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Habitat Use by Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) in Amakusa, Japan

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Abstract

Habitat use by Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) with a maximum group size > 100 individuals in the northern coastal waters of Amakusa-Shimoshima Island, western Kyushu, Japan, was examined for 51 d between October 1996 and December 1997. Systematic behavioral sampling and theodolite tracking techniques were used to collect data. The core habitat area (CHA), defined as the 50% kernel density estimate, was located in the northern coastal area near Tsuji Island. Occurrences of dolphin groups in the CHA were higher during ebb and low tides. A group behavior that corresponded to resting was seen around the CHA, while both traveling and feeding were seen in a wider area outside of the CHA. Dolphin groups were found in the eastern area of the CHA during morning hours, and the groups spent more time in the CHA in the afternoon hours. Unidirectional movements, mainly toward western offshore waters, occurred after 1600 h. Numerous dolphin-watching boats are attracted to the CHA. Managing policies and enforcement are required for the local dolphin-watching industry.

Key Words: Indo-Pacific bottlenose dolphin, *Tursiops aduncus*, cetacean, theodolite, habitat, dolphin tourism

Introduction

The Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) occurs in shallow coastal waters and around oceanic islands in the Indian and western Pacific Oceans (Hammond et al., 2012). This species' nearshore distribution makes it vulnerable to environmental degradation, direct exploitation, and conflicts with fisheries (Reeves et al., 2003). Genetically distinct, year-round populations of this species have been identified in Japanese waters (Hayano, 2013), and each population has no more than a few hundred individuals (Shinohara, 1998; Shirakihara et al., 2002; Kogi et al., 2004).

One of these populations inhabits the coastal waters of the Amakusa region in Kyushu, western Japan (Figure 1). A photo-identification survey was initiated in 1994 and continues currently; the estimated abundance is around 200 individuals (Shirakihara et al., 2002). Bycatch and dolphin-watching tourism are known to have an effect on this population; the annual bycatch has been reported to be greater than the potential biological removal (PBR) of this population based on abundance estimated using a mark-recapture technique (Shirakihara & Shirakihara, 2012). Dolphin-watching boats offer regular trips to observe dolphins during daytime hours, and changes in dolphin behavior in response to the number of boats have been documented (Matsuda et al., 2011). Dolphin-watching tourism has prospered since 1993. With the development of the tourism industry, economic profit increased four- to fivefold compared to the 1990s (Hoyt, 2001; R. Leeney, pers. comm., 20 March 2015). In 2000, the dolphin-watching companies established voluntary guidelines to regulate their actions around dolphins—for example, a minimum approach distance of 30 m (Kishiro & Mori, 2000). However, the overall level of compliance was low since boat operators did not seem to adhere to the guidelines (R. Leeney, pers. comm., 20 March 2015). The necessity of additional research on habitat use and interactions with humans was recommended for this population (Brownell & Funahashi, 2013).

Land-based observations and theodolite tracking have revealed behavior and movement patterns of bottlenose dolphins (*Tursiops* sp.) occurring in nearshore waters (Würsig & Würsig, 1979; Acevedo, 1991; Harzen, 1998; Mendes et al., 2002; Hastie et al., 2004; Bailey & Thompson, 2006; Photopoulou et al., 2011). In addition, use

