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Emigration of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) from Mikura Island, Japan

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Abstract

Emigration of individual animals is an important biological phenomenon that depends on both populations and ecosystem attributes. Off Mikura Island, a long-term identification survey of individual Indo-Pacific bottlenose dolphins has been conducted since 1994 using an underwater video system. Between 1994 and 2014, 277 individual dolphins were identified by this survey, with 41 individuals emigrating from Mikura Island during this period. Adults emigrated significantly more often than younger age classes. The sex and age classes of emigrants in 2008 and 2010 (the years with the greatest amount of emigration) differed, suggesting that social relationships within a population may affect emigration. Emigrants were observed among the Izu Island Chain and in Chiba, Shizuoka, Mie, and Wakayama Prefectures. The greatest distance dolphins emigrated from Mikura Island was 390 km to Tanabe in Wakayama Prefecture. Some individuals were observed to have emigrated to several areas during the period. The most frequent destination was Toshima Island, one of the Izu Islands Chain, where emigrants have been observed to reproduce. Emigrant groups were composed exclusively of individuals from Mikura Island; there were no immigrants to the Mikura Island area during the 20-y period of observation, although six emigrants eventually returned to their original range. Future studies of social relationships and habitat use by emigrants will reveal more about the reasons dolphins leave their habitats.

Key Words: emigration, long-distance movement, Japan, Indo-Pacific bottlenose dolphin, *Tursiops aduncus*

Introduction

The Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) inhabits tropical and temperate coastal areas from the Pacific to the Indian Ocean. The genus *Tursiops* contains one other species, the bottlenose dolphin (*T. truncatus*). *T. aduncus* is smaller, with a longer rostrum and ventral spotting at maturity (Wang et al., 2000). In Japanese waters, populations of *T. aduncus* occur in coastal areas around Mikura Island in the Izu Island Chain, off Ogasawara Island, Amakusa-Shimoshima Island, Amami Oshima, and other areas (Shinohara, 1998; Shirakihara et al., 2002b; Kogi et al., 2004; Funasaka, 2013). These populations are all genetically distinct (Hayano, 2013) and display distinct acoustic characteristics (Morisaka et al., 2005).

Burt (1943) defined an animal's home range as "that area traversed by the individual in its normal activities of food gathering, mating, and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered as in part of the home range" (p. 351). The home ranges of *T. aduncus* have been investigated in many parts of the world, especially in Australia, where there are established populations in Moreton Bay (242 individuals, 350 km^2; Chilvers & Corkeron, 2003), Port Stephens (150 individuals, > 140 km^2; Möller et al., 2002), and Jervis Bay (100 individuals, 102 km^2; Möller et al., 2002). Males tend to have larger ranges than females (Sprogis et al., 2016). Similar-sized populations of *T. truncatus* with similar home ranges have been studied in various locations such as Sarasota Bay in Florida (approximately 100 individuals, 125 km^2; Wells, 2003), Moray Firth in Scotland (129 individuals, < 100 km^2; Wilson et al., 1997, 1999), and Doubtful Sound in New Zealand (83 individuals, 83.7 km^2; Lusseau et al., 2003). The home range of the *T. aduncus*

population off Mikura Island has not been conclusively determined, but we estimate it to be about 20 km^2. This estimate is based on the island's circumference of approximately 17 km, based on the observation that dolphins come as close as 300 m offshore (Kogi et al., 2004) and the assumption that home range extends about 1 km from the coastline. In 2016, this *T. aduncus* population contained 140 dolphins (Kogi, unpub. data), and the biennial re-identification rate from 1994 to 2011 was 92.9%, suggesting that there were few emigrants and migrants (Kogi, 2013). Therefore, this *T. aduncus* population is considered to be a nearshore resident population.

