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Environmental Variables Affecting the Residence of Spinner Dolphins (*Stenella longirostris*) in a Bay of Tahiti (French Polynesia)

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Abstract

The spinner dolphin (*Stenella longirostris*) is the most common among 16 species in the Society Islands (French Polynesia). They are observed year-round during daytime in sheltered bays or within lagoons. From 1995 to 2002, we studied spinner dolphins from a shore site in Baie des Pêcheurs, a bay on the west coast of Tahiti, performing 1,033 sighting sessions with binoculars. Presence, position, and school size were noted, as well as various behavioral and environmental variables. Human presence also was recorded. Dolphins were present on average 73.3% of the days, with a higher presence rate from May to November (81.0%) than from December to April (66.7%). Dolphins stayed within the bay from early morning until 1200 to 1500 h and had school sizes ranging from as small as 15 to 30 to as large as 100 to 140 individuals. Dolphins began to move slowly offshore after 1100 h. On average, they stayed 400 m from shore, although they approached as close as 100 to 150 m. Dolphin presence and residence time seemed to be negatively affected by surface water turbidity (river flow) and lagoon current strength. Recreational dolphin watching was low from Monday to Thursday (0.20 to 0.35 boat per sighting session) and high on Sunday, with an average of 1.67 boats per session. There was a lower dolphin presence rate from Monday to Thursday (69%) than from Friday to Sunday (78%). Presence patterns were similar to those found in Hawaii, accounting for differences in environmental characteristics.

Key Words: spinner dolphin, *Stenella longirostris*, Tahiti, Baie des Pêcheurs, cove, residence, environmental factors, long-term

Introduction

The Society Archipelago in French Polynesia shelters more than 16 cetacean species, 10 of which are delphinids (Gannier, 2000, 2002a). The spinner dolphin (*Stenella longirostris*) is the most common delphinid in the Society Islands and is seen year-round around Tahiti and Moorea (Poole, 1995; Gannier, 2000). Spinner dolphins are common in tropical and subtropical waters worldwide, and in both inshore and offshore waters (Perrin & Gilpatrick, 1994). They feed primarily at night on mesopelagic fishes and cephalopods, as well as on crustaceans (Dolar et al., 2003). From their external appearance, the spinner dolphins observed off Tahiti resemble the subspecies *S. longirostris longirostris* found in the Hawaiian Islands (Norris et al., 1994; Rice, 1998; Benoit-Bird & Au, 2003; Lammers, 2004); size, pigmentation pattern, and a moderately falcate dorsal fin are coherent characteristics to support this hypothesis. Preliminary studies support an inshore distribution pattern for spinner dolphins in the Societies (Gannier, 2000, 2002b), with a day/night shift similar to that found in Hawaii. The dolphins enter the bay shortly after sunrise and leave before sunset. As in Hawaii (Norris et al., 1994), where dolphins join sheltered coves or lagoon areas during daytime for resting and socializing, dolphins wander into slope water for feeding activity at night.

The study site at Baie des Pêcheurs was located on the western shore (leeward side) of Tahiti, the largest island in French Polynesia and an area undergoing rapid development by humans. This study was carried out on a long-term basis (1995 to 2002) to assess the presence of spinner dolphins and determine temporal and environmental variables influencing the pattern. The primary data were a set of 1,033 sighting sessions from shore. Results from boat surveys were included to bring elements on the dolphin offshore distribution. Although the aim of the study was not to look precisely at the human influence on dolphin residence, our analysis included boat count as an ancillary variable. We provided the baseline elements to understand the spinner dolphin residence in Baie des Pêcheurs to help adequately manage the area in the future.

Study Area

Tahiti is located in the central tropical Pacific, at about 17° 30' S and 149° 30' W, and is the principal island of the leeward group of the Society Islands, including Moorea, Mehetia, Tetiaroa, and Maiao. Oceanic waters are oligotrophic, with sea surface temperatures ranging from 24° C (July to August) to 29 to 30° C (March to April). Its volcanic origin results in a steep slope of about 6 to 8° around the island. Water depths of 1,000 m are generally found 2.5 to 5.5 km from shore. Coral reefs form a barrier on the western and southern part of the island. A lagoon embodies shallow areas, as well as a water depth of > 20 m between the barrier and the coastline. Baie des Pêcheurs is one of these coves, and it is one of the best known spinner dolphin resting sites in Tahiti; the other is Baie du Taaone. Several other places also are known to occasionally host *S. longirostris* schools (Figure 1a). There are similarities between Baie des Pêcheurs and Kealake'akua Bay in Hawaii: both are located on the leeward side and feature moderate depth (10 to 30 m) waters over a similar square area. Unlike Kealake'akua, our study site is located at the mouth of the Punaruu River, characterized by an irregular flow driven by rainfall and by industrial installations along its lower part (Figure 1b). The bottom of Baie des Pêcheurs is partly sandy (light grey) with patches of rock and a few isolated coral heads; the 5-m depth is reached within 50 m from the pebbles beach. The cove of Baie des Pêcheurs borders on barrier reefs and lagoon areas on the north and south. Lagoon waters flow into the bay, with the strength depending on the oceanic swell. Current can be strong enough on the southern part of the cove to affect the entire bay with a heavy S to SW swell. These environmental variables are specific to our study site and affected the water quality of the bay.