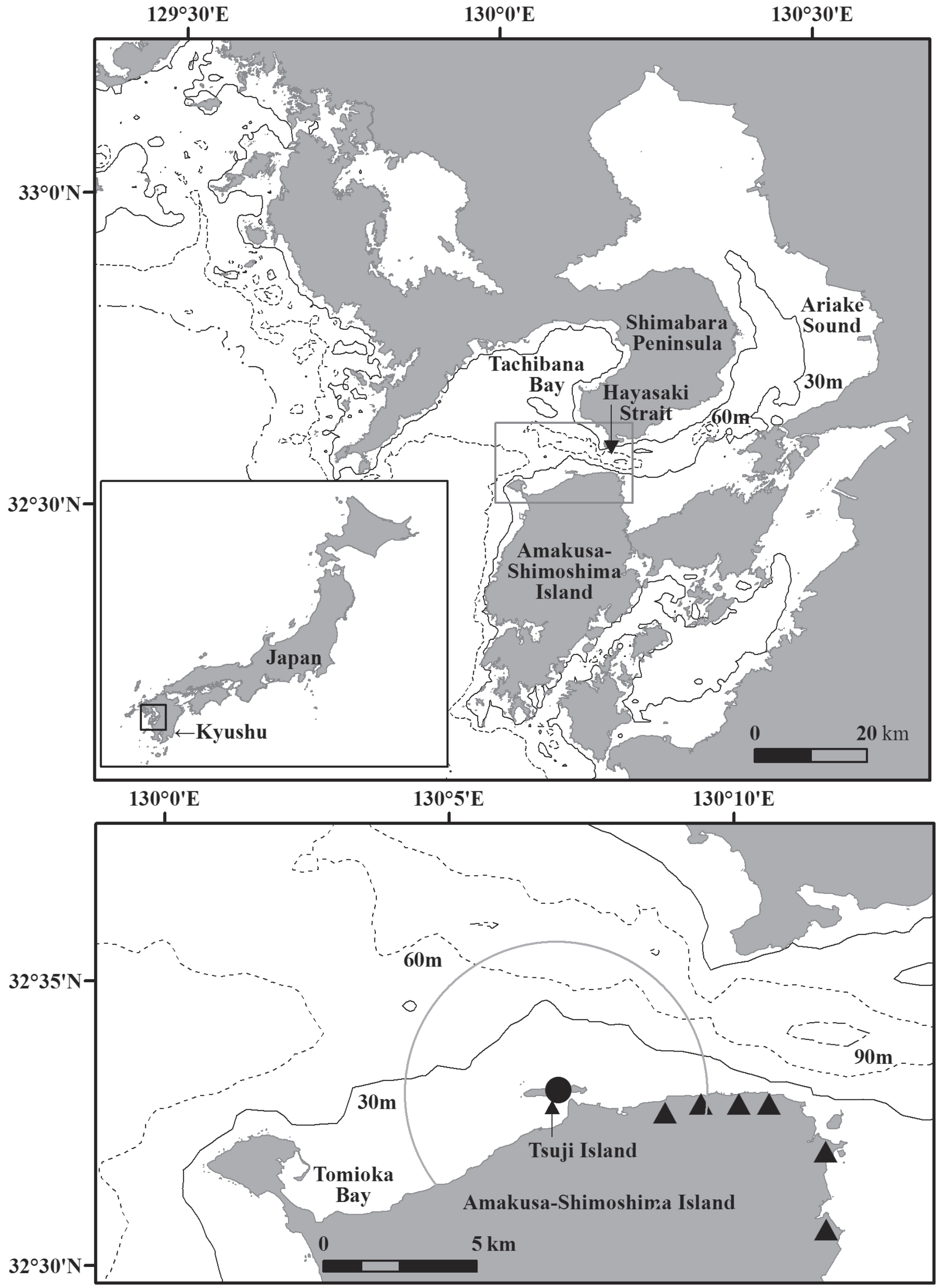

Figure 1. Location of the study area. Closed circle = theodolite station, and triangles = observation sites where behavioral observations were conducted in addition to those at the theodolite station. The half circle shows the approximate observation range of the theodolite.

of a theodolite is broadly applicable to assessments of dolphin behavioral changes potentially caused by vessels (Kruse, 1991; Bejder et al., 1999; Williams et al., 2002; Timmel et al., 2008; Matsuda et al., 2011; Lundquist et al., 2013). The advantage of this method is that dolphin behavior (in association to boats or not) can be observed without impact from research vessel presence. In the Amakusa region, dolphins, which are seen in the northern coastal waters of Amakusa-Shimoshima Island throughout the year (Figure 1), form large groups with > 100 individuals during daytime hours (Shirakihara et al., 2002). Dolphin groups can ben observed continuously from land.

The objective of this study was to reveal the habitat use patterns of dolphins in the northern coastal wastes of Amakusa-Shimoshima Island. We examined the core habitat area, diurnal group behavioral patterns, and environmental factors that might affect habitat use of dolphins via systematic behavioral sampling protocols and theodolite tracking techniques. Describing the dolphins' fine-scale habitat use will help develop better-informed policies for their conservation.

Methods

Study Area

The study area included the northern coast of Amakusa-Shimoshima Island, western Kyusyu, Japan (Figure 1). The island is located at the mouth of Ariake Sound, a highly productive estuary with a vast tidal flat and large tidal range (> 6 m). Tachibana Bay lies on the north side of the island and connects the sound to open water. The tidal current (maximum speed > 13.0 km/h) in the Hayasaki Strait runs in an east-west direction. According to Matsuno et al. (1999), the current carries low salinity estuary waters from Hayasaki Strait toward the north, while high salinity waters are distributed around Amakusa-Shimoshima Island.

Data Collection

Surveys were carried out from hilltop vantage points on Tsuji Island (40 to 46 m above sea level) located north of Amakusa-Shimoshima Island, and at six sites on the northeastern coast of Amakusa-Shimoshima Island (Figure 1). Three theodolite stations have been established on the hilltop, and we selected the most suitable for observations of dolphin groups. The search for dolphins from these hilltop vantage points by at least four people began at dawn—one theodolite tracking team and one behavioral observation team. After finding a dolphin group, we continued to track that group until it went out of view, the sea condition worsened, or the sun set. When no dolphin groups were spotted for several tens of minutes, members of the behavioral observation team moved to one of the other six sites to search for dolphins and started behavioral observations once a dolphin group was sighted. The location of a dolphin group was reported to the theodolite tracking team on the hilltop via a transceiver. The tracking team began to track the group once they found it. Most often, a single large group appeared in the study area, which prompted communication between the two teams. Surveys were conducted for between 1 and 14 h (average = 6 h) on 51 d between 16 October 1996 and 22 December 1997. Fifty-nine percent (30 d) of the surveys were conducted all day from dawn to sunset.

Many researchers classify activities of bottlenose dolphins into categories such as traveling, feeding, socializing, resting, and milling based on their surface behaviors, direction of movement, speed, and diving patterns (e.g., Shane, 1990). However, the present study did not use these categories because (1) detailed observations of surface behaviors were complicated due to the large average group size, with a mean minimum number of 62 individuals (95% CI = 48 to 76) according to photo-identification surveys (Shirakihara et al., 2002), and their large distance (> 1 km) from the coast; and (2) behavioral studies have not been previously carried out in this study area. Shane (1990) found that the pod geometry based on distance between individuals had a functional significance that varied depending on the dolphins' activity. Therefore, we recorded the following group behavioral data by focal follow and scan sampling methods (Martin & Bateson, 1986) using binoculars and a field scope. We also categorized group behavior and compared these results with dolphin activities reported in other waters:

- *Group formation* – Recorded every 3 min. Three type classes were identified as (1) compact oval, (2) line, and (3) widely dispersed. Distance among dolphins was within a body length in compact oval formation. Conversely, the distance was more than five body lengths in the other two types. In widely dispersed formation, dolphins swam in small subgroups.