There is some evidence that Indo-Pacific bottlenose dolphins travel long distances (Fujita, 2003; Shirakihara et al., 2012; Takanawa & Jiromaru, 2012; Mori, 2013; Morisaka et al., 2013a, 2013b; Nishita et al., 2015). However, because dolphins spend most of their time under water, it is difficult to observe them over long periods, either from onshore or by boat, and sex and age can be challenging to determine. For instance, in 2000, some members of a population from the northern waters of Amakusa-Shimoshima Island, including two mothers and their calves (Nishita et al., 2015), moved to the south side of the island, approximately 60 km away. Between March and May of 2001, many of these emigrants returned to the north, but a few remained behind (Shirakihara et al., 2002a; Shirakihara & Shirakihara, 2012; Nishita et al., 2015). The details of these movements and the reasons behind them were not studied, and little specific information (such as sex and age) is known about the individual dolphins involved. Factors conceivably contributing to emigrations by odontocetes are prey availability, reproduction, climate, and physical environment (Lockyer & Brown, 1981). Predation, reproduction, and competition, driven by inherent characteristics of both populations and ecosystems, may drive individual dolphins to emigrate; therefore, it is necessary to study these factors, and the movements of individuals, to gain a better understanding of the phenomenon of emigration among dolphin populations.

A survey of the Mikura Island dolphin population has been continuously conducted since 1994. We are able to directly observe Mikura Island dolphins because underwater visibility is clear (~15 m on average; Kogi et al., 2004), and so we have been able to gather data on individual characteristics such as sex and mother–offspring relationships. Recreational divers contribute photos and videos from many sites off the Pacific coast of Japan, providing further data on emigrant dolphins that otherwise would be difficult to obtain, thus greatly supplementing the data we obtain from survey vessels. Therefore, we have accumulated a wealth of sighting data on which to base an emigration study. With these data, our aim was to investigate whether there was a bias in sex/age class, destination, and year in which dolphins emigrated. This is the first report to focus on the characteristics of emigrating individual *T. aduncus* dolphins.

Methods

Mikura Island is a small island in Japan, 16.92 km in circumference (20.58 km^2), located about 220 km south of Tokyo (33 to 52' N, 139 to 43' E; Figure 1). Indo-Pacific bottlenose dolphins are often observed in the area within 300 m of the coastline, where the depth is approximately 2 to 45 m.

The population size of Indo-Pacific bottlenose dolphins around the island is about 130 individuals (Table 1), and they are considered to be an independent population from the genetic study (Hayano, 2013). Since 1994, an identification survey of the population has been conducted by the Mikura Island Tourist Information Center (using an underwater video system), which generated large quantities of data. The surveys were conducted from research boats or commercial dolphin-watching boats between May 1994 and October 2014. Boats were used to search for dolphins around the island as far out as approximately 200 m from the coastline. Surveys aimed to cover the entire circumference of the island. The biennial re-identification rate was more than 80% (Kogi, 2013). Twenty-seven dolphins have been observed for 23 y since 1994. Therefore, we defined as *resident* (members of a resident population) all dolphins filmed and identified during identification (ID) surveys. When dolphins were sighted from a boat, a researcher entered the water and recorded natural markings (e.g., fin notches and body scars) while snorkeling, using various digital camcorders (e.g., Sony CX 430V) in a waterproof housing (e.g., NTF RVH-CX700V).

We used natural marks to identify dolphins from video recordings. Animals were identified as known individuals when they had more than three natural marks that matched a previous observation. Sex was determined by in-water visual inspection of the genital area and from underwater video footage. Identified dolphins were classed into four age groups: (1) neonate, (2) juvenile, (3) subadult, and (4) adult. Neonates are defined as being less than 1 y old. Juveniles are older than 1 y old but are accompanied by their mothers, while subadults are independent of their mothers. Adult males are those older than 15 y based on the study of testis maturation in this area (Funasaka et al., 2013), while adult females are those that have produced offspring (at any age). The youngest recorded mother during the

1994 to 2012 period of data collection was 7 y old. Neonates are easily identified by their fetal folds and floppy dorsal fins or flukes. Calves (neonates and younger juveniles) swim with their mothers in the echelon or infant positions during the first few years of life (Gubbins et al., 1999), which enabled us to identify mother–calf pairs.

Individuals from Mikura Island that were not resighted in the area after 1 y since first detection were defined as *disappeared*. Individuals from Mikura Island that were observed in other areas were defined as *emigrants*, while emigrants that were observed again around Mikura Island were defined as *reconfirmed*. Individuals that were never observed again in Mikura Island and were not spotted in other areas, or were confirmed as dead were defined as *lost*.

