

Patterns of Use of Maku'a Beach, O'ahu, Hawai'i, by Spinner Dolphins (*Stenella longirostris*) and Potential Effects of Swimmers on Their Behavior

Kerri Danil,^{1,2} Daniela Maldini,³ and Ken Marten⁴

¹Department of Biology, University of California at Santa Cruz, Santa Cruz, CA 95064, USA

²Current Address: NOAA Fisheries, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA

³Earthwatch Institute, 3 Clock Tower Place, P.O. 75, Maynard, MA 01754, USA

⁴Earthtrust, 133-B N. Kainalu Drive, Kailua, HI 96734, USA

Abstract

Spinner dolphins (*Stenella longirostris*) use Maku'a Beach, a small bight along the Wa'i'ana'e coast of O'ahu, as a rest site. Behavior and use patterns of Maku'a Beach by spinner dolphins and swimmers were studied in July and August of 1995 to provide baseline data on the dolphin population and to assess potential impacts of swimmers on the dolphins' resting behavior. Dolphins were observed on 52 out of 53 days, and they entered the area between 0545 and 0845 h. Their departure time varied widely. Average school size was 67 ± 0.6 SE and decreased with time of day. The most common aerial behaviors were slaps, leaps, and spins, respectively, with a peak in aerial behavior in late afternoon associated with schools moving offshore. The number of swimmers in the study area was highest on weekend mornings ($\bar{x} = 12 \pm 0.6$ SE), with a maximum of 63 people in the water at the same time. Rest appeared delayed and compressed in this population of dolphins as compared to other studies and may be a response to the presence of swimmers in the morning. The results suggest a potential adverse impact of swimmers on the dolphins' resting patterns, with earlier departure times and shorter periods of dive behavior indicative of rest.

Key Words: spinner dolphin, *Stenella longirostris*, Maku'a Beach, O'ahu, Hawai'i, resting patterns, resting behavior, swimmers, human impact

Introduction

Spinner dolphins (*Stenella longirostris*) are year-round residents of O'ahu, the most highly populated and visited island in Hawai'i, and often come into contact with humans in the shallow waters where the dolphins rest. As human recreational activities in O'ahu's coastal waters increase,

understanding the patterns of use by cetaceans and humans in these waters becomes important.

Among the 19 species of odontocetes reported in Hawaiian waters, the spinner dolphin is the only one that is commonly found in shallow inshore areas (Shallenberger, 1981). Here, spinner dolphins spend their daylight hours resting, preferring habitats with shallow (< 50 m), unobstructed, sandy bottoms to linger in tight schools of varying sizes (Norris & Dohl, 1980; Norris et al., 1994). These inshore rest areas are thought to have been used for generations (Marten & Psarakos, 1999). The locations of some of these rest areas are well-known in Hawaiian waters, and their use by spinner dolphins seems to be fairly consistent year-round (Norris & Dohl, 1980).

Increased recreational and ecotourism use of the beaches adjacent to spinner dolphin rest areas has raised concern about the impact of human activities on the dolphins. Spinner dolphins typically feed offshore at night and enter nearshore coastal waters in the morning, settling into a lowered state of activity. After mid-day rest, they become more active, eventually leaving the coast and heading offshore in the late afternoon or early evening to feed again (Norris & Dohl, 1980; Norris et al., 1994; Östman, 1994; Poole, 1995). The continued approach of swimmers towards resting dolphin schools could diminish the quality of the dolphins' rest.

Maku'a Beach, located along O'ahu's west coast, is a well-known rest area for spinner dolphins (Marten & Psarakos, 2000). Although spinner dolphins use the entire length of this coastline, Maku'a Beach is an area where they spend a significant amount of time (Lammers, 2004). Because these dolphins are easy to approach when resting and their rest areas are close to shore, Maku'a Beach has been a popular area for more than a decade with swimmers interested in encountering dolphins (KD, pers. obs.).

The purpose of this study was to determine the patterns of use of this area by spinner dolphins and compare them with patterns found at the only other spinner dolphin rest site studied in the Hawaiian Islands—Ke'alahou Bay on the Kona coast of the island of Hawai'i (Norris et al., 1994; Östman, 1994). This information, coupled with swimmer presence patterns at Maku'a Beach, was used to assess the potential effects of swimmers on the dolphins' resting behavior.

Materials and Methods

Study Site

During two months in the summer of 1995, the behavior of spinner dolphin schools was observed from a shore vantage point at Maku'a Beach. Maku'a Beach is located on the west side of the island of O'ahu (21° 32' N, 158° 14' W), about 7 km from Ka'ena Point (Figure 1). Observations were conducted from a vantage point at the northern end of Maku'a Beach, with an overview of the entire area. The study area included a 2.4 km stretch of beach extending from the Kalu'ala'u'ila Stream mouth to Kula'ila'i Rock, and approximately 600 m offshore.