- *The orientation of dorsal fins for the majority of dolphins in group* – Recorded every 3 min. This was divided into two types: (1) same and (2) different.

- *Duration of synchronous dives of dolphin group* – Recorded whenever observed.

- *Surface behaviors* – Recorded whenever observed. The following surface behaviors, which were visible from land, were recorded and analyzed: leap, breach, head slap, body slap, and tail slap. Stationary and synchronized leaps of two or three dolphins were recorded as social leaps. We did not record orientation of the body (dorsally or ventrally). We also recorded dolphins that were porpoising and fast swimming, often with constantly exposed fins, which were likely indicative of fish-chasing behavior (Shane, 1990; Hastie et al., 2004).

The position of the focal group was recorded using a theodolite (SOKKIA DT5 or DT20ES) set at hilltop vantage points on Tsuji Island (Figure 1). Group tracking was possible within an approximate 5 km radius of the theodolite stations. Vertical and horizontal angles at the most dense part of each dolphin group were saved to a laptop computer at intervals of a few seconds to several tens of seconds. Both angles were converted into positions (latitude and longitude), considering the altitude of the theodolite station measured by leveling from a triangulation point and the predicted sea level at the time of each reading. The distance between the most distant individuals in a group (i.e., the length of the aggregation) was obtained by measuring the positions of these individuals with the theodolite. The number of commercial dolphin-watching boats was recorded every 3 min as well as the number of recreational and research boats following the group. All surveys were carried out during Beaufort Sea State conditions of ≤ 3.

Data Analysis

A dataset (3-min interval) included the position of a dolphin group (latitude and longitude), behavioral category, frequency of occurrence of surface behaviors, apparent moving speed, time of day, tidal state, season, and the number of watching boats. When theodolite angles were not recorded with a 3-min behavioral data interval, then angle readings closest to that time interval were used. The dolphin group behavior was classified into 12 categories on the basis of group formation (three types), orientation of dorsal fins (two types), and the presence/absence of synchronous dives of the group during the 3 min (two types). We calculated the frequency of occurrence of surface behaviors (FSB), excluding porpoising and fast swimming. Apparent moving speed (AMS) was defined as follows:

$$AMS = D/T$$

where D is the straight distance between the previous and following locations of a focal group, and T is the moving time between locations so that lower values indicate a longer presence of groups within a specific area. The time of day and tidal state were calculated as follows: the time from dawn to sunset was divided into quarters—early morning (Em), late morning (Lm), early afternoon (Ea), and late afternoon (La). The longest time was in summer (0510 to 1930 h). The time from high tide to low tide and the time from low tide to the next high tide were divided into quarters—T1 to T4 and T5 to T8, respectively. Each symbol was assigned below: T1 and T8 – high tide, T2 and T3 – ebb tide, T4 and T5 – low tide, and T6 and T7 – flood tide. Season categories were defined as follows: spring (March to May), summer (June to August), fall (September to November), and winter (December to February).

Dolphin-watching boats were frequently in the study area (see "Results"). To reduce the effects of boat presence, we selected the center point of a series of data collected in succession during the absence of boats ($n = 268$). We assumed that each point was an independent datum.

Using a bivariate normal kernel density method, with reference bandwidth as a smoothing parameter for Home Range Estimation in *R*, Version 3.1.2 with the *adehabitatHR* package (Calenge, 2006), the 50 and 95% kernel range was calculated for all position data ($n = 268$). We defined the 50% kernel range as the core habitat area (CHA). In addition, the kernel range was estimated by season and by behavioral categories which occurred frequently (B1-B5; see "Results").

We used generalized linear models (GLM) with binomial distribution and a logit link function to examine whether environmental or behavioral factors (e.g., season, time of day, tidal state, and behavioral category) influenced the occurrence of dolphin groups within the CHA. Probabilities of their presence were modeled using the factors mentioned above as explanatory variables. The GLM was fitted using the maximum likelihood technique in *R*, Version 3.1.2, and model selection followed the Akaike's Information Criteria (AIC).

Differences in longitudinal positions of focal groups among time of day and among tidal state were examined by a Kruskal-Wallis test. Differences in AMS and in FSB among behavioral categories that occurred frequently (B1-B5; see "Results") were compared with the same method mentioned above. In addition, Steel-Dwass All Pairs tests (nonparametric multiple comparisons) were used for AMS and FSB. Differences in time of day and in tidal state were examined for presence/absence of dolphin groups in the CHA using Pearson's chi-square test. Frequencies of occurrences of behavioral categories (B1-B5) also were compared between the presence/absence of dolphin groups in the CHA using Pearson's chi-square test. *JMP*, Version 11.0 (SAS Institute Inc., 2013) was used for statistical analyses as well.

