

DEMOGRAPHIC PARAMETERS OF
INDO-PACIFIC BOTTLENOSE DOLPHINS
(*TURSIOPS ADUNCUS*) AROUND
MIKURA ISLAND, JAPAN

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ABSTRACT

Long-term identification surveys were conducted using video records on Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) around Mikura Island, Tokyo, Japan. On 246 surveys, 3,996 min of video were recorded during each summer season from 1994 to 2001. Two hundred and twenty individuals were observed, including juveniles and neonates, that were not cataloged, but could be identified by association with their mothers. Over the eight-year study period, the total number of identified and cataloged individuals was 169. The annual number of newly identified dolphins stabilized at ~10 after 1995. In the middle of each research season, a plateau in the number of reidentified individuals was reached. Most of the dolphins were observed frequently—percentages of reidentified dolphins in adjoining years were greater than 86% and 62 individuals were seen consecutively during the eight years. There were no significant differences in the sex ratio between years. The sex ratio was skewed significantly towards male for subadults and towards female for adults. The survival rate of one-year-old calves was 86.7%, and the mean age at weaning was 3.5 yr. The calving interval averaged 3.4 yr among adult females. The mean annual birth, fecundity, and recruitment rates were 0.071, 0.239, and 0.068, respectively. Mikura Island is located in the

pelagic ocean with no protected bay area existing around the island. Dolphins do not regularly inhabit any other locations besides Mikura within the Izu island chain. Thus, this island may be important core habitat of these dolphins.

Key words: *Tursiops aduncus*, Indo-Pacific bottlenose dolphin, video-identification, demographic parameters, reproductive parameters.

Mikura Island, approximately 200 km south of Tokyo, Japan, is a dormant volcano with a boulder coastline and consistently clear underwater visibility (~15 m on average). Bottlenose dolphins (*Tursiops aduncus*) are observed frequently throughout the year within ~300 m of the island. Confirmation of the Indo-Pacific bottlenose dolphin as the species observed around Mikura Island is supported by DNA analysis (Wang *et al.* 1999, Kakuda *et al.* 2002). Adults have a smaller body and longer rostrum compared with those of *T. truncatus*. They also possess spots ventrally, similar to those in bottlenose dolphins observed in the Indian Ocean (Wang *et al.* 2000, Hale *et al.* 2000). In Japan, Indo-Pacific bottlenose dolphins are also known to occur in Amakusa (Shirakihara 2002) and Amami (Miyazaki and Nakayama 1989).

A dolphin-swim program began in the early 1990s around Mikura Island. In recent years more than 8,000 people visit this small island to swim with dolphins during summer months. The Mikurajima Bandouiruka Kenkyukai (MBK: Mikura bottlenose dolphin identification group) has continued a long-term, longitudinal photo-identification study (primarily during each summer season) since 1994.

Long-term research is indispensable for studying dolphins, which are long-lived, socially complex individuals (Wells 1991). The Indo-Pacific bottlenose dolphin group around Mikura Island is appropriate for long-term study because of their coastal habitat and apparent isolation. Understanding the basic biology of these dolphins is also indispensable for better management of ongoing swim-with-dolphin ecotourism.

METHODS

Study Area

The study area encompassed a distance of 300 m from shore. Depths ranged from 2 m near shore to 45 m at ~300 m from shore. Seventh in the Izu Island chain, Mikura Island lies 200 km south of Tokyo (Fig. 1). The island is a dormant volcano with steep, sheer cliffs and a narrow beach of small to large boulders. The island is 20.6 km² in area, is 16.4 km in circumference, and is encircled by the Kuroshio Current, primarily in summer months when the current flows past the island from the southwest side.

Data Collection

A center-console run-about, 6 m in length, with ~30-hp motor, was used to search for dolphins around the island. Five people—a captain, a videographer, two underwater observers, and one surface observer—comprised each research crew. Each trip was approximately 3 h long with surveys attempting to cover the complete circumference of the island, weather-dependending. Upon sighting a dolphin group, one

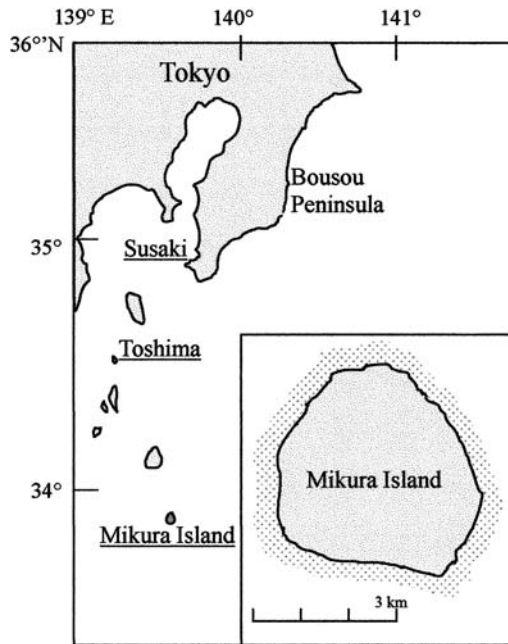


Figure 1. Study area around Mikura Island (dotted) in Izu Island Chain south of Tokyo.

observer with a waterproof video camera (Panasonic NV-DE3) entered the water to record fin notches, body scars, and genital regions while snorkeling. Two additional underwater observers followed to record identifiable dolphins and behaviors for data on dolphin group size and general activity. Data were gathered in an all-occurrence and *ad libitum* sampling protocol (Altmann 1974).