We used survey results to create an ID catalog describing natural marks on both flanks and dorsal and ventral sides, and we recorded sex and age class for each individual dolphin. We then identified individuals by comparing video data to the ID

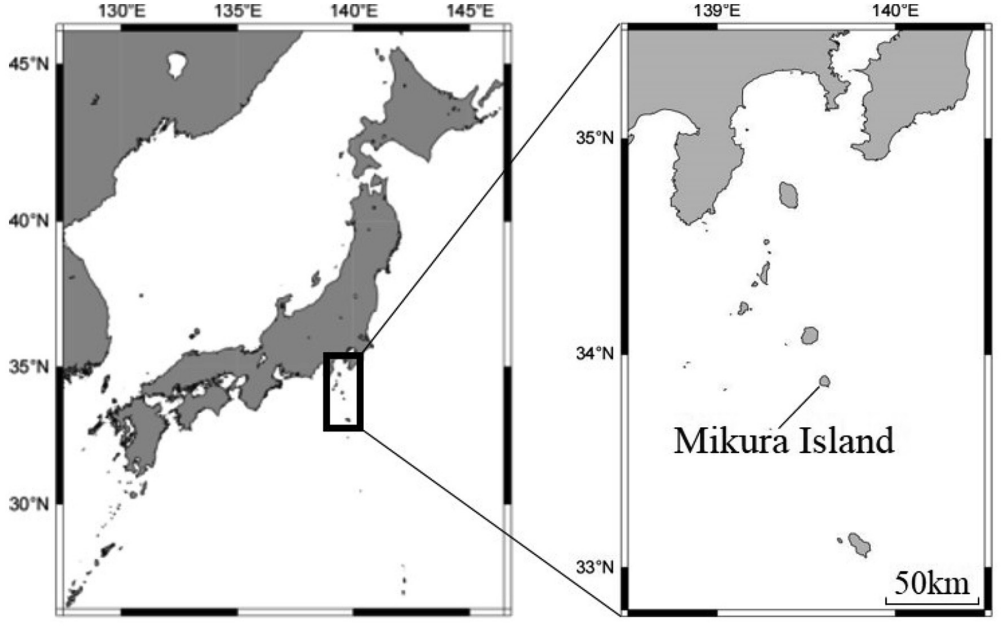

Figure 1. Location of Mikura Island, Japan, study area

Table 1. Population sizes and home ranges

Location	Population size	Home range	Source
T. aduncus			
Port Stephens, Australia	Approximately 150 individuals	Over 140 km^2	Möller et al., 2002
Jervis Bay, Australia	Approximately 100 individuals	102 km^2	Möller et al., 2002
Moreton Bay, Australia	242 individuals	350 km^2	Chilvers & Corkeron, 2003
Bunbury, Australia	More than 78 individuals	Male: 27-187 km^2 Female: 20-133 km^2	Sprogis et al., 2016
Mikura Island	131 individuals	20 km^2	This study
T. truncatus			
Sarasota Bay	Approximately 100 individuals	125 km^2	Wells, 2003
Moray Firth	129 individuals	Under 100 km^2	Wilson et al., 1997, 1999
Doubtful Sound	83 individuals	83.7 km^2	Lusseau et al., 2003

catalog. We also searched for pictures and videos of emigrants from blogs and social networking sites of dive shops and recreational divers. We only used photos of dolphins that were detailed enough for us to identify more than three natural marks. This standard was the same one we used for researcher-collected photos and photos donated by recreational divers. In addition, we only used raw photographic data that had not been manipulated. From this dataset, we analyzed sex, age class, emigration year, and destination of the individuals identified using the *R* statistical package (R Core Team, 2015). A *G*-test was used to test the sex ratio of all emigrants (all emigrant categories combined) and age class. The expected value of each age class of emigrants was calculated from the total number and proportion of identified individuals in all years. The sex ratio of each age class and difference in sex and age class in 2008 and 2010 were tested with Fisher's exact test. The number of boats and swimmers of each year were provided by the Mikurajima Village Office.