Porpoising, fast swimming, and social leaping might give direct support to the interpretation of behavioral category, but frequencies of occurrence of these behaviors in the dataset used (*n* = 268) were low. Therefore, comparison of the frequencies of these behaviors among behavioral categories (B1-B5) was not conducted. We illustrated locations of the dolphin groups in which these behaviors were observed.

Results

Appearance Situations of Dolphin-Watching Boats

Means of duration of time when no dolphin-watching boat attended a dolphin group and duration of time when any dolphin-watching boat(s) attended the dolphin group were 28 min (SD = 26) and 44 min (SD = 55), respectively. Mean number of dolphin-watching boats every 3 min increased in summer and fall and in the late morning and early afternoon (Table 1).

Table 1. Mean number of dolphin-watching boats (including research and recreational boats) following dolphin groups every 3 min

		Mean	SD	*n*	Max.
Season	Spring	1.3	2.1	1,585	11
	Summer	4.0	4.5	1,350	21
	Fall	2.9	3.3	2,014	20
	Winter	0.5	0.9	901	5
Time of day	Early morning	0.2	0.6	949	6
	Late morning	3.9	4.5	1,456	21
	Early afternoon	3.2	3.1	1,736	16
	Late afternoon	1.4	2.2	1,709	14

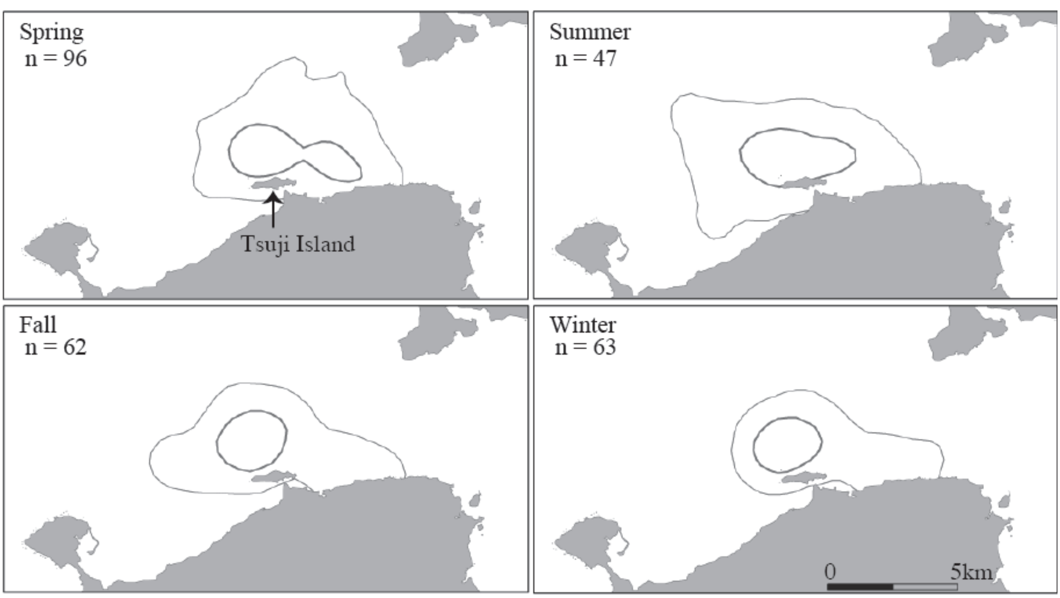

Figure 2. Spatial distribution of the 50% (inner line) and 95% (outer line) kernel ranges by four seasons

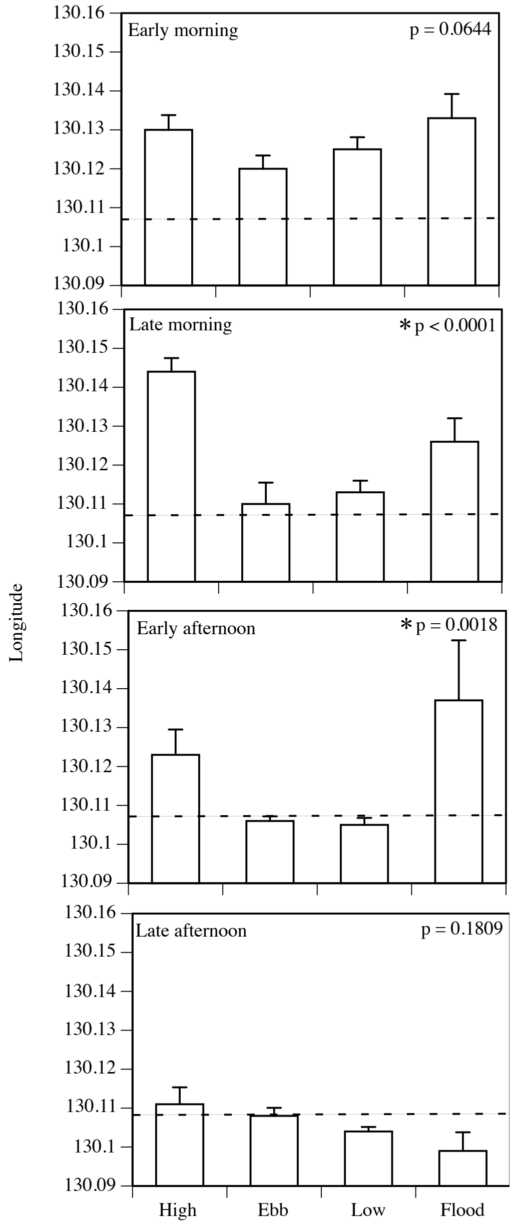

Figure 3. Mean longitudes of the focal dolphin group position by tidal state and time of day; bars and dotted line indicate SE and position of the center of the theodolite station, respectively.