Research trips were performed twice daily (maximum), during early morning (0500–0800) and late afternoon (1500–1800) hours. These times were chosen because the number of dolphin-watching activities was least. Thus, competition to observe the dolphins was low and potential harassment of the dolphins was minimized.

Identification of Individuals

Photography of individual dorsal fins is the most accepted method of identification for dolphins, especially when observations are made from above the sea surface (*e.g.*, Würsig and Würsig 1977, Defran *et al.* 1990). All but a few dolphin species possess no external sexually dimorphic characters; therefore, it is difficult to determine sex and age of all group members with only dorsal fin photos. Underwater observations aid in documenting the demographics of a dolphin population (Dudzinski 1996, Rossbach and Herzing 1999, Campbell *et al.* 2002). Individual dolphins were identified from video recorded underwater by scars and marks on the body. Dolphins with scars, marks, or fin notches that were considered permanent (≥ 1 yr) were given an identification (ID) number and nickname. Three body characteristics for each dolphin image were matched to confirm each ID from video records. Sex, relative age class, and identity of associates were also recorded on every ID sheet (Table 1). Three

Table 1. Definitions for age classes documented among bottlenose dolphins around Mikura Island, Japan.

Age class	Definition
Adult (A)	Large girth, spots cover ventral area, usually many scars, dark overall color, often swelling in genital area (difference between males and females), female often with a calf.
Subadult (S)	Girth < adult, but length similar to A, few spots on ventral area, not associated with mother.
Juvenile (J)	$\sim 2/3$ size of A (length and girth), no spots on ventral area, few scars, light gray body color, consistently associated with an A.
Neonate (N)	$\leq 1/2$ adult size, no spots, few scars, fetal folds present, floppy fins, always associated with particular adult.

or more investigators reviewed each video to arrive at a consensus for individual identifications. If an identified and cataloged individual was not seen for at least one year, that dolphin was defined as "lost." Neonates and juveniles without reliably recognizable scars or marks were identified by association with their mother until they were weaned. By this time, these individuals usually had attained individually identifying characters.

Sex was determined by visual inspection of the genital area underwater and from video recorded while underwater. A distinct external separation between the anal and genital slits indicated a male, while a single external opening for these slits indicated a female. To determine the age class of bottlenose dolphins around Ogasawara (Bonin) Island, Shinohara (1993) used spots on the ventral area. There are also trends in the body color of dolphins around Mikura Island, spots increase with age. We used spots in the ventral area as one indicator of adult age. We also considered behavioral patterns and body size (length and girth) as indicators of relative age class (Table 1). Every identified individual dolphin was categorized into a sex and age class per year.

A mother and calf pair was identified if the adult female was seen with the calf alone. Adult females that were observed on more than 50% of all sightings with a particular calf were considered a mother and calf pair. Exceptions to this 50% rule were adult females who gave birth during the secondary birth peak late in the study season. Confirmation of their motherhood was anecdotally confirmed from other researchers after the two-month MBK season was completed. We also confirmed the identity of a mother and calf pair if they were observed frequently swimming in echelon, infant, or lactating positions (Tavolga and Essapian 1957, Cockcroft and Ross 1990, Mann and Smuts 1999). A reported mother and calf pair stayed in frequent association for three years after parturition (Wells *et al.* 1987, Smolker *et al.* 1992). Thus, we assumed a calf that was associated with the same mother over this period was the same calf, even if the calf did not possess natural marks or scars facilitating individual reidentification. We defined weaning to have occurred when a calf was no longer associated consistently with its mother. The number of years between births (termed a birth interval) was calculated for each adult female and adult females for which successful weaning was documented. We also calculated the ratio of adult females with a calf to adult females for each year.

A binominal test was used to examine differences in sex ratio. Sex ratios between years and sex ratio within age classes between years were tested with a

Table 2. Schedule for data collection, days on the water, and the number of minutes of video recorded for each year of study.

Year	Dates inclusive	Days on water	No. days for video	No. min. video
1994	1 Aug.–30 Sep.	61	35	592
1995	12 Aug.–30 Sep.	51	21	450
1996	17 Aug.–27 Sep.	43	21	387
1997	19 Jul.–13 Sep.	57	30	352
1998	19 Jul.–5 Sep.	49	28	400
1999	20 Jul.–16 Sep.	59	38	583
2000	20 Jul.–14 Sep.	57	37	734
2001	25 Jul.–13 Sep.	51	36	498
Total	—	428	246	3,996

Mann-Whitney *U* Test. The Mann-Whitney *U* Test was used with StatView version 5.0 (SAS institute Inc., Cary, NC).