Data Collection

Data were collected from 1 July to 28 August, 1995. Time of day was recorded using Hawaiian standard time. From sunrise to sunset, the study area was scanned every 30 min using 7x35 binoculars until dolphins were found. Each scan, lasting 5 to 10 min, consisted of two slow sweeps across the entire area. If dolphins were sighted and were within approximately 600 m of shore, the following information was recorded every 10 min: school size, activity state, and number of human swimmers.

A swimmer was defined as a person completely immersed in the water and engaged in active swimming, snorkeling, or treading water. The number of swimmers within 100 m of dolphins and the total number of swimmers within the study area were recorded; however, total number of swimmers in the study area was used for all analyses because confidence in estimating the 100 m limit was low without the use of theodolite.

School size turned out to be a poor metric because of the difficulty in defining schools as they are very fluid. Instead, the total number of dolphins present within the study area was used. The estimated number of dolphins was then fit

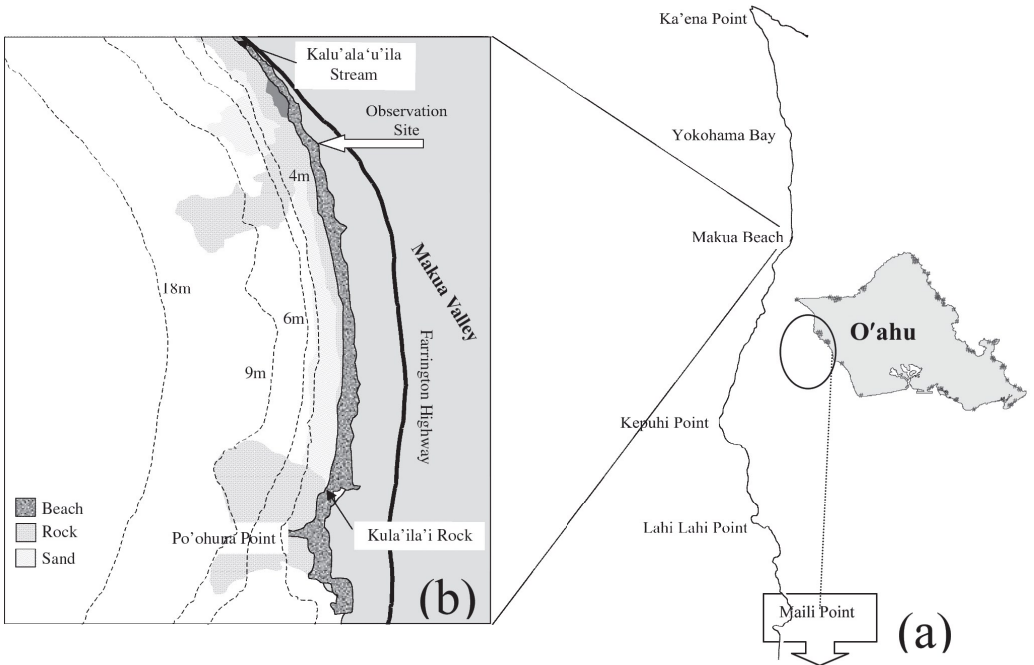


Figure 1. Maku'a Beach is located on the west coast of the island of O'ahu, approximately 7 km south of Ka'ena Point (a). Observations were conducted from a vantage point at the northern end of Maku'a Beach, with an overview of the entire area (b). The bottom topography at the site consists of a mixture of sand/coral bottom, and it is rocky in near-shore areas.

into a range (e.g., 1 to 25, 26 to 50, etc.). The midpoints of these ranges were used to determine mean number of animals. A significance level of $p \leq 0.05$ was used to test all hypotheses.

Behavioral states were divided into three categories: (1) travel (when dolphins were involved in persistent, directional movement), (2) mill (when the animals showed frequent changes in heading within a small area), and (3) dive (when focal group dive times were ≥ 30 sec). Behavioral activity was reported as the percent of the total observation time spent in a particular state.

Dolphin aerial activity was recorded for 5 min every half hour. Aerial behavior was subdivided into leaps, spins, and slaps. A *leap* was defined as the entire animal's body leaving the water. *Spins* were defined as leaps that included an airborne rotation of the body past 180° . A *slap* was defined as the sharp beating of the water surface with a body part in a manner that generated a splash. The frequency of these behaviors was determined by dividing the occurrence of aerial activity in the 5-min observation period by the number of dolphins present within that period and standardizing the result as frequency per dolphin per hour (((number of aerial behaviors/number of dolphins)/5)*60).

Swimmer activity over time was reported as the average number of swimmers present for each hourly time strata between sunrise and sunset. Dolphin residence time was calculated by summing each 10-min observation period when dolphins were observed in the study area. The time at which dolphins were last observed in the study area for the day was defined as dolphin "departure

time." We averaged the number of swimmers as a gauge for the possible impact on dolphin activity and evaluated the correlation between swimmer activity and (1) dolphins' residence time, (2) dolphins' departure time, and (3) frequency of aerial behaviors. All these comparisons were made using the Spearman's Rank Correlation test.