Occurrence Patterns of Dolphins

Indo-Pacific bottlenose dolphins were tracked on all days surveyed (330 h in 51 d). In the surveys, which were conducted all day from sunrise to sunset, mean tracking time was 8 h (range = 2.5 to 12.5 h). The 50% kernel range was found in the coastal area north of Tsuji Island throughout the year (Figure 2). The 95% kernel range tended to be larger in summer. The mean time of the first fixed point for confirmation of a group observation from sunrise was 99 min in spring, 46 min in summer, 133 min in fall, and 229 min in winter (Kruskal-Wallis $\chi^2 = 9.4021$, $df = 3$, $p = 0.0244$). The ratio of observation hours (time spent tracking a dolphin group) to survey hours (time spent tracking and searching for a dolphin group) tended to increase in summer (67% in spring, 83% in summer, 72% in fall, and 58% in winter); a significant difference was detected between summer and winter (Wilcoxon test, $p = 0.0358$), suggesting that dolphins are on the outside of the observation range of the theodolite from fall to spring.

The mean geographic longitude of dolphin group positions differed among the time of day: early morning (Em), late morning (Lm), early afternoon (Ea), and late afternoon (La) (Kruskal-Wallis $\chi^2 = 61.5951$, $df = 3$, $p < 0.0001$). Dolphins were mainly seen in the coastal waters east of Tsuji Island in the morning hours. In addition, the mean longitude differed among tidal states (Kruskal-Wallis $\chi^2 = 23.3063$, $df = 3$, $p < 0.0001$); dolphins were found in the western area during ebb and low tides. Effects of tidal states was found during the day except in LA (Figure 3).

Group Behavioral Categories

Among the 12 behavioral categories, the categories of B1 through B5 accounted for 88% of the total observations when dolphin-watching boats were absent (Table 2). The frequency of each category of B1 through B5 ranged from 9.6 to 24.3%, while that of each of the other categories was 0.05 to 4.4%. Synchronous diving in a dolphin group was only seen in B1. The mean dive duration was 95 s (SD = 28, $n = 164$) when dolphin-watching boats were absent. Synchronous diving tended to continue, and the mean of surface interval between dives was 87 s (SD = 38, $n = 131$). Behavioral categories of B1 and B2 had compact oval formation, B3 had line formation, and B4 and B5 had widely dispersed formation. The mean distance between the furthermost individuals in a group was 70 m (SD = 28) for the compact oval formation, 238 m (SD = 144) for the line formation, and 542 m (SD = 320) for the widely dispersed formation (Kruskal-Wallis $\chi^2 = 34.8415$, $df = 2$, $p < 0.0001$). The orientation of dorsal fins was the same in B1 through B4 but was different in B5. Apparent moving speed (AMS) was significantly different among the behavioral categories of B1 through B5 (Kruskal-Wallis $\chi^2 = 24.5477$, $df = 4$, $p < 0.0001$; Figure 4), and the categories B1 and B5 had lower AMS than B3 (Steel-Dwass All Pairs test, $p < 0.05$). Frequency of occurrence of surface behaviors (FSB) was significantly different among the five categories (Kruskal-Wallis $\chi^2 = 28.1662$, $df = 4$, $p < 0.0001$; Figure 4), and behavioral category B1 had lower FSB than B2 through B5 (Steel-Dwass All Pairs test, $p < 0.05$).

Core Habitat Area and Behavior

The CHA was found in the coastal area north of Tsuji Island (Figure 5). The 50% kernel range of each behavioral category (B1-B5) overlapped with the CHA. However, the 50% kernel range of B1 and B5 were narrower than that of the CHA. In contrast, the 50% range of B2 through B4 was wider than the CHA. The GLM showed that dolphin occurrences within the CHA could be explained by the tidal state and time of day (Table 3). Dolphins were found within the CHA in the early and late afternoons (Pearson's χ^2 = 27.384, $p < 0.0001$; Figure 6). Dolphins were seen within the CHA during ebb and low tides but outside the CHA at high and flood tides (Pearson's $\chi^2 = 64.189$, $p < 0.0001$; Figure 6). Behavioral categories and inside/outside the CHA was not independent (Pearson's $\chi^2 = 23.551$, $p < 0.0001$; Figure 7). Behavioral category B1 showed the highest frequency (28%) of dolphins observed within the CHA. In contrast, 68% of observations outside the CHA were associated with behavioral categories B2 (31%) and B3 (37%).

Social leaps were seen more often in the northern waters of Tsuji Island, whereas porpoising and fast swimming were seen over wider areas, including the coastal areas of the west and east side of the island (Figure 8). A focal group frequently moved in one direction (mainly offshore to the west) in the afternoon after 1600 h (Figure 8); this was observed in 57% of the surveys, which were conducted all day from dawn to sunset ($n = 30$).

