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Effects of vessels and swimmers on behavior of Hawaiian spinner dolphins (*Stenella longirostris*) in Kealake'akua, Honaunau, and Kauhako bays, Hawai'i

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Studies of the influence of boat traffic on small cetaceans have shown that the animals exhibit behavioral responses, including changes in swimming speed, diving and aerial behavior, vocalization patterns, and movement patterns (*e.g.,* Au and Perryman 1982; Janik and Thompson 1996, Constantine *et al.* 2004, Delfour 2007). Janik and Thompson (1996) cautioned that such disruptions could cause longer-term changes in behavior, ecology, or status of a population, including avoidance of certain areas or increases in mortality rates. In some cases, injury or death of dolphins (Stone and Yoshinaga 2000) and injury or death of humans (Shane *et al.* 1993, Santos 1997) have been reported. Recent studies have begun to discover dolphin avoidance of high-traffic areas (Lusseau 2004, 2005; Bejder *et al.* 2006*a*).

Concerns have been raised about the effects of vessel and swimmer traffic on spinner dolphins (*Stenella longirostris*) resting in Hawaiian bays (Lammers 2004, Delfour 2007). Vessel and swimmer traffic in Kealake'akua and other Hawaiian bays has increased (Östman-Lind *et al.* 2004, Delfour 2007) since the original studies of Ken Norris and his colleagues (Norris and Dohl 1980; Norris *et al.* 1985, 1994). Spinner dolphins in the bays attract people, and dolphin disturbance as a result of increased swimmer and boat traffic needs to be assessed. Spinner dolphins use Hawaiian bays as havens in which to rest during the day (Norris *et al.* 1994), so disturbance by vessels and swimmers may affect their activity budgets and fitness. Concerns regarding dolphin disturbance have caused NOAA Fisheries to propose new regulations for interaction with Hawaiian spinner dolphins (Department of Commerce 2005, 2006). In response to these concerns, the purpose of our study was to document behavior of Hawaiian spinner dolphins in three bays with respect to vessel and swimmer traffic.

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Studies of Hawaiian spinner dolphins have shown that approaches to dolphins can evoke behavioral responses that potentially affect the fitness of the animals (*e.g.*, Lammers 2004). Spinner dolphins use bays that happen to be high-traffic areas that are easily accessible by swimmers from shore. Forest (2001) reported that, in the afternoon, aerial activity level of spinner dolphins was higher when humans were within 10 m of a group in Kealake'akua Bay. Lammers (2004) cautioned that if human encroachment becomes too intense, Hawaiian spinner dolphins may begin to stay offshore rather than rest in coastal bays. He warned that this could affect the fitness of the species, as well as economic opportunities for dolphin-based ecotourism.

Our study area included three Hawaiian bays. Kealake'akua Bay was the largest and northernmost bay in this study (Fig. 1). Observations were made from a cliffside study site (Norris *et al*. 1994) 69 m above the southeastern side of the bay (Fig. 1). Kealake'akua Bay is a popular tourist area for kayaking, swimming, snorkeling, and commercial tours. Honaunau Bay is 8 km south of Kealake'akua Bay (Fig. 1) and is used by swimmers, snorkelers, SCUBA divers, and a canoe club. Observations were made from the central portion of Honaunau Bay, at sea level. Motorboats enter and exit *via* a boat ramp on the southern end of the bay. Kauhako Bay is 6.5 km south of Honaunau Bay and is mainly used by swimmers desiring dolphin encounters. Observations were made from a cliffside site 12 m above sea level on the northeastern side of Kauhako Bay (Fig. 1).

Behavioral data were collected from 11 February 2002 to 29 May 2002 (Table 1). Both the number of aerial behaviors and number of vessels and swimmers were recorded on tape recorders from dawn to dusk. Data were analyzed using Minitab 13.31, and Tukey Tests and multiple range tests for comparisons of means were performed according to Zar (1999). All-occurrence sampling, as defined by Altmann (1974), was used to record the aerial activity of individual dolphins. Aerial behaviors, as defined by Norris *et al.* (1994), were chosen as a metric to compare to vessel and swimmer activity because it is a noninvasive measure to collect, has been shown to indicate changes in energy levels (Norris *et al.* 1985), and can be compared to previous studies.

Time was recorded when a group of dolphins was first spotted in or entering the bay and when dolphins left or were last seen in the bay. Group size was recorded as a minimum and maximum estimate of all dolphins in the bay (*e.g.,* 20–25 dolphins) and averaged for a total group size. If a dolphin group left the bay and a group entered later, these later dolphins were considered a new group, and entry and exit times as well as group size were recorded.