Results

Dolphin Use Patterns

Observations were made for 53 days, and dolphins were observed in the area on 52 (98%) of the days. Dolphins were observed entering the area between 0545 and 0845 h. While time of arrival was predictable and fairly consistent, time of departure was more variable. Dolphins began to leave Maku'a Beach as early as 0945 h and as late as 1905 h, but generally they departed between 1500 and 1900 h (Figure 2). The average residence time (dawn to dusk) was $365.8 \text{ min} \pm 23.38 \text{ SE}$.

It was difficult to determine whether dolphins belonged to separate schools or the same school since dolphins often split into separate groups and then coalesced into one larger group. Also, some dolphins left the area while others remained throughout the day, and, at times, an influx of new individuals intermingled with a group that had been in the area for some time. The average number of dolphins present per hour during the study period was $67 \pm 0.63 \text{ SE}$ ($n = 1,763$), and the most commonly observed numbers were 51 to 75 animals (39% of the 10-min observation periods). Average number of dolphins present within

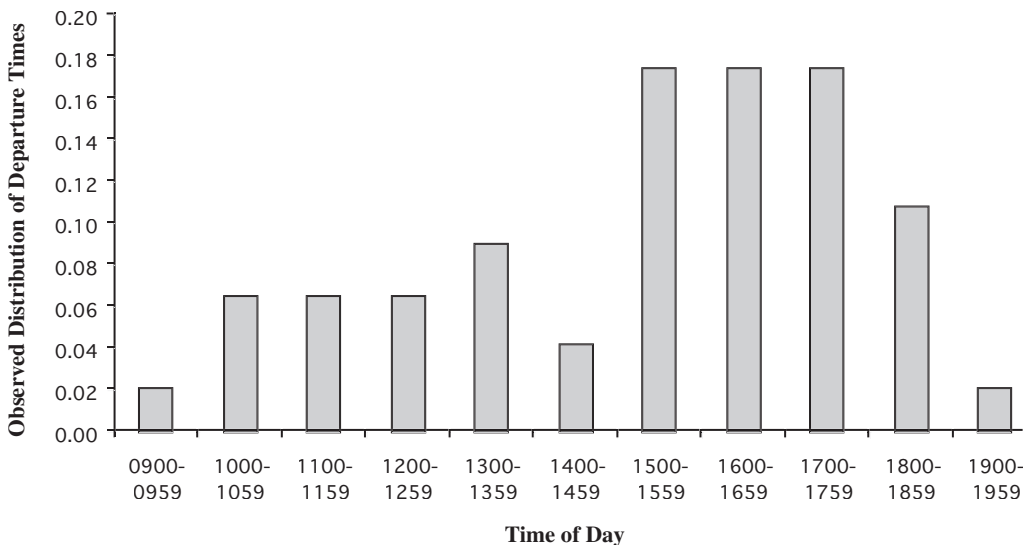


Figure 2. Frequency distribution of spinner dolphin departure times from Maku'a Beach, O'ahu, in July and August 1995; dolphins left Maku'a Beach as early as 0945 h and as late as 1905 h.

the study area decreased significantly through the day ($r = -0.25, p < 0.001$, Spearman's Rank Correlation test; Figure 3).

Dolphins moved back and forth within or through the Maku'a Beach area over half of the observation times (59%); and they milled occasionally (32% of the time); and they dove 9% of the time. The distribution of behavioral states over time shows an increase in the time spent under

water in the afternoon, with a peak in diving behavior between 1500 and 1700 h (Figure 4). Milling frequency did not vary throughout the day but appeared to occur at specific locations within the study area. Travel increased after 1700 h as dolphins moved offshore or out of the study area (Figure 4).

The most common aerial behaviors were slaps (65%), leaps (20%), and spins (15%), respectively.

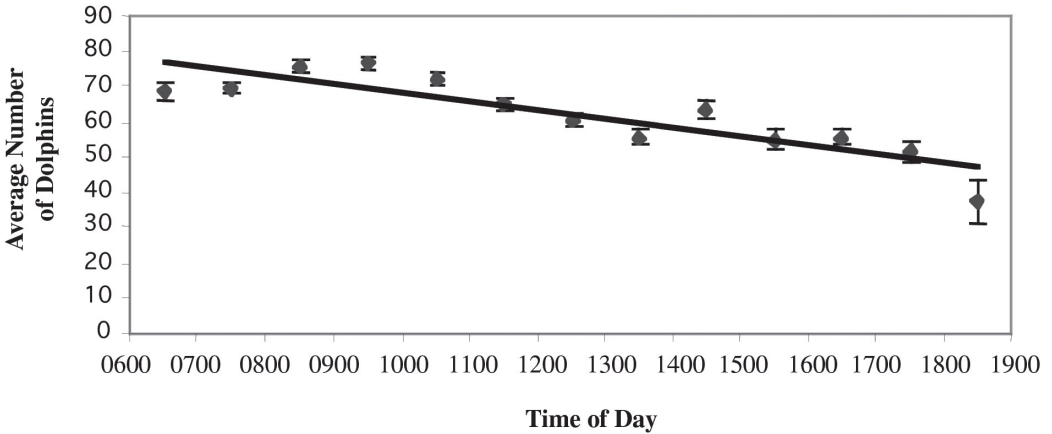


Figure 3. Variations in average number of spinner dolphins by time of day at Maku'a Beach, O'ahu, in July and August 1995; error bars represent the Standard Error (SE) of the mean.

