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Short Note

First Sighting Observations of the Pacific White-Sided Dolphins (*Lagenorhynchus obliquidens*) in December Around Japanese Waters North of Latitude 36° N

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The Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) is one of the most abundant dolphin species in the cold-temperate North Pacific Ocean (Black, 2018). They are a highly gregarious species that may occur in groups of less than hundreds or in large herds comprising thousands of individuals (Stacey & Baird, 1991; Brownell, 1999). Pacific white-sided dolphins change their distribution seasonally, which is probably related to their prey distribution (Norris & Prescott, 1961) and environmental conditions (Leatherwood & Reeves, 1978). Stomach content analyses suggest they feed opportunistically on schooling fishes and cephalopods, and their predominant prey species appear to vary by region (Kajimura & Fiscus, 1980; Black, 1994). Favourable habitats used by Pacific white-sided dolphins are associated with ocean fronts, the location of upwelling regions, and continental slopes (Gowans & Whitehead, 1995; Tynan et al., 2005; Black, 2018). Water temperatures are thought to strongly influence the timing of migration and the distribution pattern of Pacific white-sided dolphins in spring and summer (Shibata et al., 2007; Kitamura et al., 2008; Iwahara et al., 2017). Previous studies on the occurrence of Pacific white-sided dolphins in the western North Pacific indicate dolphins typically distribute in sea surface temperatures (SSTs) ranging from 7° to 22°C (Kasuya, 1978). Another sighting survey conducted in various seasons during 2009 through 2016 along the Japanese coast has also shown a similar SST range (Iwahara, 2016). Although seasonal distribution patterns of Pacific white-sided dolphins were previously studied, data collected in December only covered the coastal waters south of 35° N in the Sea of Japan (Ishikawa, 1994; Kasuya, 2011; Iwahara, 2016).

Seasonal movement patterns of Pacific white-sided dolphins along the Japanese coast have been described in historical data (Figure S1; supplemental figures for this short note are available on the *Aquatic Mammals* website). According to records from strandings, bycatch (e.g., from set net and gillnet fisheries), and whaling operations, the southern boundary of the Pacific white-sided dolphins' winter range is around the coast of Wakayama and Mie Prefectures on the North Pacific Ocean (Ishikawa, 1994; Kasuya, 2019), and off the San-in Region in the Sea of Japan (Miyazaki, 1980; Hashida et al., 2023). In spring, Pacific white-sided dolphins from both the North Pacific and the Sea of Japan start to move northward, arriving in southern Hokkaido during late spring and early summer (Ichimori et al., 2013). Onboard observations along the Hokkaido coast sighted Pacific white-sided dolphins east of Cape Erimo, southern Nemuro Strait, and along both sides of the Shiretoko Peninsula in autumn (Furumaki et al., 2023). Genetic differences have been found between Pacific white-sided dolphins in Japanese coastal waters and those in the offshore waters of the North Pacific (Hayano et al., 2004). Furthermore, along Japanese coasts, two genetically distinct populations with external morphological differences have been determined (Suzuki et al., 2023). Different populations of Pacific white-sided dolphins likely share waters in the Sea of Okhotsk during autumn. Information about seasonal distribution and migration patterns is fundamental to elucidating the ecological characteristics of Pacific white-sided dolphins around Japan. Spatial-temporal information about Pacific white-sided dolphins provides insight into understanding where and how they shift over time.

Compared to the numbers of their winter records off the Kyusyu coast in southern Japan, less information has been collected in the waters further north of 36° N owing to the rough weather and sea conditions in wintertime. Stranding and sighting data (Uni, 2006; Miyashita & Zharikov, 2013; Iwahara, 2016; Furumaki et al., 2023)

documented the occurrence of Pacific white-sided dolphins from early winter (January) to late fall (November) above 36° N, but there are no records for the month of December. With the use of a large research vessel built to withstand rough sea conditions, we were able to collect sighting data of Pacific white-sided dolphins in December around the waters further north of 36° N for the first time. This short note contributes valuable information by providing the first confirmed sightings of Pacific white-sided dolphins in December and fills a significant gap in current knowledge about the distribution of Pacific white-sided dolphins around coastal waters in the Sea of Japan, the North Pacific side of Japan, and the Sea of Okhotsk.