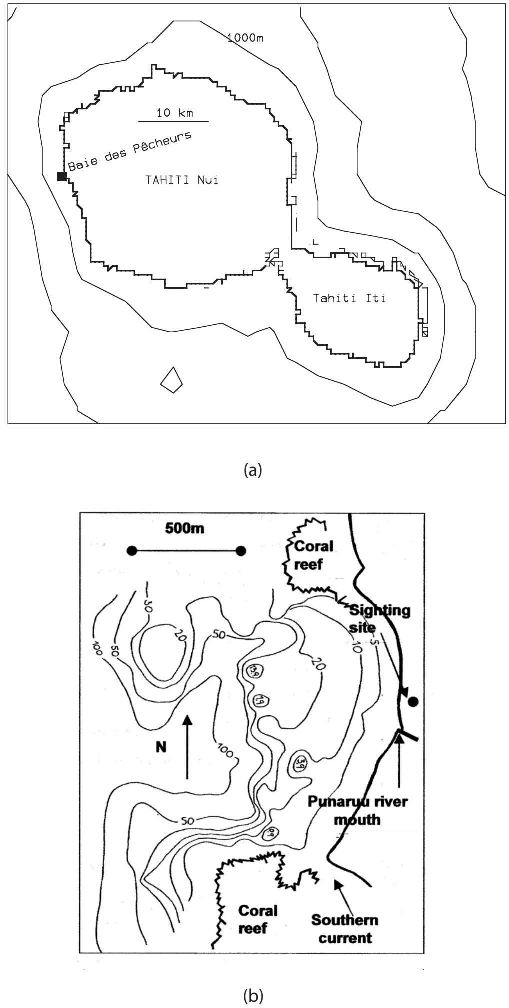

Figure 1. Area of study (a) location of Baie des Pêcheurs on the Island of Tahiti, and (b) detailed map of Baie des Pêcheurs with sighting site; Isobath 5, 10, 20, 50 and 100 m are drawn.

Materials and Methods

Shore Site Data Set

The main data set was obtained between October 1995 and September 2002 and consisted of 5-min (sometimes 10-min) sighting sessions from a shore site close to the middle of the bay, 3 m above sea level. Binoculars (7 × 30) were used to locate dolphins in the bay and to estimate school size. During the first year of study, two such sessions were carried out daily to grossly assess the dolphin residency duration. Seven variables described the dolphin presence in the bay: (1) minimum school size, (2) maximum school size, (3) estimated radial distance from shore, (4) position in the bay (north, center, river, south), (5) group structure (grouped, scattered, subgroups), (6) behavioral state (resting, socializing, avoiding boats), and (7) a count of breaching events (standardized for 5 min). Other sighting information, such as presence of calves, was recorded opportunistically. Six environmental variables also were noted (Table 1): (1) cloudiness, (2) swell height (in six categories ranging from none to very heavy, > 3 m), (3) surface turbidity, and (4) lagoon current strength (both on a scale of five). The two later variables were visually estimated from the shore station: the surface turbidity was given a value corresponding to the cove fraction covered by muddy water, ranging from 1 – bay entirely clear to 5 – bay surface totally turbid. Likewise, the current index ranged from 1 – absent to 5 – very strong over the whole bay extent (Figure 1b). A synthetic sighting condition index was adopted from our boat sighting experience (Gannier, 2000, 2002a) and described our ability to detect and count

Table 1. Definition of environmental variables at Baie des Pêcheurs in Tahiti, 1995-2002

Scale	Sky cloudiness (range 1-4)	Surface turbidity (range 1-5)	Lagoon current (range 1-5)	Swell (range 1-6)	Sighting condition index
1	Clear (0/8)	Totally clear	None	None	Bad
2	Partly cloudy (< 4/8)	Turbid waters near river mouth	Noticeable in lagoon outlet	Barely noticeable	Bad
3	Cloudy (< 7/8)	Turbid waters over half cove	Visible over half bay width	< 0.5m	Mediocre
4	Overcast	Turbid waters over 3/4 of cove	Visible over the bay width	About 1 m	Good
5	--	Turbid waters all over cove	Strong; curtails surface waters	About 2 m	Very good
6	--	--	--	About 3 m	Excellent

dolphins within the bay, ranging from 1 to 6, depending on wind speed and swell/daylight conditions. Data collected below Index 4 were not used. With Index 4, very small and inconspicuous dolphin schools may have been missed by the observer; Index 5 may generate unprecise school size estimates for dolphins more than 500 m away. With Index 6 (calm sea and low swell), all dolphins can be located and group sizes estimated over the study range. The number of boats was recorded by category (e.g., fisherman pirogue, dedicated dolphin watch, opportunistic dolphin watch, other).

In addition to the short duration sightings, 50 extended sighting sessions were held from December 2001 to July 2002 to monitor dolphin activity and boat presence. These sightings were organized to begin early in the morning and stopped after the dolphins left the cove or were no longer visible from shore. The observer used a 7 × 50 reticuled binocular to record bearing angle and estimate radial distance. These data were used to obtain the residence time of spinner dolphins in Baie des Pêcheurs, and consistent information was extracted to be used with the short session data set.