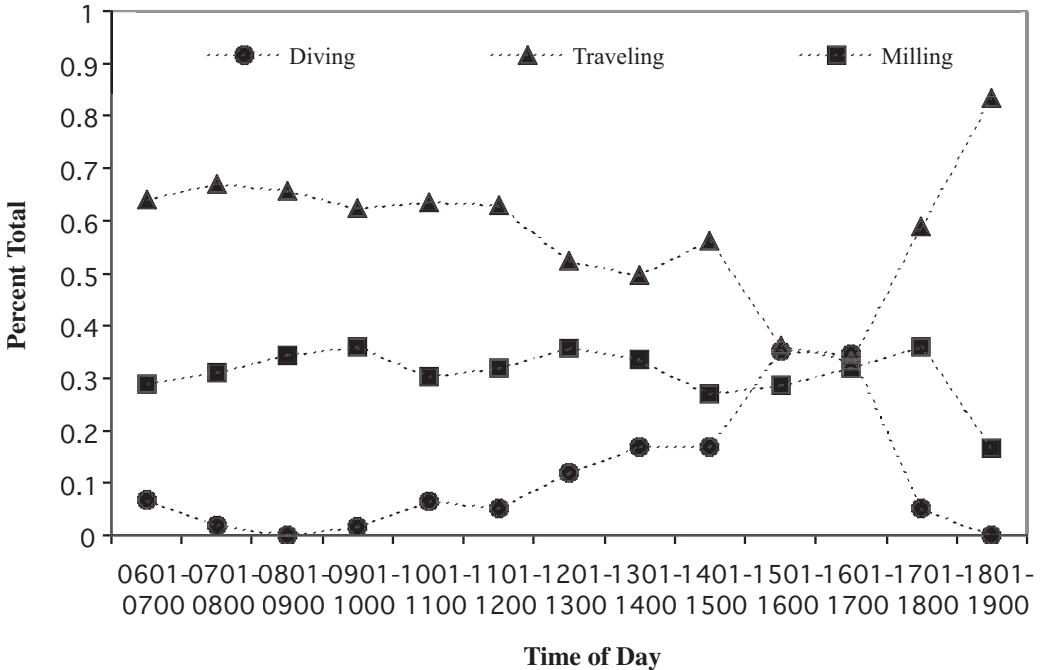


Figure 4. Distribution of spinner dolphin behavioral states (as percent total) versus time of day at Maku'a Beach, O'ahu, in July and August 1995

These behaviors occurred at significantly different rates (ANOVA: $F_{2,1005} = 64.44$, $p = 0.000$). Multiple comparisons based on the Tukey test revealed that slaps occurred at a significantly higher rate than spins ($p = 0.000$) and leaps ($p = 0.000$), while the frequency of leaps and spins did not differ significantly ($p = 0.327$). Leaps and slaps were significantly more frequent than spins between 0600-0700 h. Slaps were significantly prevalent until 1300 h. Between 1300 and 1600 h, the frequency of the three aerial behaviors was low and did not differ significantly. There was a significant difference in the effect of time on the frequency of all aerial behaviors combined (ANOVA: $F_{11,324} = 6.61$, $p < 0.001$). Multiple comparisons based on the Tukey test showed that these behaviors increased significantly between 1700 and 1800 h ($p < 0.001$), although a slight increase (not significant) was noted as early as 1600 (Figure 5). This peak in aerial behavior was associated with essentially all dolphins moving offshore. A slight decrease (not significant) in the frequency of aerial behaviors occurred around 1500 h, the time of the onset of increased diving activity at Maku'a Beach; however, while some dolphins rested, others left the area at this time, which might explain the nonsignificance of the data point.

Swimmer Effects

Swimmers were present throughout the day, with their activity being generally higher during mornings and weekends. The number of

swimmers averaged 6 ± 0.2 SE per day and 12 ± 0.6 SE on weekends before noon, with a maximum of 63 swimmers in the water at one time. Swimmer activities varied from snorkeling to SCUBA diving to treading water. Some swimmers used kayaks to reach areas slightly offshore. The number of swimmers was highest before noon and lowest throughout the afternoon (Figure 6). There was a significant negative correlation between the number of swimmers and time of day ($r = -0.337$, $p = 0.000$), with the number of swimmers decreasing as the day progressed. Sixty-five percent of the swimmers were within 100 m of the dolphins and, in general, swimmers occupied the same sector as the dolphins.