On 8 December 2020, researchers from Hokkaido University and the Atmosphere and Ocean Research Institute at the University of Tokyo boarded research vessel R/V *HAKUHO-MARU* (Japan Agency for Marine-Earth Science and Technology [JAMSTEC], Yokosuka, Kanagawa, Japan; 3,991 gross tons). The primary objective of this cruise was to collect vertical profiles of hydrographic parameters (e.g., water temperature, salinity, nutrients) to investigate the interlinkage among ocean, sea ice, material circulation, and the ecosystem around Shiretoko in the southern Sea of Okhotsk. *In situ* observation stations were predetermined in water regions bounded by latitudes 45° 09' N to 43° 40' N, and by longitudes 143° 24' E to 145° 48' E. The transect lines for the marine mammal sighting survey were carefully planned by an expert marine mammal researcher and primarily covered coastal waters on the North Pacific side of Japan, as well as in the Sea of Japan and the Sea of Okhotsk. On the North Pacific side, survey transects extended approximately 14 to 75 km from shore; while in the Sea of Japan and the Sea of Okhotsk, transects were conducted within 40 km up to 155 km of the shoreline, respectively. Only a limited number of researchers were permitted onboard due to the vessel's COVID-19 safety guidelines.

To ensure the quality of data collection, we selected two experienced marine mammal observers to conduct a sighting survey of Pacific white-sided dolphins. Both observers were trained professionals in cetacean identification. Observers carried out a dedicated visual survey on the vessel's upper bridge (height above water = 13.35 m) throughout daylight hours, from 1 h after sunrise to 1 h before sunset, between 9 to 24 December 2020. Using monopod-mounted 7×50 Fujinon binoculars, the observers continuously scanned a 180° arc from 90° starboard to 90° port relative to the vessel's course. Basic survey parameters and sighting conditions (including weather conditions, visibility, wind speed and direction, Beaufort scale, wave height, sight ability, and glare) were recorded at the start of each survey day and updated at 30-min time intervals thereafter. A meteorological observation system onboard the vessel automatically collected SST data every 10 s. For each encounter, visual cues (e.g., blow, splash, body), time, geographic location, radial distance (r), sighting angle (θ), species, behaviour, group size, and associated circumstances (e.g., flocks of birds) were collected. Radial distance was first estimated by naked eyes and then corrected using a laser rangefinder (LASER 1200S; Nikon Vision Co. Ltd, Tokyo, Japan), and sighting angle was measured with an angle board. Perpendicular distance x from the transect line to a detected dolphin group was calculated using simple trigonometry: $x = r\sin\theta$. Each observer independently counted the minimum, maximum, and best number of Pacific white-sided dolphins in each sighted group. The maximum and minimum estimates defined the range, while the "best" estimates represented the observers' most confident counts and were used in the following analyses. Observers were considered "on-effort" when the vessel speed travelled at a speed of 5 to 6 m/s under good weather conditions (i.e., Beaufort scale of level 5 or lower and visibility exceeding 3.7 km). Sightings collected under poor survey conditions were excluded to avoid potentially inconsistent or incomplete observation effort. Only "on-effort" observations were used to estimate Pacific white-sided dolphin density and daily encounter rates throughout the voyage.