Shore Data Analysis

Statistical analysis were performed with *XLStat 7.5*. Data were processed to obtain results of the temporal, the spatial, and the environmental aspects. Presence/absence, minimum and maximum school sizes, and distance-to-shore were found to be abnormal (Shapiro-Wilk test); hence, comparison between cases were carried out with the Kruskal-Wallis nonparametric test. For the temporal analysis, because 1,033 sighting sessions were performed over a 2,257-d study duration, giving an average lag-time of 2.18 d, we took one week as the basic sampling unit for the seasonal/long-term residence rate study (Legendre & Legendre, 1998). Presence/absence variables and school sizes were compared for different years, months, days, and hours. Presence/absence was then studied in relation to environmental variables taken separately (swell, surface turbidity, lagoon current), including also the presence of boats. For the spatial analysis, we examined the radial distance to shore, which was processed in relation to three environmental variables, temporal variables (year, month, hour), and school size.

The average residence time in the cove was obtained from 46 successful extended sightings. Observers arrived at the surveillance site between 0625 and 0750 h, when the dolphins were always observed within the cove. A conventional time of 0700 h was used to define a standard duration time. The dolphins were considered to leave the bay when passing beyond 600 m from shore. Although this distance was slightly off the cove boundary, the dolphins were never observed to re-enter the bay after they had crossed this 600-m limit. Dolphins always could be visually tracked up to this 600-m limit, even with a sighting index of 4.

Boat Sighting Data

From 1996 to 2002, small boat cetacean surveys were carried out in the Society Islands. Although not dedicated to spinner dolphin studies, they allowed us to determine their distribution in the vicinity of the study site. As detailed reports on cetacean distribution, including survey efforts, were given in previous papers (Gannier, 2000, 2004), only sighting locations were presented in the present paper. Results were analyzed for two periods of the day—before 1500 h and after 1500 h—and related to previously observed spinner dolphin residence trends (Gannier, 2002b).

Results

Temporal Variations of Presence

From 1,033 sessions, 999 sightings were with a condition index > 3, and spinner dolphins were observed in the bay on 733 occasions, giving an overall presence of 73.3%. The presence differed significantly among years (Kruskal-Wallis = 15.60, DF = 7, p = 0.029), with values between 82.5% (1995) and 65.2% (1996); 1995 was an incomplete year, however, and once it was removed from the test, variations of yearly presence ratio were not significant (Table 2). The average minimum school size (Smin) was 37.0 animals and was quite consistent between years (Table 2), with the exception of 29.2 in 1999 and 42.7 in 2002. We found exactly the same pattern for maximum school size (Smax): 63.4 dolphins on average, but with a low value of 48.5 in 1999 and a high value of 75.3 in 2002 (Table 2). Fluctuations of Smin and Smax between years were found significant (K-W = 52.4, DF = 7, $p < 0.0001$ for Smax), and pairwise testing showed that 1999 was distinctively different from both 1998 and 2000 (K-W, df = 1, $p < 0.01$, in both cases).

The monthly presence varied between 59.6% in February and 100.0% in July, and eight monthly values were within the range of 68 to 82% (Figure 2). A global fluctuation was highly significant (K-W = 34.2, DF = 11, $p < 0.001$) between one high presence period from May to November (81.0%), during which monthly variations were insignificant (K-W test, p = 0.186), and one lower presence period (66.7%) from December to April (K-W, p = 0.407). Estimates of Smin and Smax were at the lowest in June (31.2 and 54.5 individuals, respectively), with the highest school size in February

Table 2. Presence ratio and school size of spinner dolphins at Baie des Pêcheurs in Tahiti by year, 1995-2002

Year	Effective effort (n sessions)	Dolphin presence (P sightings)	Presence (%)	Minimum school size (average; SD)	Maximum school size (average; SD)
1995*	57	47	82.5	38.1; 16.8	64.8; 20.7
1996	92	60	65.2	32.0; 2.7	60.9; 17.7
1997	117	82	70.1	38.2; 16.7	65.3; 20.9
1998	179	122	68.2	35.5; 16.6	60.5; 23.9
1999	111	77	69.4	29.2; 12.2	48.5; 19.4
2000	103	75	72.8	38.8; 20.2	62.3; 28.5
2001	184	151	82.0	37.1; 20.5	67.9; 31.8
2002**	156	119	76.3	40.8; 19.2	72.9; 28.3