RESULTS

Success and Effort

An average of 53.5 d was spent gathering data each summer (Table 2). Video was recorded on an average of 30.8 d (range 21–38 d) per season—less than the total number of days at sea because of limited visibility and weather conditions on some days. A total of 3,996 min (~66.6 h) of video was recorded from 1994 to 2001 inclusive: dolphin identifications and preliminary behavioral observations were obtained from these videotapes.

Demography

Increase of identified individuals—An increase in the number of identified individual dolphins occurred during each field season (Fig. 2). During each year and overall for the eight-year period, the plateau (defined as the observation of 90% of the identified individual dolphins within this group per year) in sightings of identified and cataloged individuals occurred at about day 14 (range: 8–22 d) within each two-month study period. From 1994 to 2001, the total number of identified and cataloged dolphins found around Mikura Island was 169. Most of those individuals were observed and videotaped several times during each field season with few dolphins videotaped only once. During the study period, the total number of observed individuals was 220, which includes juveniles and neonates that were not cataloged because they lacked reidentifiable marks or scars; however, these young dolphins were identified by association with their mothers (Fig. 3). Without neonates, 54 individuals were new to our study during 1995–2001 (13 in 1995, 7 in 1996, 5 in 1997, 12 in 1998, 7 in 1999, 6 in 2000, and 4 in 2001). The age and sex composition of newly identified dolphins were nine adults (5 males: 4 females), 35 subadults (26:9) and 10 juveniles (1:5, four were sex unknown). The age ratio of new dolphins to the study was skewed towards subadult males. Six “new” adults were

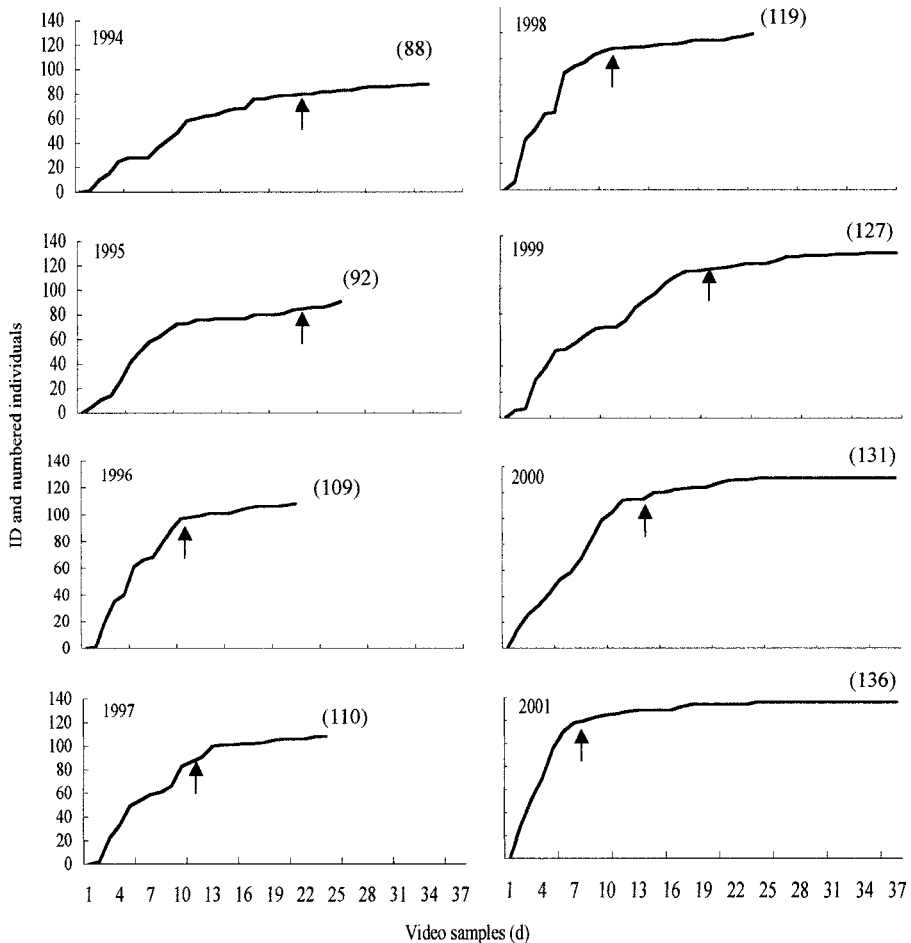


Figure 2. Discovery curves of identified and cataloged individual dolphins during surveys for each year. The number in parentheses indicates population size per year. Arrow indicates the day when 90% of all individuals were observed.

identified in 1995: two were male and four were female. Percentages of reidentified dolphins in adjoining years were greater than 86% (Table 3). From 1994 to 2001, 62 dolphins (36.7% of cataloged individuals) were observed consecutively during the eight years.