Using the *R* package 'Distance' (Miller et al., 2019), we fitted a detection function to the perpendicular distance to estimate the effective strip width (ESW: m). A half-normal detection function was applied, incorporating the Beaufort scale as a potential covariate to account for variations in detectability due to sea state. To estimate density, we divided the total number of on-effort sightings by the size of survey area, where the survey area size was calculated by multiplying the total distance of on-effort course by estimated ESW. Daily encounter rate was calculated to examine the spatial distribution of Pacific white-sided dolphins across the survey area during the cruise. We first divided the survey area into 0.1° cells along the on-effort transect lines. The total number of sightings within each grid was summed, and encounter rates were determined by dividing the total number of observed Pacific white-sided dolphins by the on-effort survey distance covered within each grid cell. Seasonal shifts in the distribution of Pacific white-sided dolphins are thought to be primarily influenced by water temperature (Shibata et al., 2007; Kitamura et al., 2008; Iwahara et al., 2017). Hence, to investigate the relationship between

SST and the distribution of Pacific white-sided dolphins along the transect line surveyed during this cruise, we prepared remote-sensed daily SST data. The SST dataset was obtained at 0.01° to 0.01° spatial resolution from the daily Multi-scale Ultra-high Resolution (MUR) SST product (JPL MUR MEaSUREs Project, 2015). Geographic coordinates of each sighting location were cross-referenced with the SST dataset each day, and SST values corresponding to each sighting were extracted using the *R* package 'rerddapXtracto' (Mendelssohn, 2020).

Excluding an onboard drill conducted on 8 December after departure and a standby day on 16 December due to rough sea conditions, observers conducted 15 d of marine mammal sighting surveys between 8 to 24 December 2020. Sighting surveys in the North Pacific Ocean were conducted on 9 and 24 December, in the Sea of Japan on 10 and 23 December, and in the Sea of Okhotsk from 11 to 22 December. During the 15-d survey, Pacific white-sided dolphins were sighted on 26.7% of the survey days. Survey transect lines spanned a total of 1,492.03 km of which 433.32 km were surveyed on-effort (Figure S2). Observers faced adverse weather conditions, including snow, strong winds (maximum wind speed: 22.7 m/s), and fog. These conditions resulted in approximately 70% of the survey effort being conducted at a Beaufort scale > 5, which was classified as off-effort observations.

Using the R/V *HAKUHO-MARU* as a sighting platform enabled us to observe a total of 413 Pacific white-sided dolphins in 15 groups during both off- and on-effort observations (Table 1). The largest group, made up of ~200 dolphins, was observed along the Fukushima coast on 24 December. Of all the observations, 77 individuals in eight groups were recorded during the on-effort surveys. Sightings were distributed both off Fukushima on the North Pacific side of Japan and around southern Hokkaido in the Sea of Japan during both the middle and end of December (Figure 1).

The density estimation of Pacific white-sided dolphins derived from on-effort observation was 0.32 individuals/km^2 (ESW = 274.41 m, CV = 0.45; Figure S3). Survey effort calculated along the on-effort transect lines per 0.1° grid cell is presented in Figure 2a. Effort was higher in the coastal waters of the North Pacific and the Sea of Japan compared to the Sea of Okhotsk. Among on-effort observations, the highest encounter rate (6.44 individuals/km) was recorded off Ishinomaki on 9 December, a relatively lower encounter rate (0.70 individuals/km) was recorded off Hiyama Subprefecture in southern Hokkaido, whereas the encounter rate was zero in the Sea of Okhotsk (Figure 2b).

SSTs, continuously collected from the onboard meteorological observation system, characterized their spatial variation along all of the survey

Table 1. Number of individuals and groups of sighted Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) during the cruise in 2020

Date (d/mo)	Number of individuals	Latitude (°N)	Longitude (°E)	SST value (°C)	Daily group number	Daily individual number	Area
9 Dec.	1	38.29	141.86	13.31	3	46	Miyagi and Otsuchi Coast (North Pacific Ocean)
	30	38.31	141.86	13.25			
	15	39.31	142.16	13.35			
10 Dec.	5	41.70	139.85	13.22	5	31	Hiyama and Oshima Coast (southern Hokkaido, Sea of Japan)
	8	41.75	139.84	12.39			
	8	41.77	139.83	11.99			
	5	42.25	139.67	11.27			
	5	42.27	139.68	11.27			
23 Dec.	2	41.54	139.91	13.40	1	2	Oshima Coast (southern Hokkaido, Sea of Japan)
24 Dec.	60	37.91	141.50	12.12	6	334	Miyagi and Fukushima Coast (North Pacific Ocean)
	40	37.80	141.45	11.96			
	200	37.31	141.22	12.04			
	10	37.29	141.21	12.06			
	20	37.19	141.16	12.18			
	4	36.99	141.13	12.19			