* October to December only

** January to September only

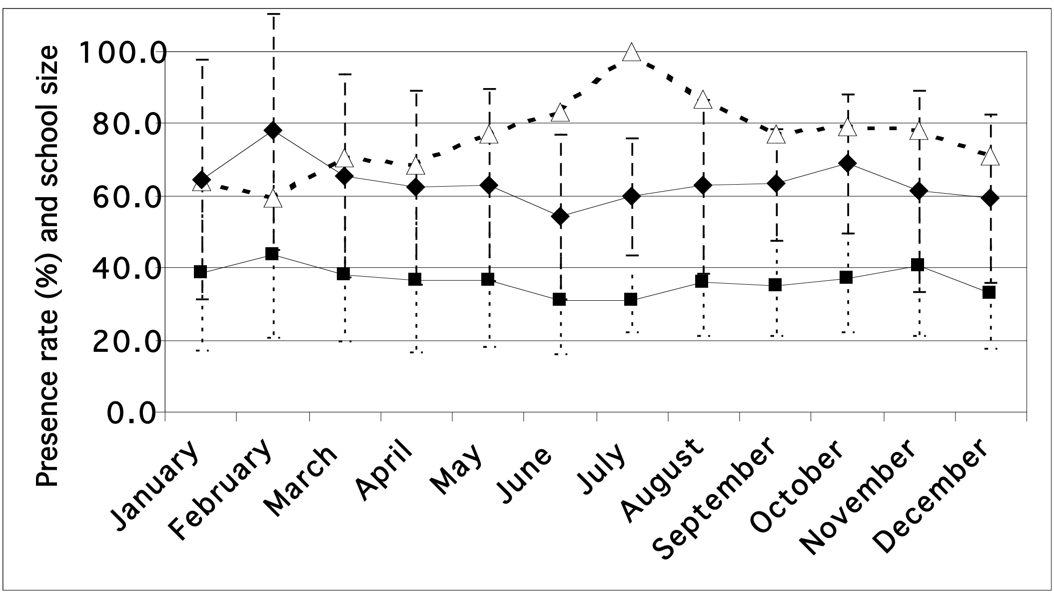

Figure 2. Presence rate of spinner dolphins in % (dashed line and open triangle) by month, minimum (solid square), and maximum (solid diamond) school size, with ± SD bars, 1995-2002

(43.8 and 78.0, respectively), and showing a significant change among months (K-W = 29.2, DF = 11, $p < 0.002$). Further analysis confirmed that February school sizes were significantly higher, even compared with January and March (Figure 2). Monthly variations, excluding February, were not significant throughout the year (K-W = 15.4, DF = 10, $p < 0.116$).

Dolphin presence showed a clear temporal pattern over the day—at maximum before 1100 h, with rates of 72.1 to 81.3%, and decreasing gradually between 1100 and 1600 h, when presence reached 43.6% (Figure 3). During the morning, hourly rates were uniform (K-W = 0.59, DF = 4, $p = 0.96$), and during the afternoon, a regular decrease of presence rate was visible, although not tested as significant (K-W, $p = 0.088$).

School sizes along the day showed a trend to higher estimates between 0600 and 0800 h, followed by a homogeneous estimate range of 33 to 37 individuals for Smin and 59 to 63 individuals for Smax, from 0800 to 1400 h (Figure 3). The Kruskal-Wallis test performed on both estimates indicated that school size changes were not significant ($p = 0.199$ for Smax).

In summary, variations of residence rates and school sizes at different time scales showed that: (1) stay rate was stable during the period of study on a yearly basis, but school sizes were lower in 1999, (2) average monthly presence was higher during the May to November period than during the rest of the year, and dolphins were more numerous in the bay during February, (3) presence during the day was stable up to 1100 h, with an apparent afternoon decrease in residence rate (not statistically significant), and (4) the observed school sizes were stable from 0800 to 1400 h.

Time of Residence

From 46 extended duration sightings, the residence time in the cove averaged 4.95 h ($n = 46$), with a minimum of 1.92 h and a maximum of 7.08 h, although most durations were in the range of 3.50 to 6.00 h. We obtained an average duration of 4.02 h ($n = 20$) for the December to April period, when the average for the May to July period was 5.66 h ($n = 26$), thus indicating that dolphin stay was shorter when daylight was longer than when daylight was shorter. This data set indicated that dolphins often passed the 600-m boundary by midday, which was similar to results obtained above with the 5-min sighting sessions.

Distance to Shore

Distance to the shore varied by time of day, with dolphins coming closer to shore early in the morning, rather than later in the day. Dolphins were observed on one occasion to approach as close as 50 m to shore, although 100 to 150 m were typical low values, with bottom depth being < 20 m (Figure 1b). Distance from shore remained constant from 0600 to 1100 h (395 m, SD = 169 m) and regularly increased by 88 m/h ($r^2 = 0.85$) until 1600 h (Figure 4). Average distances to shore varied greatly by year between 1999 (531 m, SD = 246) and 2000 (327 m, SD = 116 m). Surface