The numbers of vessels and swimmers in the bay were recorded in an instantaneous scan sample, as defined by Altmann (1974), every 5 min. In Kealake'akua Bay, it was impossible to count the number of swimmers on the north side of the bay during most of the day because of the angle and distance. The same problem was encountered by Forest (2001).

Days were broken down into 1-h increments for analyses, which was consistent with other studies in Kealake'akua Bay (Norris *et al.* 1994, Forest 2001). Data for each hour of the day were pooled across days for each bay. Aerial behaviors per hour were calculated by taking the number of aerial behaviors observed in a given hour, divided

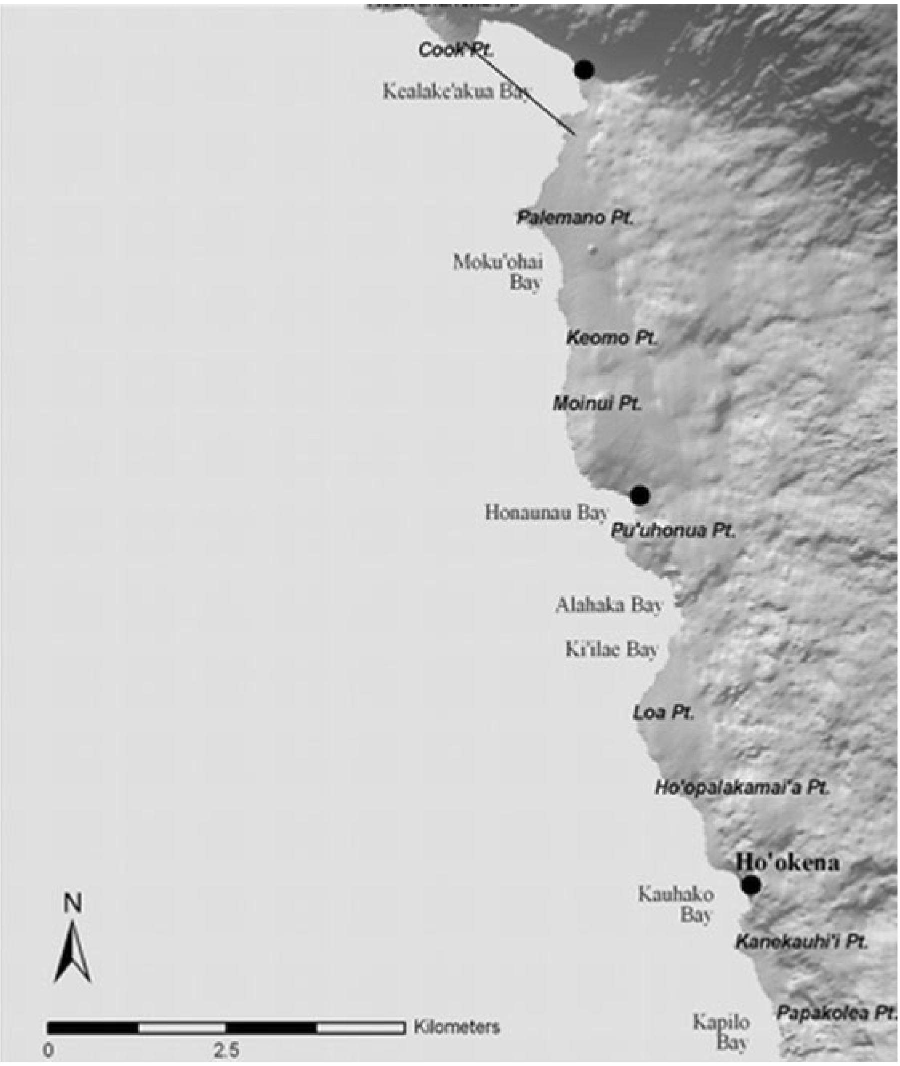

Figure 1. The three study sites were located on the west coast of the big island of Hawai'i and are pictured above. The line in Kealake'akua shows the edge of the bay as defined in the study. Black dots indicate observation stations. The map was obtained in December 2004 from the NOAA National Ocean Service internet site using ArcView 8.2 software. Approximate lengths, widths, and areas, respectively, of study sites: Kealake'akua 1,575 m, 715 m, 11.13 km^2; Honaunau 577 m, 453 m, 1.66 km^2; Kauhako 709 m, 265 m, 1.17 km^2. These values were obtained using ArcView 8.2.

by the number of minutes of observation during that hour, multiplied by 60 min. Previous studies have used such extrapolations (Norris *et al.* 1994, Forest 2001). We chose not to report behaviors per hour per dolphin because our data indicated that group size was not linearly correlated to frequency of behavior (Courbis 2004);

Table 1. Summary statistics of dolphins in Kealake'akua, Honaunau, and Kauhako bays.