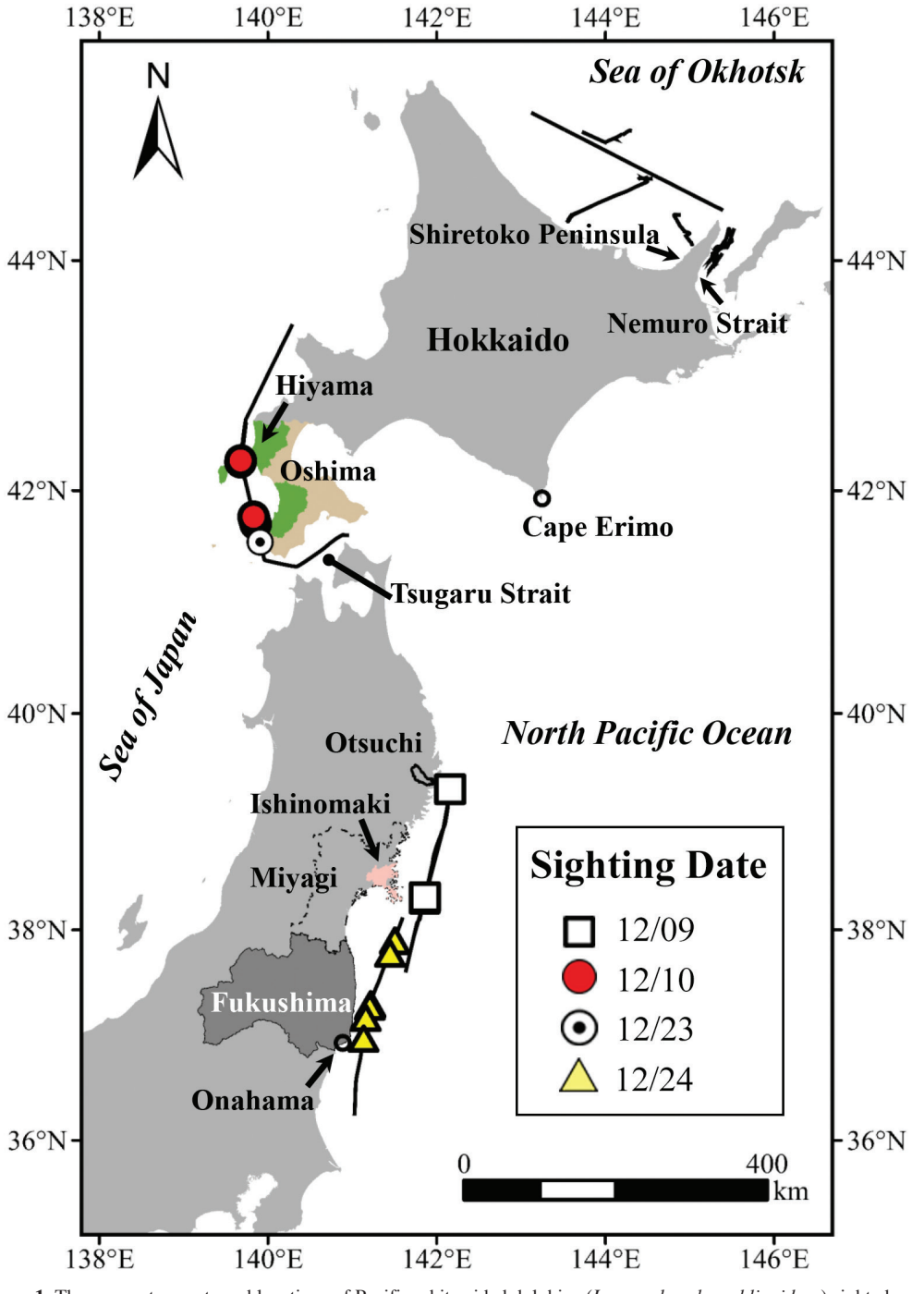

Figure 1. The survey transects and locations of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) sighted around the northern coastlines of Japan. Symbols indicate sighting dates as follows: hollow squares for 9 December, solid circles for 10 December, circles with centre dots for 23 December, and solid triangles for 24 December. The solid black line represents the vessel survey track. Major locations and sea regions are labeled on the map—specifically, Ishinomaki City is highlighted in pink, Hiyama Subprefecture in green, and Oshima Subprefecture in beige. The Shiretoko Peninsula, Nemuro Strait, and the Tsugaru Strait are labeled with arrows.