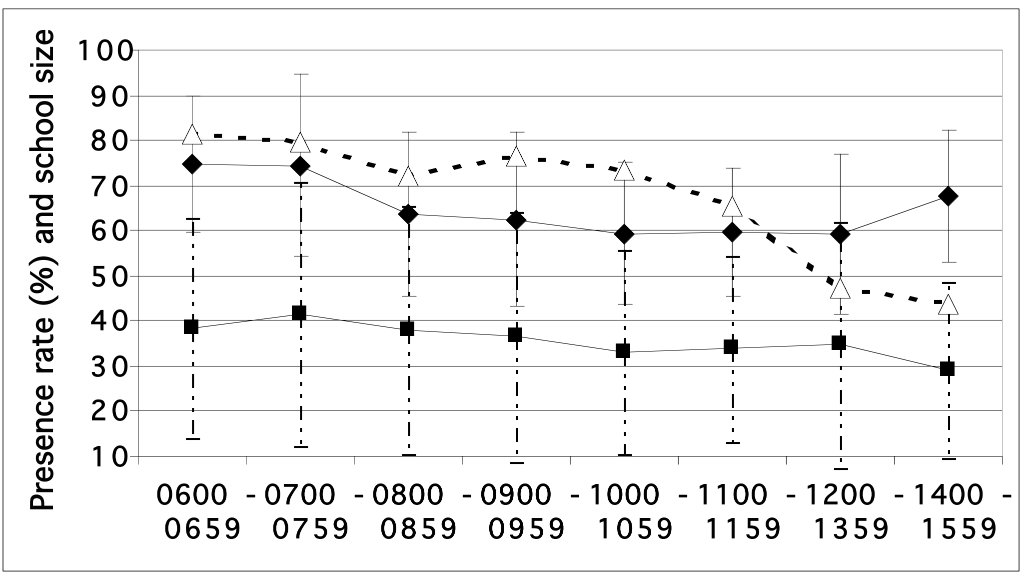

Figure 3. Presence rate of spinner dolphins in % (dashed line and open triangle) by time of day, minimum (solid square), and maximum (solid diamond) school size, with ± SD bars, 1995-2002

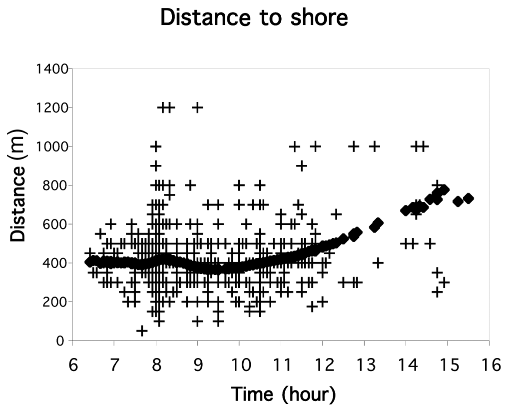

Figure 4. Distance to shore as a function of time of day; raw sighting data and a regression model

turbidity of the bay had a strong effect on average distance to shore. Dolphins were closer to shore (392 to 410 m) when surface water was clear to moderately turbid (Indices 1 to 3), but were on average 463 m and 515 m from shore under turbid waters (Indices 4 and 5, respectively). On the contrary, swell height did not seem to influence distance to shore (K-W = 6.8, DF = 6, $p = 0.337$). In addition, the dolphins tended to be closer to shore when there was no lagoon current (distance to shore, 358 m) or when the current was weak (406 m). Dolphins tended to be further from shore when a medium (423 m) or strong (458 m) cross-current was in place. In summary, the dolphins were likely to come closer to shore with clear surface waters and a weak lagoon current, and they stayed farther offshore when the bay waters were very turbid or crossed by a strong lagoon current.

Presence Variations with Environmental Variables
The surface turbidity was the most influential variable, with dolphin presence varying from 71.3% to 79.3% when water was very clear to moderately turbid (Indices 1 to 3) to only 43.6% and 60.0% when water turbidity was high or very high (Indices 4 and 5). This influence was statistically significant (K-W = 13.2, DF = 1, $p < 0.001$). Surface turbidity was highly variable during the year (Kruskal-Wallis = 126.8, DF = 11, $p < 0.0001$), with a period of clear water from August to November, a period of very turbid water in March, and the rest of the year characterized by moderate turbidity.

The swell height did not seem to influence directly the dolphin presence (K-W = 9.75, DF = 6, $p = 0.136$), which was affected by the lagoon current (K-W = 31.7, DF = 4, $p < 0.0001$), itself a consequence of S-SW swell. The dolphin presence was 80.0 and 88.2%, with the current null or weak (Indices 1 and 2), and 57.7 to 70.4% with a medium or strong current (Indices 3 to 5). Hence, the same variables which caused the dolphins to stay farther from shore were also shown to have a negative influence on their presence rate. The high presence period of May to November is primarily a dry season in Tahiti, during which river flow is low and the river water is generally clear. The low presence period is affected by rainy episodes, during which the cove surface waters could be entirely turbid.

Dolphin Presence in Relation to Boats
The presence of boats was not uniform during the week (K-W = 84.8, DF = 6, $p < 0.0001$) with a range of 0 to 8 boats observed in the bay during 5-min observation sessions. Average boat numbers were low on Monday and Tuesday (0.20 boat in both cases), slightly higher on Wednesday and Thursday (0.32 and 0.31 boat on average, respectively) and higher again from Friday to Saturday (0.47 and 0.55, respectively), but it reached a clear peak on Sunday, with an average of 1.67 boats noticed during a 5-min observation. This weekend traffic was confirmed by a test on boats. When fishermen's pirogues or SCUBA-diving traffic was homogeneous, small recreational boats showed significant heterogeneity between days of the week (K-W, $p < 0.0001$). Most recreational boats were observed to come close to the dolphins, while pirogues or SCUBA-diving boats did not systematically visit the spinner dolphins. Therefore, three periods could be delimited during the week (K-W = 80.1, DF = 2, $p < 0.0001$): from Monday to Thursday, few boats visited the bay; from Friday to Saturday, the presence of boats was moderate; and on Sunday, the dolphin watch reached its maximum intensity. Average boat presence increased throughout the period of study, from 0.17 to 0.23 boat in 1995 to 1997, to 0.28 to 0.29 in 1998 to 1999, to 0.59 boat in 2000, and finally to 0.74 in 2001 to 2002.