Emigration and mortality—Between 1994 and 2001, 33 identified and cataloged dolphins (19.5%) were “lost” from this study population; lost dolphins are those that were considered to have emigrated to another location or were confirmed dead. Age and sex distribution of lost dolphins includes nine adult males, five adult females, 11 subadult males, three subadult females, two juvenile males, one juvenile female, and one sex unknown subadult and juvenile each. Eight of these dolphins were sighted in other geographic locations. Migration of a few dolphins was verified: ID#074, adult female, was seen last around Mikura Island on 27 September 1995 with a neonate. In late autumn 1995, ID#074 was observed around Toshima Island without a neonate

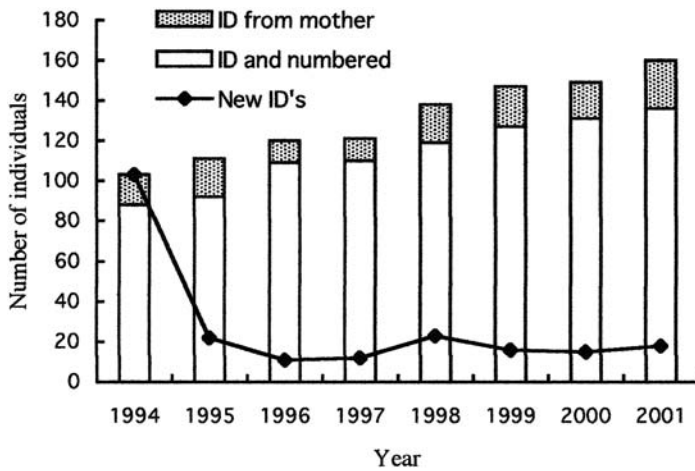


Figure 3. Number of identified individual dolphins around Mikura Island per year of study.

(Fig. 1). For seven years (1995–2001), this female has been observed consistently at Toshima Island as a solitary dolphin.¹ Two adult males (ID#009 and ID#048), an adult female (ID#003) and a subadult male (ID#013) were observed frequently in the study area from 1994 to 1997. In 1998 these four dolphins were not recorded around Mikura Island but around Susaki, Bousou Peninsula (Fig. 1).² These four dolphins have not been sighted at Mikura Island since 1997.

Sex and Age Class Group Composition of Mikura Dolphins

There was no significant variation in the age class distribution of identified dolphins from 1994 to 2001 ($\chi^2 = 20.6$, $P > 0.05$; Fig. 4). There was no significant change in sex ratio within age classes between years ($\chi^2 = 28.8$, $P > 0.05$; Table 4). There were no significant differences in sex ratios between years ($\chi^2 = 2.3$, $P > 0.05$). The sex ratio was skewed significantly towards females in adult dolphins, and towards males in subadult dolphins (binomial test, $P < 0.05$). The sex ratio of juveniles and neonates was not different significantly from a 1:1 ratio (binomial test, $P > 0.05$).

Female Reproduction

Calving season and intervals—It was difficult to detect a seasonal calving peak because our study was conducted during summer months only. However, neonate calves were observed frequently from April through October (Imamura, unpublished data, 2000–2001; Dudzinski, unpublished data, 1997–1999). Reproductive

¹ Personal communication from M. Fujii, Toshima Diving Service, 59 Toshima, Tokyo, 100-0301, October 2002.

² Personal communication from K. Fujita, 6 Dorsals Kayak Service, 1073-2 Tateyama, Chiba, 294-0036, October 2002.

Table 3. Number and percentage of reidentified individual dolphins for each season and the next season.

Year	Number of individuals	Number of reidentified individuals	Percentage of reidentified
1994	103	N/A	N/A
1995	111	89	86.4
1996	120	101	94.5
1997	121	107	90.8
1998	138	106	89.2
1999	147	129	93.4
2000	149	135	91.8
2001	160	142	95.3

histories for each adult female are presented in Appendix 1. The average birth cycle for all mothers was 3.4 yr (median = 3.0, $n = 26$, $SD = 0.93$) with a range from 1 to 6 yr. The shortest birth cycles documented spanned 1 yr ($n = 2$) and 2 yr ($n = 1$) and were for adult females that had lost a calf and subsequently became pregnant the following or same year. Two adult females were not observed with calves during the eight-year period (Appendix). Forty-three calves (57.3%) were identified before weaning with 22 (29.3%) of these observed from the birth year. The average calving interval for mothers that succeeded in bringing a calf to weaning age was 3.5 yr (median = 3.0, $n = 19$, $SD = 0.61$, range 3–5 yr). The mean calves' age at weaning was 3.5 yr (median = 3.0, $n = 22$, $SD = 0.74$, range 3–6 yr). The age at weaning was not significantly different between male and female calves (males: females = 10:12, Mann-Whitney U -test, $U = 48.0$, $P = 0.36$).