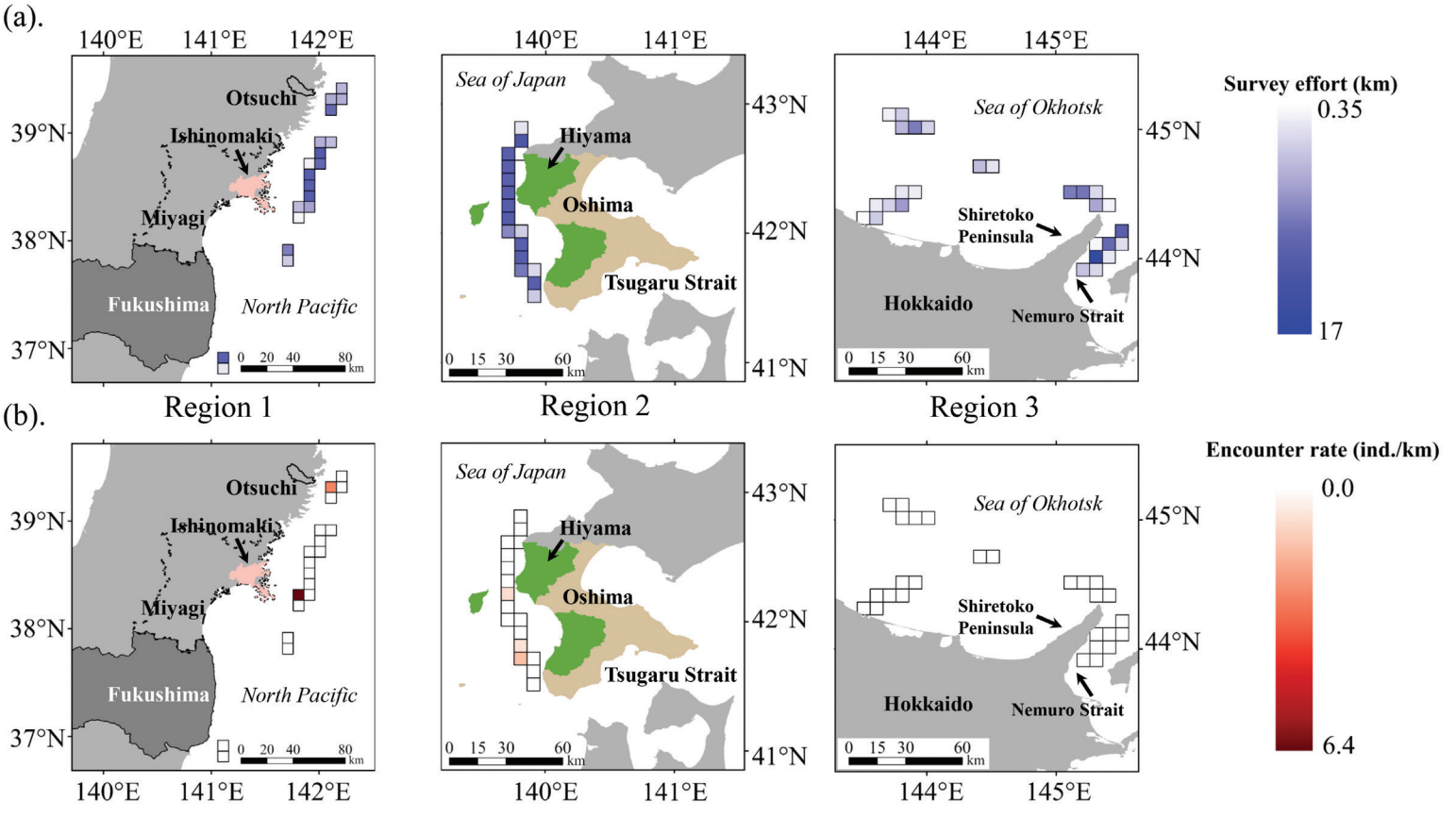

Figure 2. Maps showing (a) daily survey effort (km) and (b) encounter rate (sighted individuals/distance) of Pacific white-sided dolphins. The survey area is divided into three subareas: Region 1 (37 to 40° N, 140 to 142° E), Region 2 (41 to 43° N, 139 to 141° E), and Region 3 (43 to 45° N, 143 to 146° E). The color scales represent survey effort (km) within each grid cell during the survey period in panel (a) and encounter rate (individuals/km) in panel (b). Darker grid cells indicate greater survey effort in (a) and higher encounter rates in (b). Coastlines with major locations and water bodies are labeled on the map—specifically, Ishinomaki City is highlighted in pink, Hiyama Subprefecture in green, and Oshima Subprefecture in beige.

transect lines (including both off- and on-effort observations). On the North Pacific side of Japan, the transect lines covered areas with SSTs ranging from 12.03° to 18.04°C (mean: 13.87°C). In the Sea of Japan, SSTs along the transect lines ranged from 9.80° to 15.70°C (mean: 12.19°C). In the Sea of Okhotsk, water temperatures were the lowest, with SSTs ranging from 1.36° to 6.95°C (mean: 3.49°C). Daily remote-sensed SST data corresponding to sighting locations indicated that Pacific white-sided dolphins were observed in SSTs ranging from 11.27° to 13.40°C. The mean SST for both off- and on-effort sightings was 12.40°C (Figure 3).

The R/V *HAKUHO-MARU* provided a stable platform that enabled us to conduct a sighting survey of Pacific white-sided dolphins despite challenging sea states in northern Japanese waters above 36° N during December. Although large research vessels are essential for conducting such surveys in rough sea conditions, their operation is costly and requires significant resources, including fuel, crew members, and experienced observers. Although the Fisheries Agency of Japan has been monitoring cetacean species in the waters adjacent to Japan since the 1980s, dedicated sighting surveys of cetaceans were restricted due to budget schedules, and they more often occurred in summertime (Kasuya,