Table 2. Group behavioral category of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Amakusa, Japan ($n = 1{,}755$)

Category	Synchronous dive	Group formation	Orientation of dorsal fins	Frequency %
B1	Present	Compact oval	Same	16.2
B2	Absent	Compact oval	Same	24.3
B3	Absent	Line	Same	21.5
B4	Absent	Widely dispersed	Same	9.6
B5	Absent	Widely dispersed	Different	15.9
Others				12.4

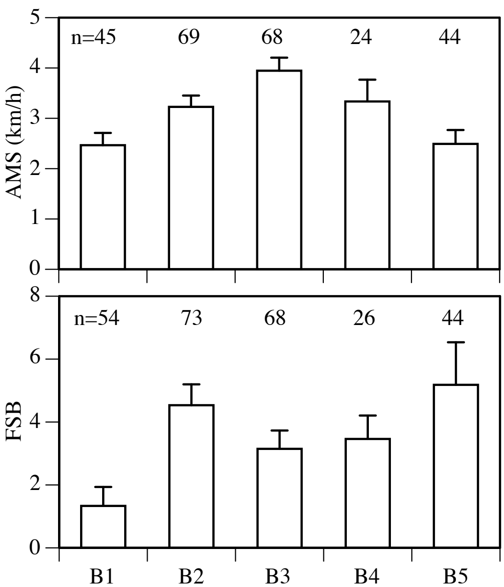

Figure 4. Means of apparent moving speed (AMS) and frequency of occurrence of surface behaviors (FSB) in each of the five behavioral categories (B1-B5); bars indicate SE.

Discussion

Indo-Pacific bottlenose dolphins were observed in the northern waters of Amakusa-Shimoshima Island, western Kyushu, Japan, throughout the year. The CHA was located in the coastal area north of Tsuji Island, where dolphins spent much of their time daily. Distribution of bottlenose dolphins, *Tursiops* sp., has been examined in aerial and ship surveys, which were conducted over a wide range of Ariake Sound and Tachibana Bay (Shirakihara et al., 1994; Yoshida et al., 1997; Shirakihara & Shirakihara, 2012). The results indicated that there were only a few sightings of *Tursiops* sp. except for in the northern waters of Amakusa-Shimoshima Island. We concluded that the waters north of Amakusa-Shimoshima Island, especially the coastal area north of Tsuji Island, are important habitat for this dolphin population.

In the present study, five behavioral categories (B1-B5) were recognized (Table 2). We compared these categories with dolphin activities reported in other waters (Shane, 1990; Lusseau, 2003; Mann & Watson-Capps, 2005; Stensland et al., 2006; Steiner, 2012; Karniski et al., 2015) and reclassified our behavioral categories to these dolphin activities. Behavioral category B1 with its low AMS and very low FSB had similar characteristics to the activity known as resting. Behavioral categories B2 and B3 had a high AMS, suggesting that

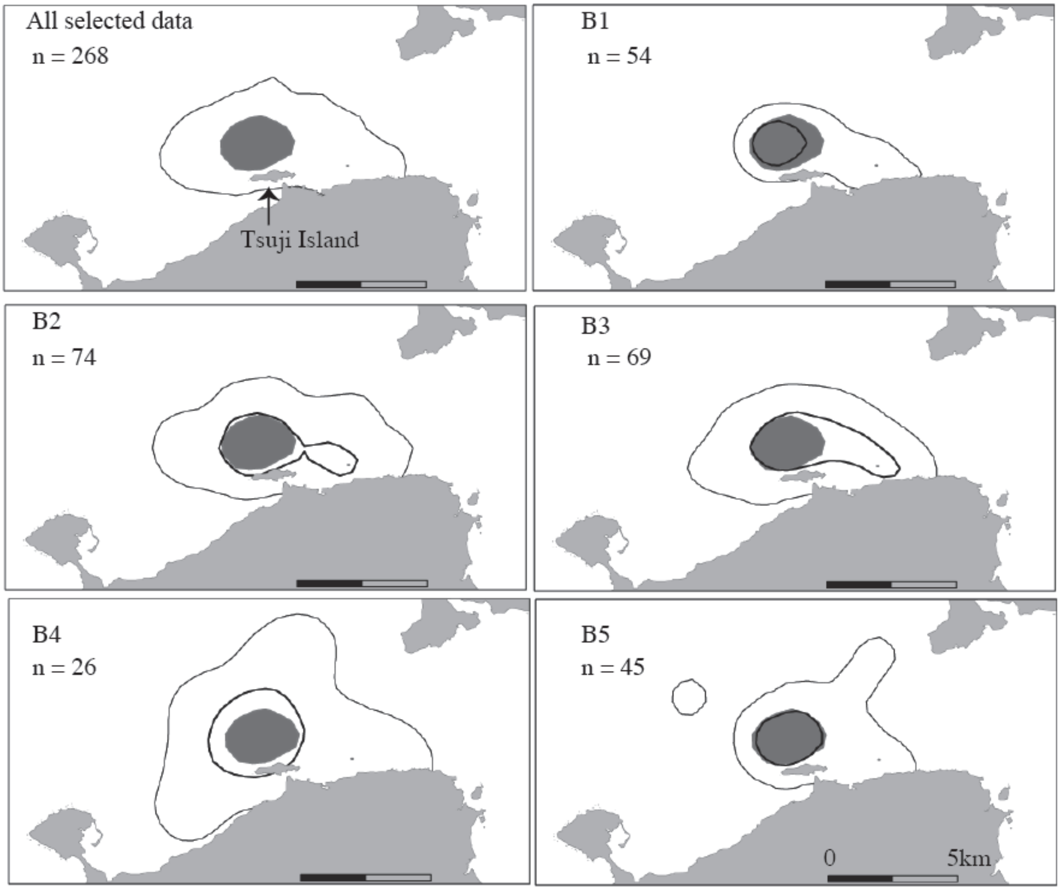

Figure 5. Spatial distribution of the 50% (inner line) and 95% (outer line) kernel ranges; dark gray shows core habitat area (CHA). The behavioral categories of B1 through B5 are defined in Table 2.