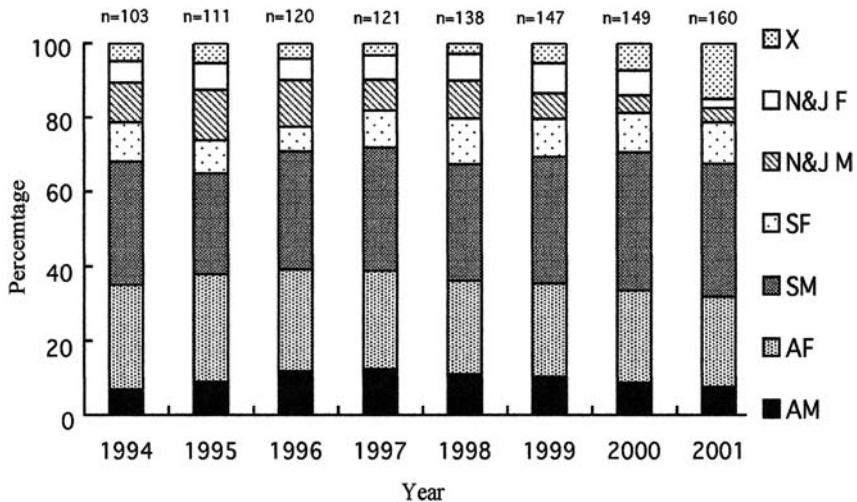


Figure 4. Age category and sex distribution of identified bottlenose dolphins from 1994 to 2001. A = adult, S = subadult, N&J = neonates and juveniles, M = male, F = female, X = sex unknown. X included only N&Js except one subadult. The sex ratio of neonates and juveniles was not significant with 1:1, therefore we combined them.

Table 4. Sex and age composition for the Mikura dolphin study group, 1994–2001. Given are the numbers of males and females per year per age class and the sex ratios (m:f). A total population count per year with sex ratios is also included.

	Year							
	1994	1995	1996	1997	1998	1999	2000	2001
Adult	7:29 (1:4.14)	10:32 (1:3.20)	14:33 (1:2.36)	15:32 (1:2.13)	15:35 (1:2.33)	15:30 (1:2.47)	13:37 (1:2.85)	12:39 (1:3.25)
Subadult	34:11 (1:0.32)	30:10 (1:0.30)	38:8 (1:0.21)	40:12 (1:0.30)	43:17 (1:0.40)	50:15 (1:0.30)	55:16 (1:0.29)	57:18 (1:0.32)
Juvenile	6:1 (1:0.17)	10:7 (1:0.70)	12:7 (1:0.58)	8:4 (1:0.50)	10:5 (1:0.50)	8:10 (1:1.25)	5:9 (1:1.80)	6:4 (1:0.67)
Neonate	5:5 (1:1)	5:2 (1:2.5)	3:0 (1:0)	2:4 (1:2)	4:5 (1:1.25)	2:2 (1:1)	2:1 (1:0.5)	N/A (N/A)
Total	52:46 (1:0.88)	55:51 (1:0.93)	67:48 (1:0.72)	65:52 (1:0.80)	72:62 (1:0.86)	75:64 (1:0.85)	75:63 (1:0.84)	75:61 (1:0.81)

Calf mortality, birth rate, fecundity rate, and recruitment rate—Seventy-five neonates were observed during the study period (1994–2001) with 10 (13.33%) lost during their first year of life (Appendix). Calf mortality at Mikura may be underestimated; primiparous (or young) adult females are not easy to identify as pregnant during their first pregnancy. Thus, calves may have been born and lost before we were able to observe them. The percentage of adult females with a calf for all adult females per year was greater than 70%, with 1997 showing the only exception (Table 5). The crude annual birth rate was 0.07 (SD = 0.02, range 0.03–0.12) on average. This rate may also be an underestimate as some calves may have died prior to documentation. The fecundity rate averaged 0.24 (SD = 0.08, range 0.12–0.38). In 2001 the calculated fecundity may be overestimated; we used only the number of calves that had been lost during the 2001 field season. The recruitment rate was 0.068 (SD = 0.03, range 0.03–0.12) on average (Table 5).

DISCUSSION

Habituation, the acceptance by wild animals of human observers as neutral elements in their environment, is of major concern to all researchers starting a direct observation, long-term study on free-ranging wild animals (*e.g.*, Aldrich-Blake 1970, Tutin and Frenandez 1991, Van Krunkelsven *et al.* 1999). Habituation to a boat or underwater observers is also important for long-term, small cetacean research (Scott *et al.* 1990, Smolker *et al.* 1992, Berrow *et al.* 1996, Herzing 1997, Dudzinski 1998). Around Mikura Island, dolphins seem well-accustomed to, and tolerant of, human swimmers (Kogi 2001). Differences in the extent of habituation between dolphin sex and age classes however might contribute to a bias in this observed habituation to humans (Berrow *et al.* 1996, Herzing 1997). Nevertheless, most of the identified dolphins were observed and videotaped several times in each field season.