	Kealake'akua	Honaunau	Kauhako
Mean dolphin entry time[a]	0824 (SE ± 0.8 h, n = 10)	0749 (SE ± 0.7 h, n = 6)	0828 (SE ± 0.7 h, n = 15)
Mean dolphin departure time[a]	**1528 (SE ± 1.0 h, n = 10)**	1322 (SE ± 2.1 h, n = 6)	**1051 (SE ± 1.0 h, n = 14)**
Mean dolphin residence time[a]	**7.1 h (SE ± 1.0 h, n = 10)**	5.3 h (SE ± 1.9, n = 6)	**2.3 h (SE ± 0.9, n = 14)**
Mean dolphin group size	27.1 (SE ± 4.7, n = 8)	19.3 (SE ± 5.0, n = 5)	25.0 (SE ± 3.5, n = 7)
Mean aerial behaviors per hour	20.2 (SE ± 2.4, n = 72)	15.6 (SE ± 3.2, n = 36)	**89.0 (SE ± 12.9, n = 40)**
# of days dolphins observed	9 d	5 d	11 d
# of hours dolphins observed	68 h 52 min	33 h 25 min	32 h 3 min
Total observation days	13 d	23 d	18 d
Total observation hours	142 h 55 min	273 h 34 min	227 h 25 min

Significant differences are in bold.

[a]Because dolphins did not always engage in entry and exit behavior, in those cases, time of entry and exit were recorded as first time dolphins seen and last time dolphins seen.

however, we report overall behaviors per hour per dolphin in order to compare with Norris *et al.* (1994) and Forest (2001) to determine trends over time. Procedures for vessel and swimmer calculations are described in Courbis (2007).

Unexpectedly, in Kealake'akua Bay, dolphins displayed little aerial activity while entering the bay except during two afternoon entrances. Similar to their entrance, dolphins did not display intense aerial behavior as they were leaving the bay (*i.e.,* they did not spin or leap out to sea). Six of the 10 entries into this bay were not observed because of lack of aerial behavior. There were no problems with visibility on these days. Departure from the bay was never observed, with dolphins seen surfacing with no increased behavior and then suddenly no longer seen. In Honaunau, on only one occasion were dolphins seen performing aerial behaviors while entering the bay. However, they arcuate leapt out to sea as a group on three out of 5 d. In Kauhako Bay, on 5 out of 11 d, dolphins were seen entering the bay while spinning and leaping. On the other 6 d, they appeared in the bay without being observed entering. They were seen engaged in aerial behavior while leaving the bay on every occasion except one on 27 March when dolphins surfaced once at 08:58 h and were not seen again.

Mean frequency of aerial behaviors was not significantly correlated to mean frequency of vessels and swimmers in any of the three bays (see Courbis 2004 for further analyses). This was also true in the study of Danil *et al.* (2005) at Maku'a Beach, O'ahu. In our study, mean aerial behaviors per hour were not significantly different for any hour of the day within a bay (Fig. 2), except in Kauhako Bay in which the means were significantly higher later in the day, but sample sizes for later hours were small (see Courbis 2004 for further analyses). Mean dolphin group sizes were not significantly different among the three bays. Summary statistics for dolphins are

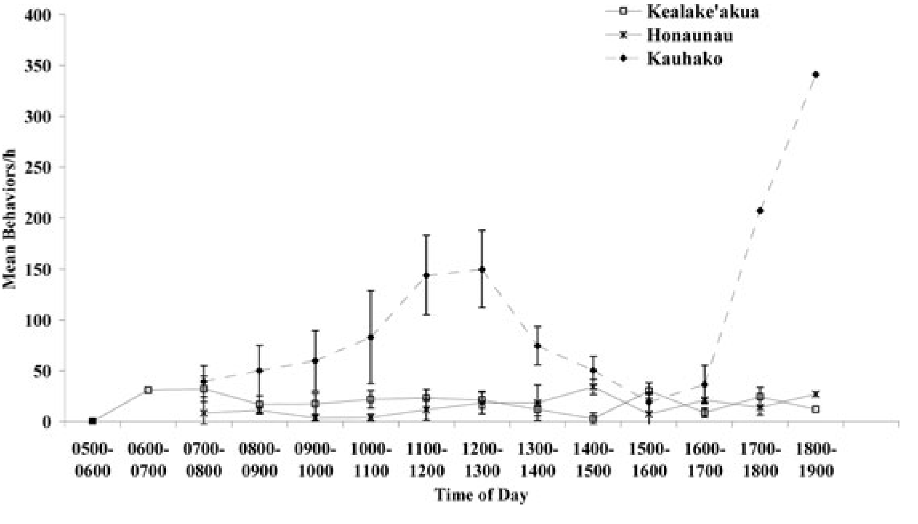

Figure 2. Mean behaviors per hour in relation to time of day for Kealake'akua, Honaunau, and Kauhako bays. Standard error bars are shown.