The spinner dolphin presence was not uniform during the week (K-W = 12.6, DF = 6, $p = 0.048$), with the highest presence rate on Friday (81.8%) and the lowest on Wednesday (64.9%). The trend was even more significant (K-W = 7.12, DF = 1, $p = 0.008$) when grouping the days in two periods, with a lower rate from Monday to Thursday (69.0%) than from Friday to Sunday (78.0%). This difference in daily presence rate was no longer significant (K-W observed 10.9, DF = 6, $p = 0.092$) when restricting the analysis to data obtained only with very good to excellent sighting conditions (Indices 5 and 6). Then, it is likely that dolphin-watch boats—which were much more frequent during the weekends—triggered our visual detection of dolphins, especially when sighting conditions were barely "good" (Index 4). The statistics on school sizes also indicated differences (*t*-test, $p = 0.022$) with a Smin slightly lower from Monday to Thursday (Smin = 35.6, SD = 17.3) than from Friday to Sunday (Smin = 38.8, SD = 18.6). Similar results were obtained with Smax estimates.

Boat Survey Results

We observed spinner dolphins on 67 occasions around Tahiti from March 1996 to September 2002. In spite of significant good weather prospection effort on the windward side of the island, sightings were concentrated off the leeward shore. Before 1500 h, we observed spinner dolphins in, or close to, resting sites hourly (Table 3). Our sighting results did not reflect the true distribution of resting dolphin schools off Tahiti since survey coverage was heterogeneous, favouring the western leeward side of the island because of its proximity to our boat's home port.

Another important and regular resting site was located close to the northern point of Tahiti (Pointe Venus); other sightings show that spinner dolphins might use other sites for resting, perhaps regularly (Figure 5a). After 1500 h, sightings were spread along the western shore, extending from Pointe de Faa'a to Pointe Maraa at the south of this coastline (Figure 5b). Likewise, these sightings did not reflect the true spinner dolphin distribution around Tahiti. Sightings remained inshore of the 1,000-m isobath, however, reflecting the slope preference of spinner dolphins around Tahiti from afternoon to dusk. This suggested that after leaving their coastal resting sites, the spinner dolphins of Baie des Pêcheurs did not wander into open sea for feeding purposes, rather they stayed within a few kilometers from the reef barrier.

Table 3. Effort and sightings of spinner dolphins at Baie des Pêcheurs in Tahiti, 1995-2002

(a) by month

Month	Sessions (*n*)	Sightings (*n*)
January	109	70
February	109	65
March	112	79
April	112	77
May	110	85
June	78	65
July	37	37
August	30	26
September	87	67
October	63	50
November	59	46
December	93	66

(b) by time of the day

Time of day (h)	Sessions (*n*)	Sightings (*n*)
0600-0659	16	13
0700-0759	132	105
0800-0859	405	291
0900-0959	159	122
1000-1059	147	108
1100-1159	90	59
1200-1259	26	14
1300-1359	12	4
1400-1459	28	13
1500-1559	11	4
1600-1859	7	0

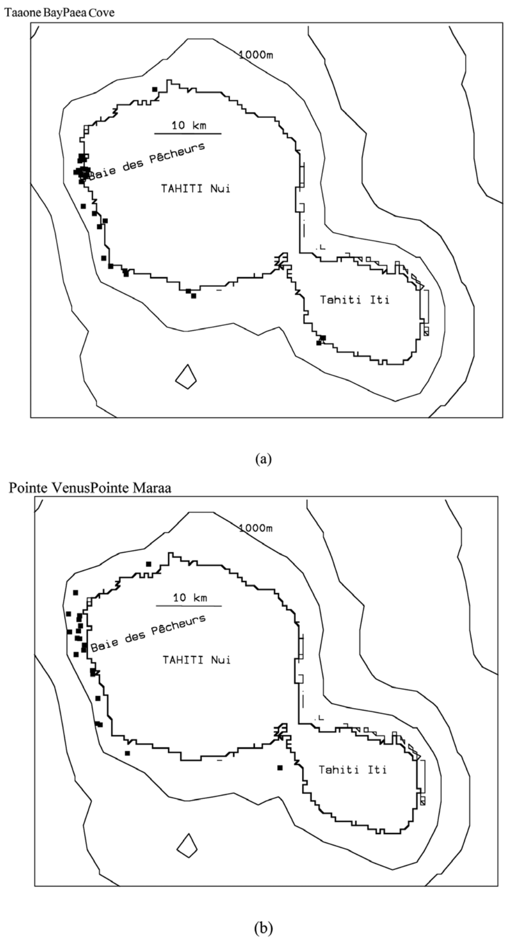

Figure 5. Sightings of spinner dolphins from boat surveys around Tahiti (1996 to 2001); (a) before 1500 h and (b) after 1500 h

Discussion

This long-term study features similarities with the one year of research in Kealake'akua Bay (Hawaii) reported in Norris et al. (1994). First, the study sites are analogous in size, bottom topography, and are both located on the leeward side of the islands of Hawaii and Tahiti. The bottom itself features large extents of sand (p. 51) (light to medium grey in the case of Baie des Pêcheurs), which make the cove an attractive site for resting spinner dolphins (Norris et al., 1994).