Population Size

More than 60 known individual dolphins were resighted every season since 1994, and the number of individuals identified reached a plateau at approximately

Table 5. Annual reproductive rate of Indo-Pacific bottlenose dolphins around Mikura Island, Japan. N = number of all identified individuals. FA = number of adult female dolphins. Mc = number of mothers with a calf, number in parentheses is the percentage of Mc pairs from all FA. B = number of neonates. B₁ = number of neonates which survived at least one year after birth.

	1994	1995	1996	1997	1998	1999	2000	2001	Mean ^a	SD
N	103	111	120	121	138	147	149	160		
FA	29	32	33	33	36	37	37	39		
Mc	21 (72.4)	29 (90.6)	27 (81.8)	21 (63.6)	28 (77.8)	30 (81.1)	26 (70.3)	34 (87.2)		
B	12	9	4	7	11	9	9	14		
B ₁	11	8	4	6	11	6	9	10		
<i>Grude birth rate</i>										
B/N	0.117	0.081	0.033	0.058	0.080	0.061	0.061	0.088	0.071	0.0248
<i>Fecundity rate</i>										
B ₁ /FA	0.379	0.250	0.121	0.182	0.306	0.162	0.243	0.256	0.239	0.0825
<i>Recruitment rate</i>										
B ₁ /(N-B)	0.121	0.078	0.034	0.053	0.087	0.043	0.064	0.068	0.068	0.029

^a Weighted mean.

two-thirds into every study period (Fig. 2). Thus, we assume that these identified dolphins represented most of the population and that an habituation bias was not a significant factor to our examination of the dynamics of population size or reproductive rate for this dolphin group. Not only did the number of newly identified individuals decrease sharply during the second year of study (Fig. 3), but most of the new identifications belonged to young dolphins which showed new natural scars or marks. Forty-five (83.3%) dolphins were subadult or juvenile among the 54 newly identified dolphins that were not accompanied by a neonate from 1995 to 2001. Therefore, we feel confident that we were able to identify most of the dolphins that frequent the coastline of Mikura Island during the summer season each year. Most of the individuals that could not be identified by their own natural markings were calves or juveniles. If there were subadult dolphins without obvious natural scars, they still could be identified by rake marks during a single season. We anecdotally noted these dolphins and could estimate their number as about 10 individuals within each study season. Thus, we surmise that the number of dolphins that we could not identify (older than the weaned age) was low. We estimate that the population size of dolphins around Mikura Island was at least 160 individuals with maybe a dozen or so more dolphins without reliably reidentifiable scars or marks between years. Our estimate of population size of the Mikura dolphins is comparable with sizes reported in the literature for other *T. aduncus* groups. Population estimates for *T. aduncus* at other locations include 218 in Amakusa, Western Kyushu, Japan (Shirakihara *et al.* 2002), ~200 at Shark Bay, Monkey Mia, Australia (Mann *et al.* 2000) and 700–1,000 at Off Point Lookout, Queensland, Australia (Chilvers and Corkeron 2003). While the population size estimated at Off Point Lookout is more than three times that of the other sites, the Off Point Lookout study represents a small section of a much larger geographic area as compared with the other studies presented. Also, the re-sight rate per individual for Off Point Lookout dolphins was much lower than rates reported at Mikura, Monkey Mia, and Amakusa.

Some dolphins that were identified and recorded during our summer field season were also documented by other observers between December and April (Dudzinski, unpublished data, 1997–1999; Sakai, unpublished data, 2000–2002; Taguchi unpublished data, 1999). Site fidelity is a typical characteristic of coastal bottlenose dolphins of both the *aduncus* and *truncatus* species (*e.g.*, Connor and Smolker 1985, Shane *et al.* 1986, Fertl 1994, Maze and Würsig 1999, Gubbins 2002). With more than 60 individual dolphins resighted during eight years, we can assume that these dolphins are long-term and stable residents of the area.

Emigration, Migration, Loss

The sex ratio of adult and subadult individual dolphins lost from the population was skewed towards males (20:8). Wells *et al.* (1987) suggested that a decrease in the proportion of males in the adult stage was possibly caused by a higher mortality for males. The sex ratio of newly identified subadult dolphins was also skewed significantly towards males ($n = 26$). The higher proportion of newly identified subadult males over females could be explained if female calves had a higher probability of gaining a natural scar or mark before weaning than males. If so, then female calves would also have a higher possibility of being identified when compared with males. However, no significant difference was found between the sexes in the number of calves that had natural marks before weaning. Wells (1991) and Reynolds *et al.* (2000) indicated that the size of a dolphin's home range is governed by age and

