dapeng Bay for nearly 2 mo, but food availability is the most likely driving force. The spawning seasons of prey fish were June to August for *Thryssa* spp., May to July for *S. zunasi*, and April to June for *K. punctatus* (Jiao et al., 2001); *M. cephalus* spawns throughout the year (Shi et al., 2003). Xiaobu presumably chased fish stocks into Dapeng Bay and then became separated from its group. Because fishery resources are most abundant in summer (Mao et al., 2017), Xiaobu presumably remained in Dapeng Bay and missed migrating with other whales.

Another reason for its appearance in Dapeng Bay may be the low density of shipping and boats in this area. Because of the impact of the COVID-19 pandemic, which lasted until February 2023 in China, activity in the YICT was suspended between 21 May and 24 June 2021; thus, there were no large cargo ships in the area.

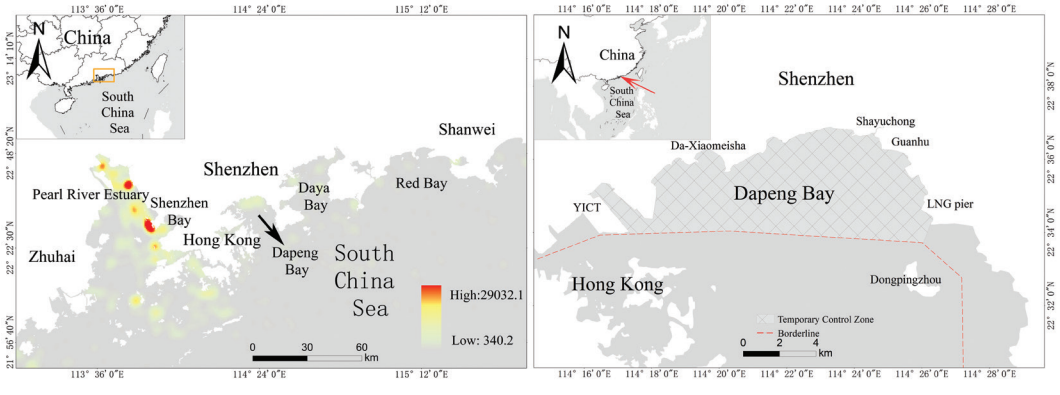

Figure 6. Vessel density near where the Eden's whale was observed (left) and a temporary control zone (right) in Dapeng Bay, Shenzhen, and adjacent waters in July 2021

The fishing moratorium period was from 1 May to 16 August in the East China Sea and South China Sea; no fishing boats operated on the sea during this period. Therefore, the low boat density (Figure 6, left) provided an opportunity for the whale to enter the area.

Xiaobu may have traveled into Dapeng Bay while searching for richer feeding sources. At the beginning of July, Xiaobu preyed on fish in the Guanhu-LNG using four feeding methods (PIF, TPF, UPL, and RLL). These feeding behaviors are a common form of predation in both the Beibu Gulf and the Gulf of Thailand. In Beibu Gulf, Eden's whales displayed abundant feeding behaviors—for example, PIF, TPF, UPL, RLL, left lateral lunge feeding, vertical lunging, and cooperative lateral lunging. In the Gulf of Thailand, Eden's whales displayed oblique (UPL), vertical, and lateral lunging, as well as a novel tread water feeding method. The tread water feeding method is characterized by holding the vertical posture for several seconds with an open mouth at the water surface (Iwata et al., 2017); it possibly belongs to a variation of TPF (Chen et al., 2023). The baleen whale lunge feeding strategies UPL and RLL are energetically costly because of the drag produced by swimming with an open mouth at high speeds (Goldbogen et al., 2017). Several days later, the whale in Dapeng Bay appeared to abandon UPL and RLL; instead, it adopted the less energetically costly PIF and TPF strategies. After its arrival at the YICT in August, foraging frequency considerably increased as compared with observed foraging activity in July. This increase indicated that the whale may have found larger fish schools in the YICT than in the Guanhu-LNG.

Since Xiaobu may have been recently weaned, as an inexperienced juvenile, it was susceptible to human disturbance. In Dapeng Bay, which has a developed tourism industry, Xiaobu avoided approaching tour vessels; it usually changed direction, stopped predation, or dived. Under the leadership of the relevant departments of the Dapeng New District and with the participation of marine biology research experts, the Dapeng New District Cetacean Conservation Joint Working Group was established on 2 July 2021. Dapeng New District asked the public not to watch or feed the whale. It also warned passing vessels to (when possible) maintain a safe distance from areas in which the whale had been sighted. Coastal police, maritime affairs, and marine comprehensive law enforcement departments strengthened the intensities of their patrols and persuaded whale-watching boats to leave the area; relevant departments also collected floating garbage for subsequent disposal. On 1 August, Shenzhen planned to establish a Temporary Control Zone in the Dapeng Bay (Figure 6, right) in an effort to reduce the impact of the fishing season on the Eden's whale. On 16 August, the Shenzhen government prolonged the fishing moratorium period until the whale disappeared on 29 August. What triggered the young whale to venture inside Dapeng Bay remains unknown, but our observations of this young whale independently foraging in this location were unexpected.

Acknowledgments

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