There are also two differences between our study site and Kealake'akua Bay. Baie des Pêcheurs is at the mouth of Punaruu River, which can bring muddy water into the bay. Norris et al. noted only "brackish ground water plumes" (p. 38) at the Hawaii site. Second, there is no barrief reef close to Kealake'akua Bay, unlike our study site, where the reef and lagoon system generate a strong stream across the cove during periods of S to W swell. Like Norris et al., (1994) who noted that spinner dolphins were "moving away from the Kona coast" (p. 46) in times of rough weather, we observed that poor environmental conditions in our cove were causing a decrease in presence rate and/or in average school size. Turbidity of surface waters in Baie des Pêcheurs was recorded to be low from August to November, when dolphin presence rate was high (80.2%) compared to December to April (66.8%), a period of higher turbidity. Similarly, dolphins seemed to respond to higher surface turbidity with a lower presence ratio (range 43 to 64%), compared to "clear" water situations (presence rate range 71 to 79%) and by staying farther from shore. We observed (by snorkeling) that turbid waters generally did not extend more than a couple of meters deep because of their low salinity; hence, they caused the dolphins to be temporally "blind" during their breathing sequences. According to Norris et al., one of their chief reasons for selecting a resting site (p. 290) is the predominance of clear water, enabling proper detection of potential predators, such as sharks. The lagoon current may influence the dolphin presence or their position relative to shore, but it also contributes visibly to surface turbidity. In times of a moderate to strong stream, turbid waters are clearly curtailed inshore of the current, thus causing a marked division of the cove between a muddy area and a clear water domain. In this case, dolphins were never observed to cross the stream and enter the muddy water area (Gannier pers. obs.). On the longer term, a very intense rainy period late in December 1998 resulted in a flood of the Punaruu River, bringing numerous debris (including industrial debris) and a lot of sediments into the cove. The effect was that the average turbidity index was higher during the first six months of 1999 than during the same period in 1998. We observed lower average school sizes (Smin, 29.2; Smax, 48.5) in 1999 compared to other years—perhaps the higher surface turbidity dissuaded a certain animals from staying in the bay during this period. Apart from exceptional or regular seasonal weather events, human activity has an influence on water turbidity—gravels and other raw construction materials are extracted routinely from the Punaruu River bed, and this has a visibly negative impact on the water quality in Baie des Pêcheurs (Gannier pers. obs.). In summary, the surface turbidity was shown to vary and to influence dolphin presence, school size, or their distance to shore.

The Smin and Smax of spinner dolphins were 37 and 63 individuals, respectively, over the study period, with a low in June (31 to 55) and a high in February (44 to 78). Norris et al. (1994) indicated that Kealake'akua Bay sheltered an average of 33.5 dolphins (p. 51) (SD = 27), with a maximum of 80, against a maximum of 80 to 120 spinner dolphins in Baie des Pêcheurs. Although not always visible (depending on the school distance to shore), calves were recorded in the cove during 41 sightings from January to April, and they were also observed during boat trips at the same season. It is therefore possible that the February peak in school size is linked to the reproduction cycle, mentioned to be diffusely seasonal for offshore spinner dolphins (Perrin & Gilpatrick, 1994), either because female-calf subgroups are present or because more adults are grouped for mating. School size estimates obtained from shore at a distance of 300 to 600 m may not be accurate and could be influenced by behavior; for example, the apparent downshift of Smin-Smax between 0700 to 0800 h and 0800 to 0900 h from 41.5-74.5 to 37.9-63.6 might be attributed to a progressive change in activity of spinner dolphins upon their arrival in the cove, namely the "descent into rest" (pp. 78-81) observed by Norris et al. (1994) in Hawaii. On some occasions, our shore school size estimate was confirmed during a boat observation later the same day. Lammers (2004) also observed a gradual decrease in spinner dolphin group size off Oahu as a function of the time of day.

The residence time was mentioned to vary seasonally in Norris et al. (1994), from an average of 4 to 5 h in winter, peaking at 7 to 9 h in spring, and then decreasing in summer, while arrival times were somewhat correlated to sunrise. A different pattern seemed to arise from our extended sighting data set. Although we were not present when the dolphins arrived in the cove, we found an average stay of 4.0 h from December to April (austral summer) and 5.6 h from May to July (austral autumn and winter). Perhaps the residence time was mostly influenced in our case by surface water turbidity, rather than by daylight duration. Stay duration has to be in relation with the time necessary to reach the feeding area before sunset, and an indication of those areas was obtained with our boat sightings after 1500 h (Figure 5b). Within the whole slope zone, one would expect that particular places to be especially attractive for spinners, such as off major passes (with the exportation of organic materials suitable to the food web), including that of Papeete and Punaauia, and also coastal convergence zones, such as Venus and Maraa Points (Figure 5b). Given the distances from Baie des Pêcheurs to those places and assuming a travel speed of 6 km/h, the feeding areas could be reached within 1.5 to 3 h, thus allowing dolphins enough transit time. Such favorable feeding sites were shown by Lammers (2004) during a boat-tracking experiment off Oahu. In Hawaii, spinner dolphins have been shown to have an active predation strategy during the night, exploiting inshore and offshore areas in close correlation with their prey distribution (Benoit-Bird & Au, 2003). They were recorded more often offshore around 2100 h, then quite inshore around midnight, and finally offshore at 0300 h, before heading to coastal resting coves in the morning. Part of the variability in daily or seasonal residence duration might be explained by the suitability of particular feeding zones at a given period.