As the number of swimmers increased at Maku'a Beach, the dolphins departed earlier from the study area ($r = -0.293$, $p = 0.043$) (Figure 7). Dolphin residence time also appears to decrease with an increase in the number of swimmers at Maku'a Beach (Figure 8); however, this relationship is not significant ($r = -0.251$, $p = 0.109$). There was no relationship between the number of swimmers present and the frequency of aerial behavior ($r = -0.266$, $p = 0.067$).

Discussion

Dolphin Use Patterns

The consistency with which dolphins appeared at the site (98% of the days) supports our perceived importance of Maku'a Beach as a rest site along

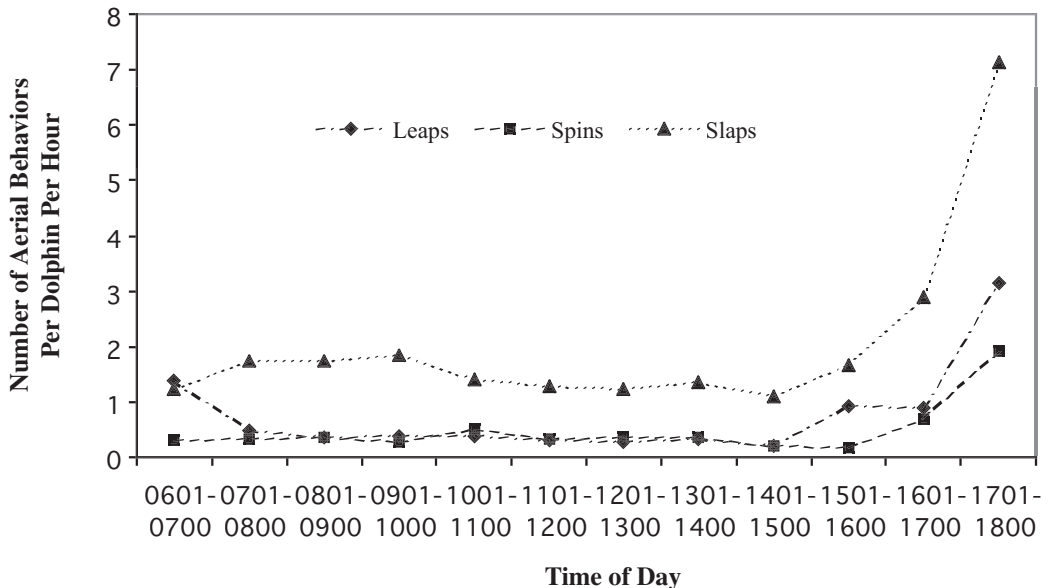


Figure 5. Frequency distribution of three aerial behaviors of spinner dolphins versus time of day at Maku'a Beach, O'ahu, in July and August 1995; error bars represent the SE of the mean.

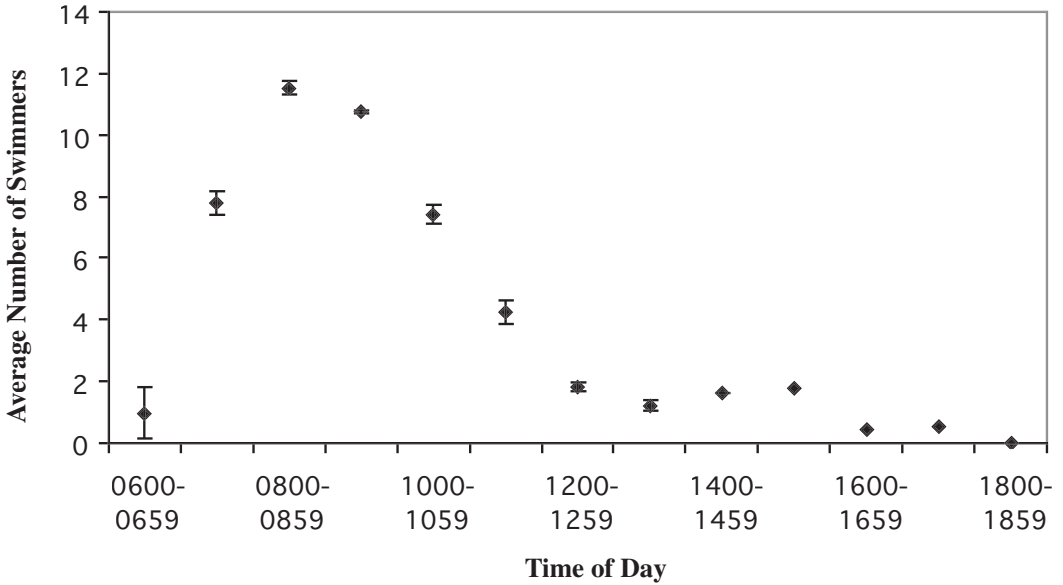


Figure 6. Average number of swimmers versus time of day at Maku'a Beach, O'ahu, in July and August 1995; error bars represent the SE of the mean.