Results

Sex and Age Class

We identified 277 dolphins between 1994 and 2014. Of these, 179 disappeared from Mikura Island of which 41 (25 males and 16 females) were identified as having immigrated to other areas (Table 2). These emigrants included 15 adult males (MA), 14 adult females (FA), eight subadult males (MS), one subadult female (FS), two juvenile males (MJ), and one juvenile female (FJ) (Table 3). All the juveniles were still with their mothers.

There was no significant difference in the sex composition of all emigrants (*G*-test, $G = 0.63242$, $p = 0.4265$) or across age classes (Fisher's exact test, $p = 0.14$). However, a greater number of emigrants were adults ($n = 29$) than subadults ($n = 9$) or juveniles ($n = 3$), making age class a significant factor related to emigration (*G*-test, $G = 9.2207$, $p < 0.05$; Figure 2). For emigrants, 70.7% were older than 10 y. The oldest was a female more

Table 2. Annual number of individuals; "Unidentified (but they were in Mikura Island)" means individuals unobserved during 1 or 2 y but identified after that continually. They could have emigrated, but it occurred in beginning of identification survey, so we regarded it as oversight by deficient survey. There was no report that an emigrant emigrated again after being reconfirmed in Mikura Island, so individuals in this category are thought to remain around Mikura Island normally.

			Disappeared breakdown			
Year	Identified	Disappeared	Dead	Unidentified (but they were in Mikura Island)	Emigrants	Lost
1994	101	--	--	--	--	--
1995	112	9	0	6	1	2
1996	122	6	1	4	0	1
1997	126	6	0	5	0	1
1998	135	12	0	2	4	6
1999	141	1	1	0	0	0
2000	147	3	2	0	0	1
2001	153	5	0	0	0	5
2002	152	11	0	1	0	10
2003	156	6	3	0	0	3
2004	155	9	0	1	0	8
2005	162	3	0	0	1	2
2006	158	11	1	0	2	8
2007	156	6	0	0	2	4
2008	135	27	0	0	16	11
2009	133	9	2	0	1	6
2010	122	18	0	0	8	10
2011	108	19	1	1	2	15
2012	115	4	0	0	1	3
2013	117	9	5	0	2	2
2014	124	5	2	0	1	2

Table 3. Emigrated year and number of emigrants

	Male			Female			
Year	Adult	Subadult	Juvenile	Adult	Subadult	Juvenile	Total
1996	0	0	0	1	0	0	1
1998	3	0	0	1	0	0	4
2005	0	0	0	1	0	0	1
2006	0	0	0	2	0	0	2
2007	1	1	0	0	0	0	2
2008	5	3	2	4	1	1	16
2009	0	0	0	1	0	0	1
2010	4	4	0	0	0	0	8
2011	2	0	0	0	0	0	2
2012	0	0	0	1	0	0	1
2013	0	0	0	2	0	0	2
2014	0	0	0	1	0	0	1
Total	15	8	2	14	1	1	41

than 20 y old. When we first identified her in 1994, she was already accompanied by a calf. The mean age at first birth in the Mikura population was 10.31 y (Kogi, 2013), and so her actual age was likely more than 30 y at the time of emigration. The youngest emigrant was a 3-y-old male accompanied by his mother. Six individuals (five males and one female) were observed near Mikura Island again, after emigration, and three of these were observed there in 2014. In addition, there was a significantly small proportion of mothers with calves among FA emigrants (Fisher's exact test, $p < 0.05$).