the group did not stay in one region. Their 50% of kernel ranges were wide. We considered these categories to resemble the activity known as traveling. Behavioral category B4 may occur at the starting time of feeding behavior; we have seen that dolphins milled in various locations after they moved rapidly in a dispersed formation. Similar behaviors have been reported for bottlenose dolphins in Argentina and South Africa (Saayman et al., 1973; Würsig & Würsig, 1979). Behavioral category B5 had the lowest AMS and the highest FSB. According to previous studies, FSB and no forward movement were characteristics of the behavior known as socializing; thus, B5 was somewhat similar, but behavioral category B5 may include feeding behavior as well.

We compared frequency of occurrence of each behavioral category (B1 corresponds to resting, 16%; B2 and B3 correspond to traveling, 46%; and B4 and B5 correspond to feeding or socializing, 26%) to the activity budget of Indo-Pacific bottlenose dolphins reported elsewhere: 9 to 34% for resting, 20 to 61% for traveling, and 32 to 66% for feeding or socializing (Möller & Harcourt, 1998; Chilvers et al., 2003; Mann & Watson-Capps, 2005; Stensland et al., 2006; Steiner, 2012). Frequency of occurrences of B1 through B3 (corresponding

Table 3. Evaluation of factors affecting occurrence within the CHA (estimated by 50% kernel density estimate) using Akaike's Information Criteria (AIC) of generalized linear models (GLMs) with explanatory variables. The symbol (*) shows the lowest AIC.

Explanatory variables	AIC
Tidal state + Time of day	385.9*
Tidal state × Time of day	388.0
Tidal state + Time of day + Behavior	388.7

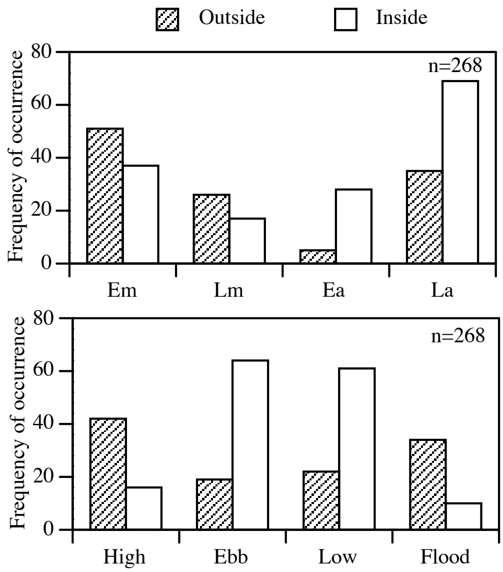

Figure 6. Frequency of occurrences of the focal dolphin group inside and outside of the CHA (estimated using the 50% kernel density) by time of day and tidal state. Sample numbers: n = 151 for inside of the CHA, and n = 117 for outside of the CHA. Em = early morning, Lm = late morning, Ea = early afternoon, and La = late afternoon.

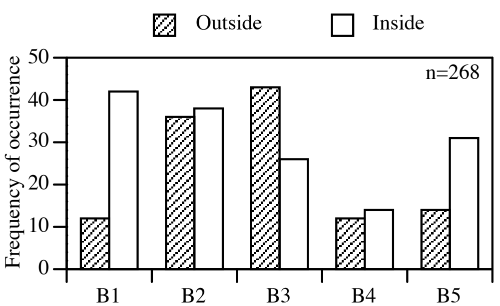

Figure 7. Frequency of occurrences of behavioral categories inside and outside of the CHA (estimated using the 50% kernel density). Sample numbers: n = 151 for inside of the CHA, and n = 117 for outside of the CHA.

to resting and traveling) was within the range of previous findings, but those of B4 and B5 (feeding or socializing) were below the range. This trend might be attributed to differences in survey methods and behavioral definitions (Steiner, 2011; Karniski et al., 2015). Feeding behavior might have been included in the other categories in Table 2; however, dolphins may have other feeding areas outside the study area, or dolphins may feed more actively at night.

There is a possibility that dolphins use a wider area beyond the study area at night. Most of the daily first sightings were located in the coastal area east of Tsuji Island. Often, a dolphin group moving in the direction of Tsuji Island was seen in the morning, suggesting that dolphins came from the Ariake Sound. In contrast, in the afternoon, movements offshore to the west were frequently observed. This pattern resembles the behavior of Hawaiian spinner dolphins (*Stenella longirostris*), which entered the bay in the early morning and departed in the late afternoon for nighttime feeding in deep waters (Norris et al., 1994). Most of our study area is shallow (< 30 m), but there is a deep sea area (> 60 m) between Shimabara Peninsula and Amakusa-Shimoshima Island, and near the middle of Ariake Sound (Figure 1). Bycatch of Indo-Pacific bottlenose dolphins and possible depredation of dolphins were reported in the central waters on the east coast of Tachibana Bay and in the middle waters of Ariake Sound (Shirakihara & Shirakihara, 2012). To clarify whether Amakusa dolphins hunt prey over wider areas at night, introduction of various research techniques, such as biologging techniques, including satellite tracking to this study area, would be required. Research using stationed acoustic buoys clarified some nocturnal behavior of the Indo-Pacific bottlenose dolphins around Mikura Island, Japan (Morisaka et al., 2015).