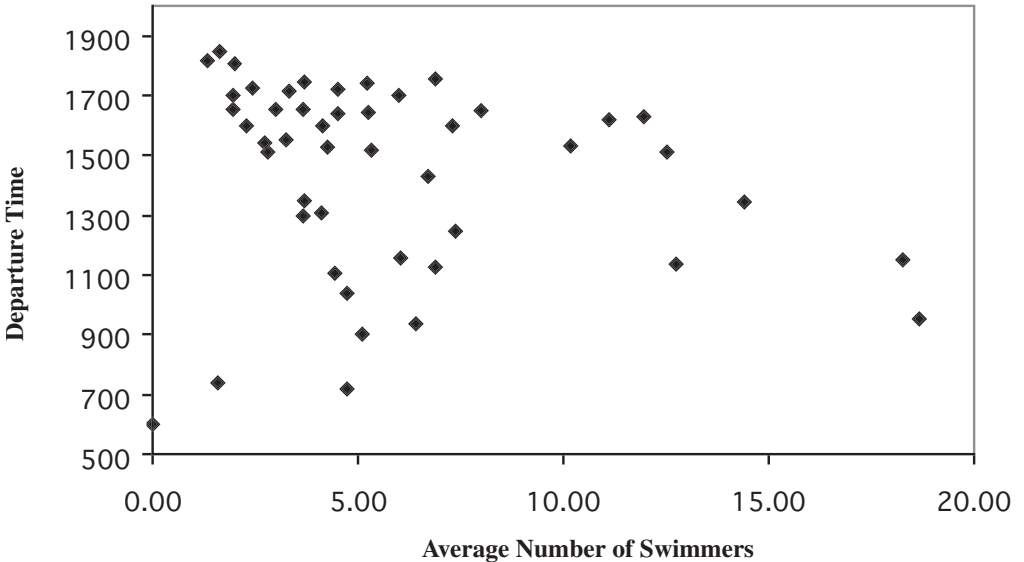


Figure 7. Average number of swimmers in the water by spinner dolphins' departure times at Maku'a Beach, O'ahu, in July and August 1995

the Waianae Coast. Maku'a Beach appears to be part of a larger rest area, which likely extends from the northern end of Ka'ena State Beach Park south to Kepuhi Point, forming a large protected bight. On numerous occasions, spinner dolphin schools were observed leaving the study area headed north and then were seen turning around at the end of Ka'ena State Beach Park to re-enter the study

site off Maku'a Beach. Lammers (2004) found that, for the northern portion of the west coast of O'ahu, 95.2% of all morning sightings of spinner dolphins were made along the stretch of coast in front and just north of Maku'a Beach. The bottom topography off Maku'a Beach is characterized by sandy areas interspersed with rocky outcrops (Figure 1). Norris & Dohl (1980) suggested that

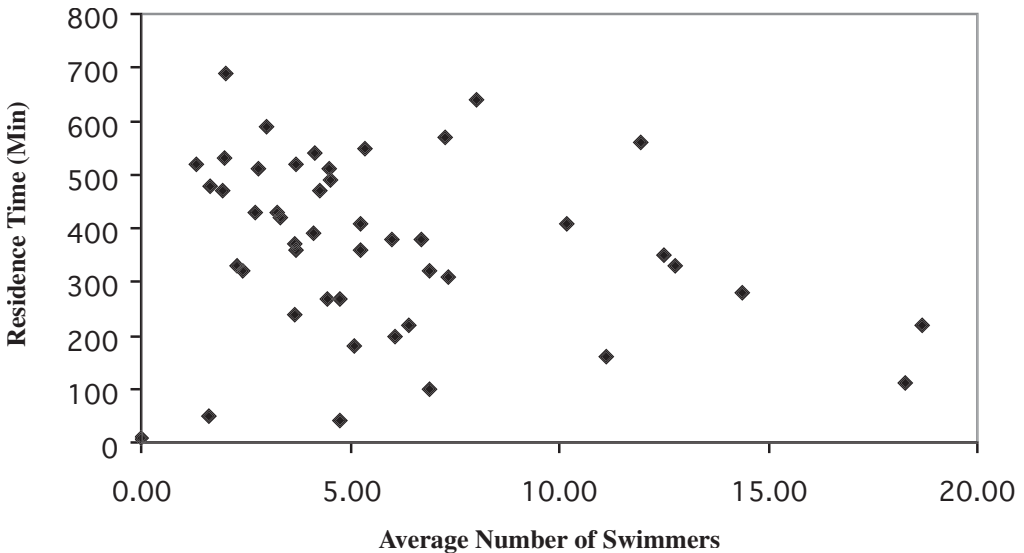


Figure 8. Average number of swimmers in the water by spinner dolphins' residence times at Maku'a Beach, O'ahu, in July and August 1995

a sandy bottom is an important feature of a spinner dolphin rest site because it offers protection from potential predators, such as sharks, which are easier to see against the light background provided by a sandy bottom than they are against dark coral formations. Another potentially desirable characteristic of Maku'a Beach is its proximity to deep waters. The mesopelagic community (or deep-scattering layer), which occurs at depths of 400 to 1,200 m and migrates vertically at night (Amesbury, 1975), has been proposed as an important food source for spinner dolphins (Fitch & Brownell, 1968; Perrin et al., 1973; Norris & Dohl, 1980; Norris et al., 1985, 1994; Benoit-Bird & Au, 2000). Off the west coast of O'ahu, where Maku'a Beach is located, the density of mesopelagic organisms is high, reaching a maximum of 1,800 organisms \times m^3 (Benoit-Bird et al., 2001). In addition, mesopelagic organisms were found within 1 km of shore during the daytime, in much shallower waters than previously believed (Benoit-Bird et al., 2001). Such findings suggest that spinner dolphins may not have to travel far from their rest sites to feed.