Destinations

Emigrants were observed around the Izu Island Chain (Miyake Island, Sambondake, Hachijo Island, Toshima Island, Izuoshima, Shikine Island, Udone Island, Kouzu Island, and Chinai Island), Chiba Prefecture (Tateyama, Kamogawa, and Katsuura), Shizuoka Prefecture (Mikomoto Island, Inatori, and Futo), Mie Prefecture (Kumano), and Wakayama Prefecture (Kushimoto and Tanabe) (Figure 3). All immigrants to these islands originated from around Mikura Island, where they had been observed from 2 to 20 y. The eastern and western limits of emigration were Katsuura and Tanabe, located about 150 and 390 km from Mikura Island, respectively (Table 4). The northern and southern limits of emigration were Katsuura and Hachijo Island, located about 150 and 90 km away from Mikura Island, respectively. The most common destination was Toshima Island in the Izu Island Chain, where nine individuals were observed. Several emigrants near Toshima Island were observed every year from 2009 to 2014, although some were only observed in that area for less than 1 y (N. Takanawa, pers. comm.). Some dolphins reproduced in Toshima Island waters, bringing the total population to 23 dolphins (in 2015; N. Takanawa, pers. comm.). Three individuals have resided off Sambondake for 7 y, and one has been in Hachijo Island for 4 y. However, most emigrants spent only a short time in one location before traveling to other places along the Japanese coast. Some emigrants were observed in several areas within the observation period, indicating that they traveled during that time.

Emigrants were observed in groups of one to five dolphins. The composition of these groups changed as dolphins joined other groups or became separated; however, in all cases, the groups were composed only of individuals originally belonging to the Mikura Island population.

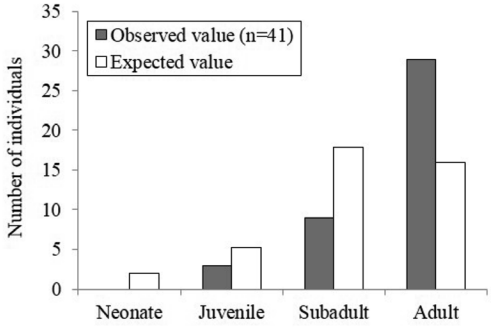

Figure 2. Actual number of emigrants and expected value calculated from all identified individuals for each age class