sex. Kasuya *et al.* (1997) found that the proportion of female bottlenose dolphins (*T. truncatus*) off Japan increased after 10 yr of age, when sexual maturity likely started. They suggested that one of the reasons for this change might be related to behavioral changes in males, involving sexual maturation. The fact that the number of lost and newly identified dolphins was skewed towards males that were older than subadults in this study area may indicate frequent migration of males. However, only two adult males and females and one subadult male were confirmed to have migrated from the study area. These individuals were observed year-round in the new site, after migration, and were never again seen around Mikura. Adult female ID#074, migrated to Toshima during winter 1995/1996, and was thought to have become solitary. However, she was observed with a neonate calf in 1998.¹ ID#074's reproductive success may indicate the existence of an unknown dolphin population(s) within the Izu Islands chain. The Ogasawara Islands lie ~800 km south from Mikura Island and are a reported habitat of Indo-Pacific bottlenose dolphins. While long distance migratory patterns for *T. aduncus* have not been documented in the literature, long distance movements of *T. truncatus* have been reported: 300 km in Argentina (Würsig and Würsig 1979) and 470 km in the Southern California Bight (Defran *et al.* 1999). At the Ogasawara Islands, identification research on Indo-Pacific bottlenose dolphins is also underway; therefore, we may be able to investigate the question of migration between the two sites as data become available. The continuation of identification research in cooperation with researchers in other proximate locations is essential to further study of the distribution and possible migratory patterns of bottlenose dolphins south of Tokyo.

Birth Interval, Reproductive Rate

A definitive peak in births was not estimated because of the seasonally limited research period. Nonetheless, we consistently observed mother and calf pairs across seasons. We are confident that we documented all new calves born in the area during the spring to late summer months. Neonates born later in the summer or early fall months were considered to be at a greater risk of mortality in winter because of their lack of blubber thickness concurrent with the onset of colder water temperatures. Each season, the first newborn calf was documented in April and the last one was observed in October, usually by a dolphin-watching guide or captain (Dudzinski, unpublished data 1997–1999; Imamura, unpublished data 2000). The parturition peak of *T. truncatus* in Sarasota Bay is in June (Wells *et al.* 1987). At Indian River Lagoon, bimodal peaks in early spring and late summer were reported for the same species (Urian *et al.* 1996). In the Southern Hemisphere the parturition peak for *T. aduncus* was reported to be between October and December in Shark Bay, Monkey Mia (Mann *et al.* 2000) and in January in Doubtful Sound (Haase and Schneider 2001) for *T. truncatus*. These peaks were observed in the season during which water temperature was the highest during the year. Wells *et al.* (1987) found that the number of births was significantly correlated with water temperature. Water temperature likely influences the survival of newborn calves, which have a small volume-to-surface-area ratio and a thin blubber layer. Since the water temperature around Mikura Island is the highest (29°C) in July and August, we assumed that a parturition peak was likely during these months.

The calving interval at Mikura during this study was 3.4 yr. This average interval was similar to cycles for *T. truncatus* elsewhere: 2.5–3 yr off Japan (Kasuya *et al.* 1997), 3 yr in Doubtful Sound, New Zealand (Haase and Schneider 2001), 3 yr along

the East Coast of Southern Africa (Cockcroft and Ross 1990). Estimated following a similar method, the Bahamas' Atlantic spotted dolphins (*Stenella frontalis*) showed a calving interval of 2.96 yr (Herzing 1997). However, the calving interval for Atlantic spotted dolphin mothers that raised calves successful in weaning averaged 3.5 yr. Mann *et al.* (2000) reported a 4.1-yr birth cycle for *Tursiops* sp. in Shark Bay, Australia. Because this value was also calculated on intervals after success in weaning, it seems slightly higher than the others reported. Most adult females give birth once every 3 or 4 yr, and tend to become pregnant immediately after the loss of a calf.

The mean age at weaning that we observed was 3.5 which was similar to that for Indo-Pacific bottlenose dolphins in Shark Bay (Mann *et al.* 2000) and for *T. truncatus* in Florida (Wells *et al.* 1987). There was no significant difference in the weaning ages between sexes. The average calving interval (3.5 yr) and weaning age (3.5 yr) indicate that dolphins around Mikura tended to wean their current calf at about mid-pregnancy, as Mann *et al.* (2000) reported for other bottlenose dolphins. More detailed information on a potential birth peak and calving intervals should be gathered with an expansion of research on bottlenose dolphins at Mikura Island including observations during the other seasons.

Annual birth rates averaged 0.07 and ranged from 0.03 to 0.12. These estimates fall within the range of values for bottlenose dolphins in Sarasota (0.055; Wells and Scott 1990, 0.082; Irvine *et al.* 1981) and for Atlantic spotted dolphins in Bahamas (0.08; Herzing 1997). The mean fecundity rate (0.239) and recruitment rate (0.068) were also similar to those described for common bottlenose dolphins in Sarasota (0.144 and 0.048, respectively; Wells and Scott 1990) and for Atlantic spotted dolphins in Bahamas (0.23 and 0.06, respectively; Herzing 1997). First-year mortality rates for Indo-Pacific bottlenose dolphins around Mikura Island averaged 0.13, however this value may be underestimated. For other bottlenose dolphins, first-year mortalities were 0.19 for *T. truncatus* in Sarasota (Wells and Scott 1990), 0.20 in Doubtful Sound (Haase and Schneider 2001) and 0.23 for *T. aduncus* in Shark Bay (Mann *et al.* 2000).