Östman (1994) suggested that the proximity to an abundant food source may influence school size at rest sites. According to this hypothesis, Maku'a Beach may be an optimal rest area because of the abundance of nearby food resources. Benoit-Bird et al. (2001) found that the relative abundance of mesopelagic organisms off the Maku'a Beach area was consistently higher than the areas around Ke'alakeku'a Bay. It is therefore possible that food availability plays an important role in

the use of a particular area by spinner dolphins and in the size of the dolphin schools. Lammers (2004) found that foraging spinner dolphins along the Wa'i'ana'e Coast consistently traveled to three specific foraging sites, and that animals departing from Maku'a Beach most likely traveled to the edge of a shallow water bank off Ka'ena Point or to a bank off Ma'ili Point.

School size at Maku'a Beach could be upwardly biased at times, reflecting the presence of spotted dolphins (*Stenella attenuata*), which were observed in the study area on several occasions, often mixed with spinner dolphins. Spotted dolphins do not exhibit a resting pattern during the day (Norris et al., 1994). Their number is unrelated to the size of the rest area available, but their presence near shore would be consistent with the availability of food within 1 km from shore (Benoit-Bird et al., 2001).

In contrast, Norris et al. (1994) suggested a relationship between school size at resting beaches and the size of sandy bottom areas available at a particular site. If this is the case, the extent of the sandy bottom area at Maku'a Beach is such to support schools of at least 50 to 75 animals—a school size larger than that reported by Norris et al. (1994) at Ke'alakeku'a Bay ($\bar{X} = 33$).

School size tended to decrease with time of day. This pattern is consistent with findings by Lammers (2004), who tracked schools of spinner dolphins along the entire Wa'i'ana'e Coast throughout the day. While some animals entered rest areas and remained there throughout the day, others moved over much larger areas in an apparently modified

resting pattern. Lammers (2004) found that dolphins progressively moved along larger portions of the Wa'i'ana'e coastline as the day progressed, generally staying within the 10 fathom (18 m) isobath. Norris et al. (1994) speculated on the reasons for the existence of two patterns—one where spinner dolphins remained slightly offshore and the other where some entered resting coves. He suggested a segregation by age class, with juveniles coming inshore to rest under the supervision of alloparents. There are few observations to support this hypothesis. Miyazaki & Nishiwaki (1978) found age class subdivisions in striped dolphin (*Stenella coeruleoalba*) schools taken by Japanese fishing vessels near the Izu Peninsula along the inner margins of the northward-flowing Kuroshio Current.

The arrival and departure times of spinner dolphins at Maku'a Beach are consistent with findings by Norris et al. (1994) and Östman (1994) on the Island of Hawai'i at Ke'alakeku'a Bay, where, on average, dolphins entered the bay close to sunrise (around 0600 h in July and August) and left close to sunset, with a wider variation of departure times. Norris et al. (1994) also found that the daily cycle of spinner dolphins was related to sunrise and sunset patterns across the season, and that residence times varied, being longest in the spring and shortest in the winter. Such yearly patterns are not available for Maku'a Beach, but they are likely to be similar. The average time that spinner dolphins spent at Maku'a Beach during the months of July and August (6 h 7 min) is comparable to the 6 to 7 h that spinner dolphins spent in Ke'alakeku'a Bay during the same time of year (Norris et al., 1994).

Aerial behaviors have been related to the average energetic state of a spinner dolphin school by time of day (Norris et al., 1985). The frequency of these behaviors was found to be higher in the morning when schools enter resting coves after nocturnal foraging, and to increase in the afternoon as schools "wake up" and prepare to leave rest areas and head offshore. On average, schools at Maku'a Beach showed an increase in aerial activity late in the afternoon (after 1600 h) while the peak was not so clear in the morning. The rest of the day, aerial behavior was infrequent and, if present, generally consisted of tail slaps. Our observations missed a greater portion of the morning and evening peaks of aerial activity simply because dolphins were too far offshore to be monitored from our shore site. Lammers (2004), using a boat to follow spinner dolphins in deeper water, found these activity peaks along the Wa'i'ana'e Coast to be similar to those found by Norris et al. (1994) at Ke'alakeku'a Bay.