The residence time was clearly influenced by boat presence since dolphins were observed to leave the cove as early as 1100 to 1200 h during weekends in relation to increased boat pressure. An increased pressure from dolphin-watch boats apparently resulted in a faster offshore movement, with spinner dolphins heading to deeper waters to avoid interaction, as mentioned by Lammers (2004), under particular school structures and behavioral states. Some of our results suggested that maximal boat disturbance during the weekend might sometimes dissuade dolphins from coming back to the bay the next day, but this remains questionable since our visual detection process was eventually positively biased by the presence of dolphin-watch boats. School sizes estimated from shore might also be influenced by surface behaviors stimulated by dolphin watch vessels.

The annual presence rate was observed to change between 65% and 82%, though it was not tested as significant. One could identify possible bias effect between the annual estimates and monthly presence rates, which have been shown to fluctuate between a high presence period (May to November) and a low presence period (December to April). One possible reason for the high presence rate in 2001 is that 30% of that year's sampling was obtained in June-July-August, almost twice as much as was usually obtained. The presence in the cove did not reflect the strong El Niño Southern Oscillation event of 1997 to 1999. Annual rates of those years were particularly similar (0.701, 0.682, and 0.682, respectively), although we have seen that in 1999 dolphins stayed farther from the coast (531 m) than usual, and with apparent lower school sizes.

Contrary to the spinner dolphins of Hawaii, which can access resting sites along more than 100 km of leeward coast, those of Baie des Pêcheurs do not have as much space. Tahitian spinner dolphins have only a 25-km stretch on the west coast of Tahiti, with another 18 km on the northwest coast where another major resting site lies (Figure 5). This is much like the situation found off Oahu, with the leeward Waianae coast and the more exposed south shore (Lammers, 2004). In Tahiti, the barrier reef itself is generally a shallow plate with a steep slope to 40 to 60 m in depth and is not suitable for dolphin rest (Norris et al., 1994). Alternative areas suitable for spinner dolphin daytime activity are located 3 km N (Punaauia Pass) and 16 km N (Papeete Pass). Both are important entrances to ports and, hence, rarely used by the dolphins (Gannier pers. data). The other regularly used site on the western coast is Paea Cove, which is 9 km S on a tiny (150 x 250 m) break in the barrier reef and at the mouth of a small river. Paea Cove is sometimes used when dolphins are not seen at Baie des Pêcheurs, and it generally hosts less than 40 dolphins (Gannier pers. data).

Lagoon topography in Tahiti includes very shallow (1 to 3 m) areas and channels 20- to 40-m deep. These channels are sometimes used as spinner dolphin resting areas, although variables, such as distance to the nearest pass and distance from the pass to the feeding areas affect suitability. In the nearby island of Moorea, several resting sites are located within lagoon areas (Poole, 1995; Gannier pers. data), as in the Leeward Islands (Gannier, 2000), where dolphins may be observed up to 5 km from the nearest pass. The lagoon area is not extended in Tahiti because the island is geologically young, 1 to 2 MYA (ORSTOM, 1993), and suitable areas with white or light grey coral-based sand are rare.

Should the access to Baie des Pêcheurs be limited due to degraded conditions, one wonders what would be the second choice of those spinner dolphins, given that long-term site fidelity seems to be a characteristic of this dolphin ecotype (Marten & Psarakos, 1999). Spinner dolphins are observed inshore in most islands of the Marquesas (Gannier, 2002a); however, they do not enter within very turbid coves, preferring to stay in relatively clear and deeper (20 to 40 m) waters outside bays (Gannier pers. obs.). Conversely, they often form mixed schools with spotted dolphins (*S. attenuata*). In the Tuamotu, spinner dolphins do not usually enter into lagoons (Gannier unpub. data), presumably because passes are hot spots for several species of shark. These results confirm that spinner dolphins are selective in their choice of inshore resting sites in French Polynesia, as already suggested for Hawaii (Norris et al., 1994), even if spinner dolphins are also capable of resting while offshore (Lammers, 2004).

The presence of spinner dolphins in Baie des Pêcheurs was documented over a 7-y period. Environmental factors, such as surface water turbidity or current influenced dolphin presence, as well as residence time. In addition to natural events, human activity along the Punaruu River can cause surface turbidity increase. Although a causal relationship could not be established, there is an indication that recreational boat presence is detrimental to the dolphin residence in the cove, and boat activity increased steadily during the period of study. In 2002, the government of French Polynesia established a whale and dolphin sanctuary. Under this advanced regulation, Baie des Pêcheurs possibly deserves status as a Specially Protected Area, given that the bay is likely the most exposed dolphin resting site in French Polynesia.

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