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Appendix 1. Reproductive histories of adult female Indo-Pacific bottlenose dolphins at Mikura Island, Japan. P = pregnant, N/O = not observed, S = female dolphin was subadult, — = no reproductive activity witnessed or documented. Hyphenated letters indicate sex and age class of calves that accompanied adult females. M = male, F = female, X = sex unknown, N = neonate, J = juvenile. Neonates lost in first year of life are in bold.

ID No.	Year								Total calves (mortality in %)
	1994	1995	1996	1997	1998	1999	2000	2001	
001	M-J	M-J	—	P	M-J	M-J	M-J	X-N	3 (33)
003	M-N	—	—	P	N/O	N/O	N/O	N/O	1 (100)
021	S	S	S	S	F-N	F-J	F-J	F-J	1 (0)
022	—	—	—	—	N/O	N/O	N/O	N/O	0 (0)
023	—	M-N	M-J	—	M-J	X-N	P	X-J	3 (33)
025	F-N	F-J	F-J	F-N	F-J	F-J	X-N	X-J	3 (0)
027	M-N	M-J	M-J	M-N	M-J	X-N	X-N	X-J	4 (25)
028	S	S	S	S	S	S	X-N	X-J	1 (0)
030	S	S	S	S	S	S	S	X-N	1 (0)
032	X-J	M-N	M-J	M-J	M-N	M-J	M-N	M-N	4 (0)
033	M-J	F-N	F-J	F-J	X-N	X-J	X-J	X-N	4 (0)
035	M-J	M-J	X-N	X-J	X-J	X-N	P	X-J	4 (25)
037	S	S	S	S	S	S	S	X-N	1 (100)
039	F-N	F-J	F-J	X-N	—	F-N	F-J	F-J	3 (33)
040	S	S	S	S	S	F-N	F-J	F-J	1 (0)
041	S	S	S	S	F-N	F-J	F-J	X-N	2 (0)
052	—	N/O	—	—	M-J	—	X-N	X-J	2 (0)
056	—	M-N	M-J	—	X-N	X-J	X-J	X-N	3 (33)
057	P	M-J	M-J	M-J	M-J	M-J	—	—	1 (0)
058	M-N	M-J	M-J	M-J	—	X-N	X-J	X-J	2 (0)
059	X-N	X-J	X-J	N/O	F-N	F-J	F-J	X-N	3 (0)
060	F-N	F-J	F-J	—	F-N	F-J	F-J	X-N	3 (0)
061	F-N	F-J	F-J	F-J	F-N	F-J	F-J	X-N	3 (0)
063	M-J	N/O	N/O	N/O	—	X-J	—	X-N	4 (25)
064	—	M-N	M-J	M-J	M-N	M-J	M-J	M-J	2 (0)
065	S	S	S	S	F-N	F-J	F-J	F-J	1 (0)
066	S	S	M-N	M-J	M-J	M-J	X-N	X-J	2 (0)
068	S	S	S	F-N	F-J	F-J	F-J	X-N	2 (0)
070	M-N	M-J	M-J	—	M-N	M-J	N/O	N/O	2 (0)
072	M-N	M-J	M-J	M-N	M-J	M-J	X-N	X-J	3 (0)
073	F-J	F-J	M-N	M-J	M-J	M-N	M-J	M-J	3 (0)
074	S	X-N	N/O	N/O	N/O	N/O	N/O	N/O	1 (0)

Appendix 1. Continued.

ID No.	Year								Total calves (mortality in %)
	1994	1995	1996	1997	1998	1999	2000	2001	
080	P	X-J	X-J	F-N	F-J	F-J	M-N	M-J	3 (0)
081	X-J	X-N	X-J	X-J	X-J	—	—	X-N	3 (33)
086	M-J	M-J	—	P	F-J	F-J	—	X-N	3 (0)
094	X-J	X-J	M-N	M-J	M-J	M-N	M-J	M-J	3 (0)
099	X-N	X-J	X-J	F-N	F-J	F-J	F-N	F-J	3 (0)
102	—	—	—	—	—	—	—	N/O	0 (0)
103	F-N	F-J	F-J	F-J	—	X-N	X-J	X-J	2 (0)
143	N/O	F-N	F-J	F-J	—	—	—	—	1 (0)
151	N/O	M-J	M-J	—	—	—	—	—	1 (0)
162	N/O	M-N	M-J	M-J	M-J	—	—	—	1 (0)
178	N/O	M-J	M-J	—	—	—	—	—	1 (0)
314	N/O	N/O	N/O	N/O	S	S	S	X-N	1 (100)