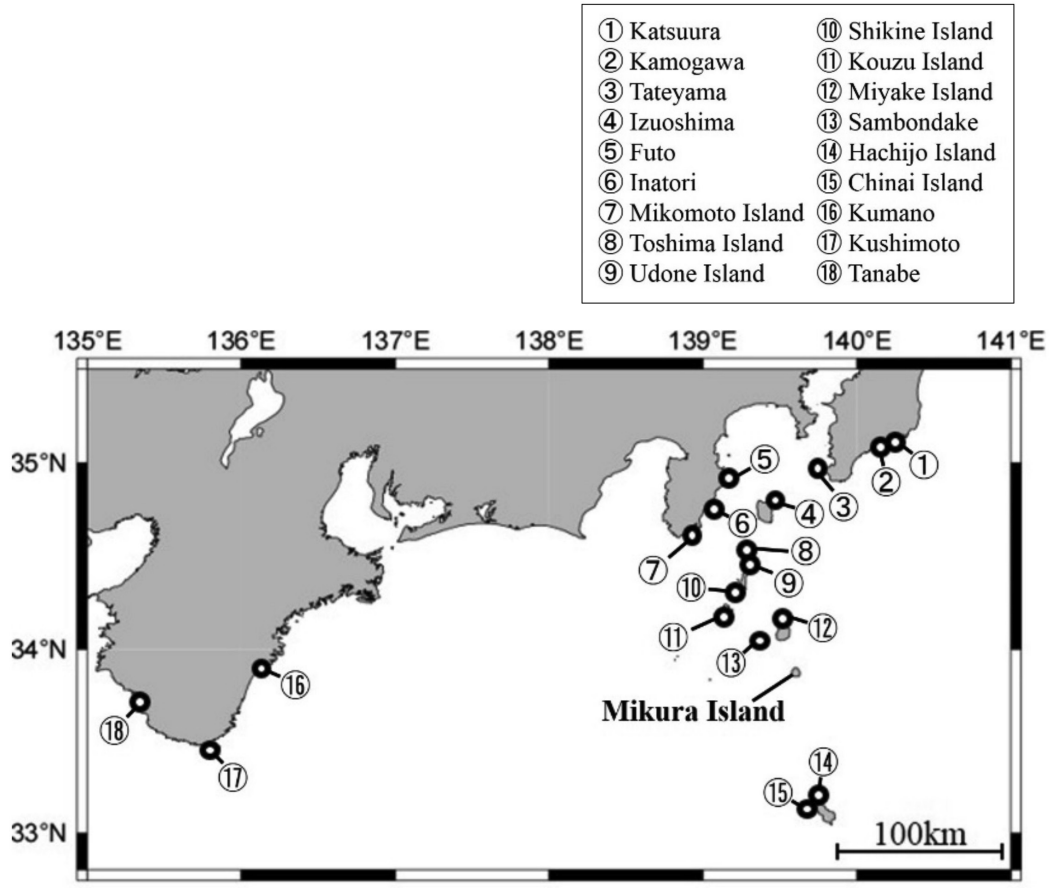

Figure 3. Locations of destinations

Table 4. Location and distance from original habitat of emigrations around Japanese coast

Location	Distance	Source
Torishima Island from Ogasawara Island	400 km	Morisaka et al., 2013b
South of Amakusa-Shimoshima Island from north	70 km	Nishita et al., 2015
Notojima Island from north of Amakusa-Shimoshima Island	1,000 km	Mori, 2013
Kunda Bay from north of Amakusa-Shimoshima Island	770 km	Morisaka et al., 2013a
Tsukumi Bay from Kagoshima Bay	350 km	Shirakihara et al., 2012
Tanabe from Mikura Island	390 km	This study

Year

There were more emigrants in 2008 (n = 16) and 2010 (n = 8) than in other years ($n \leq 4$) (Figure 4). Differences in sex and age class of emigrants between 2008 and 2010 were not statistically significant (Fisher's exact test, p = 0.3865). More dolphins were also classified as "lost" in 2008 and 2010 than in most other years, although there were even a greater number of lost dolphins in 2011 than in 2010. The number of lost dolphins was generally correlated with the number of emigrants (Table 2).

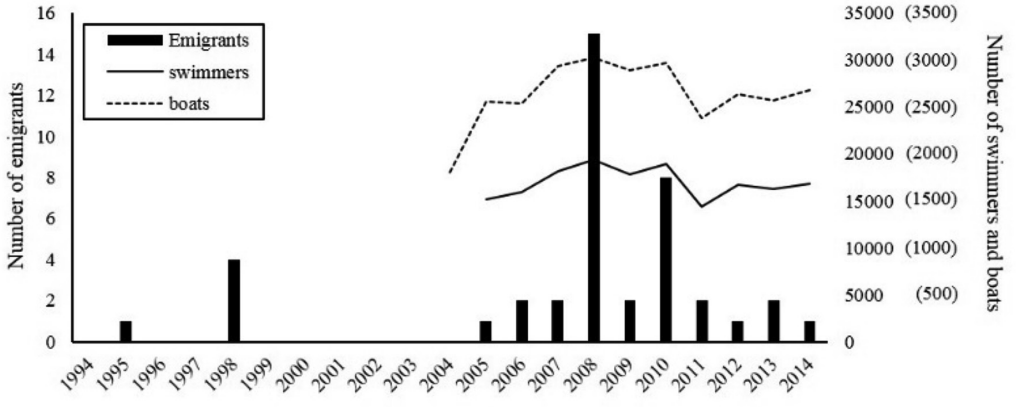

Figure 4. The number of emigrants, swimmers, and boats; the number shown in parentheses is number of boats.

Discussion

Sex and Age Class

In prior studies of *Tursiops* spp., males tended to disperse more widely than females (Krützen et al., 2004; Sprogis et al., 2016). A likely explanation for this pattern is that the reproductive success of females depends on procuring enough prey to support the heavy energy investment required to raise and protect calves, whereas the reproductive success of males depends largely on gaining access to females (Scott et al., 1990). In this study, however, there was no significant difference in the frequency of emigration between males and females. However, a significantly large proportion of emigrating females did not have calves with them. One FJ, part of an emigrant mother–calf pair, was observed alone in Mikura Island 1 y after emigrating, but she has not been observed since then; also, her mother has not been observed since she was initially identified as an emigrant. Two MJs that had emigrated with their mothers were not observed in 2015, but their mothers were observed alone. These three juveniles may have died before becoming independent, or they may have immigrated alone to other areas. From these results, it seems that females in Mikura Island may need to avoid emigration to protect their calves. On the other hand, juveniles may affect their mothers' willingness to emigrate. More study of the basic ecology of Mikura Island dolphins, including foraging behavior, is needed to clarify behavioral factors affecting emigration.