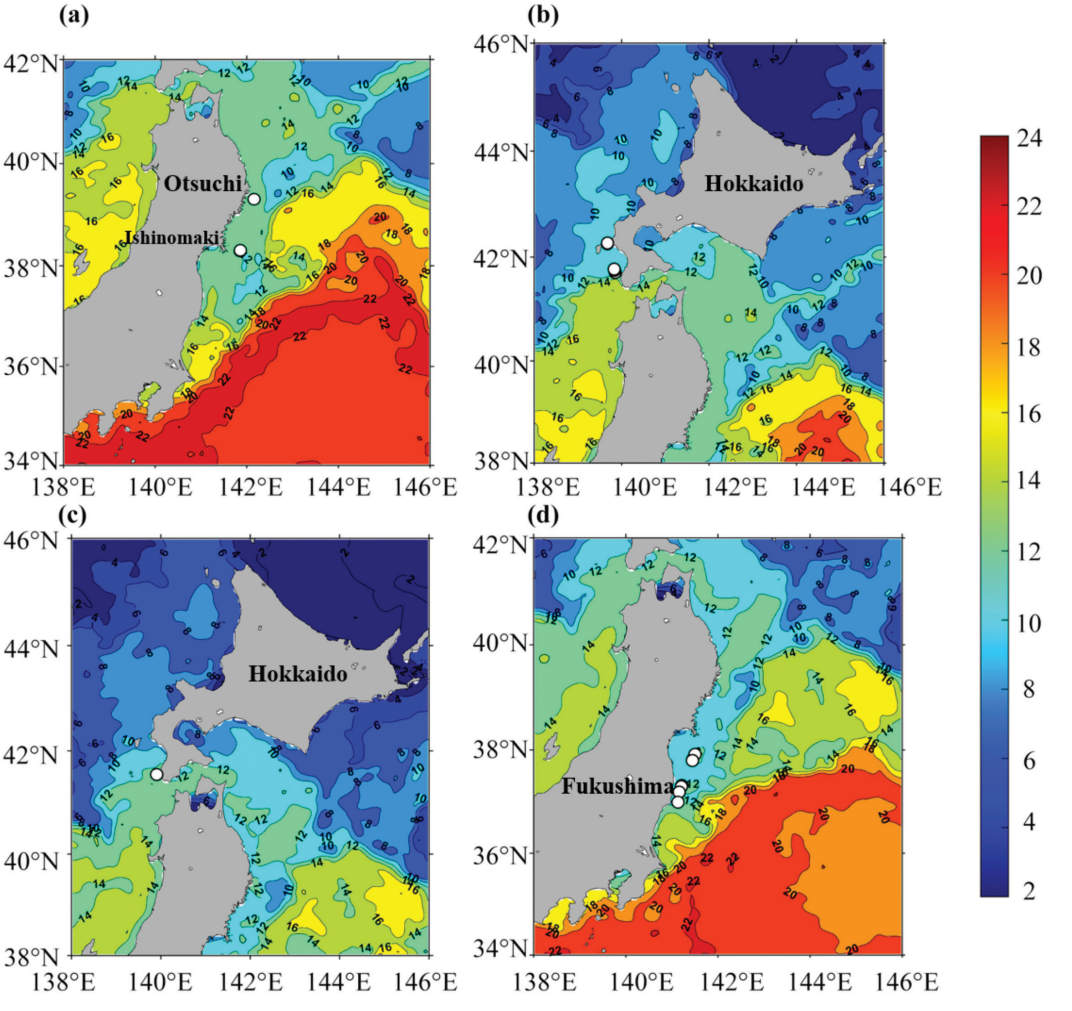

Figure 3. At-sea locations of Pacific white-sided dolphins with corresponding daily sea surface temperature observed on (a) 9 December, (b) 10 December, (c) 23 December, and (d) 24 December. White circles with black outlines represent sighting locations of Pacific white-sided dolphins.

2019). Besides our survey, only one other sighting survey of Pacific white-sided dolphins has been conducted in winter months (between 12 November and 21 December 2010). That survey focused on the coastal waters south of latitude 36° N in the Sea of Japan but did not record any Pacific white-sided dolphins during the survey period (Iwahara, 2016). Using an integrated oceanographic research cruise, our study provides more information on the distribution of Pacific white-sided dolphins in waters north of 36° N during December. Transect lines in this study were intentionally planned to target coastal areas where Pacific white-sided dolphins are more likely to occur (Furumaki et al., 2023). Our report may help to determine future transect lines for ship-based surveys of Pacific white-sided dolphins during winter. We suggest future surveys use a large vessel that can operate in rough sea conditions and also that observers continue to concentrate efforts in areas where dolphins are more likely to occur.