Spinner dolphin resting patterns are difficult to interpret because school size, time of day, and other confounding factors may alter the onset of rest (Norris & Dohl, 1980). The typical behavior exhibited by spinner dolphins at rest sites is a slow back and forth movement accompanied by low to no aerial activity. This type of "rest swimming" also was described in captive bottlenose dolphins (*Tursiops truncatus*) by Gnone et al. (2001). During the "deeper" portion of the resting cycle, spinner dolphins spend the majority of their time under water (Norris & Dohl, 1980). We defined this type of rest as "deep rest."

The gradual increase in dive behavior from 1000 to 1500 h (Figure 4) indicates that descent into rest may take many hours. The significant increase in dive behavior between 1500 and 1700 h suggests that this might be the period of "deep rest" at Maku'a Beach, and, if this is the case, the occurrence of this period may be delayed and compressed here compared to Ke'alakeku'a Bay. On the other hand, the period between 1500 and 1700 h was also the time when approximately 20% of the schools observed left the area and an increase in aerial behavior was noted. The apparent conflict between increased dive behavior and increased aerial activity during the same time period may reflect schools in different phases of rest. Those observed diving might be those exhibiting delayed rest within the study area. Aerial behavior during the same time period may be attributed to other schools that rested at adjacent sites along the coastline and passed through the study area as they traveled offshore. Overall, travel increased after 1700 h and was associated with the movement of animals offshore or out of the study area. Lammers (2004) found foraging typically began between 1700 and 1900 h.

The lack of historical data on the resting cycle of the Maku'a Beach dolphins weakens our ability to determine whether the occurrence of "deep rest" has shifted through the years or is simply variable; however, changes in dolphin behavior with an increasing number of swimmers suggests that deep rest at Maku'a Beach may have shifted to be later in the afternoon because of human disturbance.

Swimmer Effects

The presence of swimmers at Maku'a Beach follows a consistent cycle, with a greater number of swimmers present from early morning to noon and then generally absent in the afternoon. It was common in the morning to observe swimmers in close proximity to the dolphins, following their movement patterns and, at times, pursuing them. Once the dolphins eluded one group of swimmers, they were likely to encounter another group, positioned slightly ahead of the dolphins' path.

Although most swimmers' behavior was subdued around dolphins at Maku'a Beach, their presence may keep the dolphins in a constant state of alert. Alertness is, behaviorally, the antinomy of rest. The delay of dive behavior may indicate a diminished quality of rest in the presence of swimmers in the morning. Kyngdon et al. (2003) observed a similar response in common dolphins that surfaced more frequently in the presence of swimmers during "swim-with-dolphin" programs. At Maku'a Beach, since most swimmers left in the afternoon, some schools may then have had the opportunity to subside into a short period of "deep rest."

Dolphins could ameliorate the potential disturbance from swimmers by moving to alternate rest sites or remaining offshore. Our study suggests some schools opt for this strategy by departing earlier if swimmer presence is high. Residence time appears to be a weaker proxy than departure time for determining swimmer effects because of the fluid use of the study area by different schools. This measure is diluted because it likely sums the time spent by several different schools that enter and leave the area at different times; however, the relationship between residence time, as well as departure time and number of swimmers, may be strengthened with a greater sample size for large numbers of swimmers. On several occasions, observers at the study site noted that smaller schools (< 25 animals) refrained from entering Maku'a Beach when swimmer presence was high.

Interestingly, the frequency of occurrence of aerial behaviors within the rest site was not correlated to the number of swimmers in the water, and it was low but consistent whether swimmers were in the water or not. This supports the idea that aerial behaviors are a part of the natural cycle of spinner dolphins at resting beaches and, in this case, not necessarily a reaction to disturbance.

Constantine (2001) found that wild bottlenose dolphins became sensitized to the presence of swimmers and that the animals' avoidance responses increased through the years. Since many of the animals at Maku'a Beach are recurrent visitors of the area (Marten & Psarakos, 2000), it is possible that the dolphins' resting patterns shifted to accommodate for the pattern of occurrence of swimmers. The same animals may be exposed to disturbance over time, and the effects of that disturbance on an individual over time may be considerable. Concerns about the cumulative effect of prolonged exposure to disturbance and the inability of the dolphins to rest properly include a reduction in their ability to forage and be alert to predators.

The potential effects of swimmers on cetaceans have been studied in a variety of species

(Samuels & Spradlin, 1995; Bejder et al., 1999; Constantine, 2001; Ritter, 2002), but never where the main behavioral context of the animal was rest. Although the current study provides some evidence of the potential adverse effects of swimmers on resting spinner dolphins, its findings are by no means conclusive. Other factors, such as underwater noise, the occurrence of predators, water conditions, and the distance and behavior of human swimmers, also should be taken into account when looking at patterns of rest in spinner dolphins. Year-by-year comparisons and controls provided by studies in a rest area not affected by swimmers (such as Ke'alahou Bay was, to a great extent, at the time Norris and his colleagues studied spinner dolphins) would greatly enhance our understanding of the swimmer-dolphin dynamic. Continued monitoring of the Maku'a Beach site and other rest sites around the Hawaiian Islands would provide essential data to understand the behavioral ecology of spinner dolphins.

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