Although differences in sex and age class of emigrants in 2008 and 2010 were not statistically significant, all eight emigrants in 2010 were male.Four were adults, and four were subadults. Sexes and age classes of emigrants in 2008 were more varied, with five MAs, three MSs, two MJs, four FAs, one FS, and one FJ.

Nishita et al. (2015) studied a *T. aduncus* community that split into two groups. The males had formed two distinct subcommunities, whereas the females had formed no distinct social groups before the separation of the community. In addition, Lusseau & Newman (2004) observed the existence of centralized "brokers" in a population of *Tursiops* spp., bridging the split between subcommunities. They reported that interactions between subcommunities were restricted when one adult female was away temporarily, and they became more common when this female reappeared. Extrapolating from these observations, changes in social relationships in the Mikura Island population may be tied to emigration. The six reconfirmed individuals that we observed may have had a similar effect on social relationships in the Mikura Island population. In addition, differences in sex and age class of emigrants between 2008 and 2010 may reflect different drivers of emigration.

Destinations

Emigration is generally considered permanent (Kogi, 2013). This study supports this with only six of 41 emigrants having returned to Mikura Island after emigration. These six dolphins traveled among islands. Periods of time between emigration and reconfirmation (leaving and returning to Miyake Island) were observed to be 3 y (Miyake Island), 0.5 to 1 y (Udone Island), 2 y (Sambondake), 1 y (Hachijo Island), and 4 y (Tateyama). However, the periods away from Mikura Island did not correspond to the distances they emigrated. Tanabe, 390 km from Mikura Island, was the farthest distance any emigrant was observed to travel from the point of origin. Similar results have been observed for other dolphin populations (Shirakihara et al., 2012; Mori, 2013; Morisaka et al., 2013a, 2013b; Nishita et al., 2015).

Year

The numbers of emigrating dolphins increased dramatically in 2008 and 2010. This increase could have been an artifact of the study design due to the development of digital equipment, such as the digital camcorder, or to there being more observers in later years of the study period. However, the number of reported emigrations in all other years, including 2005 to 2007, 2009, 2011, and thereafter, stabilized at one or two. The numbers of lost individuals were low in 2012 and thereafter. Therefore, the large number of reported emigrations in 2008 and 2010 likely reflected a true increase in emigration—not a result of any improvement in recording technology or an increase in the number of observers.

Mikura Island has seen a marked increase in the numbers of tourists swimming with dolphins in recent years. Tourist numbers peaked in 2008 and have remained fairly constant since 2009. The increase in tourists and commercial boats in the area might have been responsible for the high increase in dolphin emigration in 2008. Similarly, Forest (2001) suggested that decreased spinner dolphin (*Stenella longirostris*) recordings in Kealake'kua Bay, Hawaii, may have been due to increased tourism activity.

The Mikura Island dolphin population was at its highest level from 2003 to 2007 when there were about 160 individuals. Compared to prior studies, the estimated size of the dolphin home range around Mikura Island, 20 km^2, seems to be too small for this population size (Wilson et al., 1997, 1999; Möller et al., 2002; Chilvers & Corkeron, 2003; Lusseau et al., 2003; Wells, 2003; Sprogis et al., 2016). Therefore, migration away from Mikura Island might have been a response to the population exceeding its carrying capacity there.

A more accurate assessment of the size of the Mikura Island home range, as well as more basic information on the local population and environmental conditions there, will be necessary to better understand some of the reasons for emigration. Additionally, because 90 individuals were lost from the Mikura Island population over the 20 y of monitoring, more complete surveys are needed in areas around the Izu Islands Chain to determine the final destinations of emigrating dolphins. Focusing future research on these additional areas will help uncover the ecological and ethological reasons that dolphins emigrate to other areas.

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