The sea states were challenging throughout the survey period, with approximately 70% of observations conducted in Beaufort scale > 5. Although detection probability may decrease with increasing Beaufort scale, group size and detection cues also play an important role in detecting dolphins (Barlow, 1995; Brandon et al., 2002). Pacific white-sided dolphins are generally conspicuous and are unlikely to be missed when large groups occur on the transect line, even under rough sea conditions. Pacific white-sided dolphins are known to be attracted by vessels for bow-riding (Black, 2018). During the survey, smaller groups (≤ 20 individuals) were detected within 1 km, with detection cues including conspicuous splashes and distinctive body features (e.g., colour patterns, hooked dorsal fins). Medium-sized groups (20 to 100 individuals) were sighted at distances of 0.15 to 0.8 km, while the largest groups (200 individuals) were detected at 2.5 km. Bow-riding behaviour was frequently observed during the survey period, which further enhanced detection reliability. On-effort observations were conducted under optimal sea conditions (Beaufort scale ≤ 5), which ensured higher detection probability and more reliable density and encounter rate estimates. We highly recommend extending survey periods and collecting data across multiple years while sighting surveys of Pacific white-sided dolphins are being conducted in northern Japanese waters during winter. These approaches may help to collect comprehensive data on the distribution of Pacific white-sided dolphins and may enable robust analyses on sighting data. In addition, integrating visual surveys with other methods, such as passive acoustic monitoring, may help confirm the presence of dolphins under challenging conditions.

We found the water temperature varied across the surveyed ocean regions. The mean SST along the transect line in the Sea of Okhotsk (3.49°C) was the lowest among all survey areas. Decreasing water temperatures in mid-December in the Sea of Okhotsk likely motivates Pacific white-sided dolphins to move southwards to reduce the metabolic cost of thermoregulation (Rechsteiner, 2012). In our study, Pacific white-sided dolphins occurred in SSTs ranging from 11° to 14°C in the waters above latitude 36° N during December. These results are consistent with their preferred inhabiting water temperatures in other locations (Kasuya, 2011; Iwahara, 2016). Unfavourable SSTs may explain the absence of Pacific white-sided dolphins in the Sea of Okhotsk.

In addition to providing first-hand information on the distribution of Pacific white-sided dolphins in northern Japanese waters above 36° N, this study can inform conservation priorities for cetaceans. The sightings recorded on 23 December were detected within 2 km of floating offshore wind farms around the Fukushima coast (Figure S4). Offshore wind farms can affect cetacean species both during the construction phase, when noise-generating activities may disrupt cetacean behaviours, and after construction when the resulting artificial reef (i.e., wind turbine foundations) alter the structure and environment for local marine organisms (Madsen et al., 2006; Petersen & Malm, 2006). The offshore wind farms located near the sightings of Pacific white-sided dolphins have been operational for several years and likely affect marine fauna at lower trophic levels. A study on the fish communities and habitat composition in the central Baltic Sea identified changes in the aggregation and abundance of demersal fishes around wind farms (Wilhelmsson et al., 2006). Pacific white-sided dolphins feed on various prey species along the Japanese coast, including mesopelagic fishes, demersal fishes, and cephalopods (Matsuda, 2017).

Our data showing the presence of Pacific white-sided dolphins in the vicinity of wind farms highlight the importance of long-term monitoring and assessment of how offshore wind farms alter the local marine ecosystems and behavioural response of this species. The coastal waters around Fukushima are likely to serve as a migration pathway for dolphins that overwinter off northern Kyushu, as well as in the coastal areas of Mie and Wakayama Prefectures (Kasuya, 2019). There is a potential seasonal overlap between dolphins and wind farms. A better understanding of the distribution patterns of highly mobile Pacific white-sided dolphins may help decision-makers plan the installation of wind farms in time and space. The Japanese government is expanding offshore wind farms to increase production from renewable wind

energy sources with a goal of 10 GW capacity by 2030 (Ministry of Economy Trade and Industry, 2018). The selection of potential areas for offshore wind farm development around northern Japanese waters has historically only considered fish communities, but less is known about the impact on cetacean species like Pacific white-sided dolphins (Obane et al., 2021). Hence, continuous data collection is needed to quantify the interactions between human activities and Pacific white-sided dolphin behavioural patterns.

Note: The supplemental figures for this short note are available in the "Supplemental Material" section of the *Aquatic Mammals* website: https://www.aquaticmammalsjournal.org/supplemental-material.

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