Porpoising and first swimming, and B4, which may suggest feeding, were seen in the wide area, including the outside of the CHA, suggesting multiple feeding areas exist in the northern coastal waters of Amakusa-Shimoshima Island. Dolphins preferred to stay in the CHA during ebb and low tides. According to the Marine Cadastre by the Japanese Coast Guard (www1.kaiho.mlit.go.jp/KAN10/kaisyo/tidal_c/index.htm), at ebb tide, the tidal current is predicted to flow toward the west in the coastal area east of Tsuji Island, near Hayasaki Strait, while it flows toward the east in the coastal area west of the island, near Tomioka Bay (Figure 1). At flood tide, the currents run eastward in both the east and west side of the island (i.e., the tide flows in the same direction). The longer time Amakusa dolphins spent within the CHA during ebb and low tides may be related to this complex flow pattern of tidal currents. The tidal current may provide feeding areas around Tsuji Island, especially during the ebb and low tide. Tidal effects on bottlenose dolphin movements, activities, and area use have been studied worldwide (e.g., Würsig, 1978). In the inner Moray Firth, dolphin sightings were most frequent during flood tide (Mendes et al., 2002). In contrast, in the outer estuary of the River Shannon, the sighting peaked during ebb tide (Berrow et al., 1996). These surveys were carried

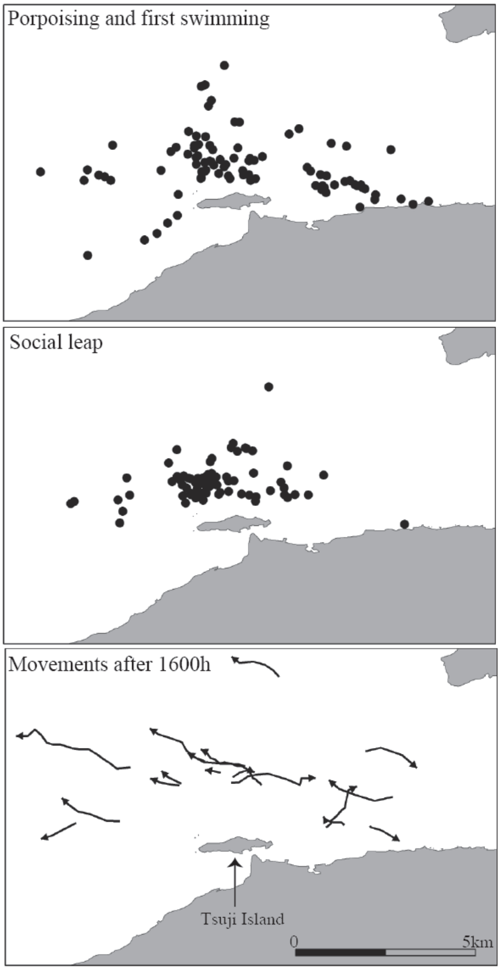

Figure 8. Locations of dolphin groups where porpoising, first swimming, and social leaping were observed, and where evening movements occurred after 1600 h

out from land. In a boat-based sighting survey for Indo-Pacific bottlenose dolphins in the Clarence River estuary, sightings peaked during flood tide, and dolphins were widely dispersed during high and flood tides rather than during low and ebb tides, possibly in response to prey distribution, temperature, risk of stranding, and habitat accessibility (Fury & Harrison, 2011).

Although this research was carried out in the late 1990s, ongoing research in the region confirms that a large group of dolphins is still present, and these dolphins are the focus of a large dolphin-watching industry (R. Leeney, pers. comm., 20 March 2015; M. Nishita, pers. comm., 20 March 2015). Numerous dolphin-watching boats are attracted by the CHA, but there are no official regulations for their activity in Amakusa. The B1 category, which corresponds to rest, was the most frequently observed behavioral category in the CHA. The CHA is considered to be an important resting area for the population. Lusseau (2003) revealed that the resting behavior was sensitive to boat interactions. In Amakusa, the effects of the presence of dolphin-watching boats on the behavioral category B1 were detected—namely, an increasing number of boats led to longer diving times, higher moving speed at the surface, larger distances from diving to subsequent surfacing positions, and shorter inter-diving intervals (Matsuda et al., 2011). The dolphins are vulnerable to dolphin-watching activity.

Given the intrusive nature and the frequency of dolphin-watching activities around Amakusa, which focuses solely on this population, the importance of the industry to the local economy, and also the known negative impacts of irresponsible cetacean-watching activities on wildlife, it is essential that this industry is better managed. Management actions should include a limit on the number of boats approaching a dolphin group and the amount of time that any vessel may spend with dolphins within a 24-h period. In Japan, there are dolphin-swimming locations where a limitation on the number of boats has been introduced (Mori, 2005; Kogi, 2009). Though voluntary, such self-imposed regulations are strongly recommended for managing dolphin-watching activities in the coastal area north of Tsuji Island. Our results related to habitat use by dolphins in the region support the development of dolphin-watching regulations.

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