shown in Table 1. A description of vessel and swimmer traffic patterns in each bay has been reported elsewhere (Courbis 2007).

The lack of significant correlation between levels of behavior and traffic may be because there is no relationship, the relationship between them is not linear, or there are motivations for aerial behavior aside from vessels and swimmers. Given the preliminary nature of our study and the small number of observation days we were able to fund, we believe this warrants further research. Specific instances of aerial behavior appeared to be closely correlated with approaches by vessels and swimmers (*e.g.,* in Kealake'akua on 28 March, dolphins were seen repeatedly tail slapping, spinning, and leaping near swimmers and kayaks that were following the group; see Courbis (2004) for additional examples). We believe that these instances indicate that there is potentially a biologically significant relationship between these reactive aerial behaviors and traffic. Further, Bejder *et al.* (2006*b*) concluded that what may be considered "low" levels of short-term behavioral responses to vessel and swimmers were not necessarily indicative of a lack of long-term impacts.

One way to gauge the effect of vessel and swimmer traffic on spinner dolphin behavior is to compare daily aerial behavior patterns across studies. Comparison of the results of our study with previous studies indicates that the pattern of aerial behaviors during the day has changed over time in Kealake'akua Bay. Norris and Dohl (1980) stated that schools of dolphins arriving in Kealake'akua Bay could sometimes be seen as far as 4 km beyond the bay and could be watched during the entire entry traverse. They found that these entering schools were quite active, engaging in lots of spinning and aerial behavior. Once the bay was reached, aerial behavior usually subsided, but it persisted to a small degree for as long as 2 h after initial entry. When leaving the bay, spinner dolphins usually had an abrupt arousal with sudden active aerial behavior. Würsig *et al.* (1991) and Norris *et al.* (1994) made similar observations of spinner dolphins entering and exiting Kealake'akua Bay. Forest (2001) indicated that in her 1993–1994 study in Kealake'akua Bay, spinner dolphins displayed a bimodal distribution of aerial behavior, with higher rates of aerial activity before 07:15 and after 15:15. In contrast, during our study, dolphins did not usually engage in aerial behavior while entering Kealake'akua or Honaunau Bays. In Kealake'akua Bay, dolphins only performed aerial behaviors during entry on two occasions, both of which were entries that occurred after noon. Dolphins were never seen while they were leaving Kealake'akua Bay. There were no previous studies in Honaunau and Kauhako Bays with which to compare our aerial behavior data. However, studies elsewhere have reported behavior patterns similar to those seen by Norris and Dohl (1980), Norris *et al.* (1994), and Forest (2001). For example, this pattern has been seen in O'ahu (Lammers 2004, Danil *et al.* 2005). In our study at Kealake'akua Bay, although there were small peaks in mean aerial behavior per hour in the morning and late afternoon (Fig. 2), those peaks were not significant. This suggests that the number of aerial behaviors occurring in the midday, during what was considered the rest period by Norris *et al*. (1994), has increased, and/or the number of aerial behaviors occurring in the morning and late afternoon has decreased.

This change in aerial behavior pattern coincides with traffic increases in Kealake'akua Bay. Although a directed study of traffic did not occur before our study, increases in traffic are evident when comparing descriptions of traffic from Doty (1968) to Norris and Dohl (1980) to Forest (2001) to Courbis (2007). Our study was the first in which there were no times during which dolphins were present in Kealake'akua Bay without swimmers or vessels present. The changes in aerial behavior pattern may indicate that vessel and swimmer traffic has reached a level that is affecting the daily behavior patterns of the dolphins.

When our data from Kealake'akua, Honaunau, and Kauhako bays were compared, mean number of aerial behaviors per hour was significantly higher in Kauhako Bay than the other two bays, regardless of group size. This may be related to differences in size, shape, location, bottom topography (*e.g.,* Honaunau Bay has a deeper area in the center and Kauhako Bay does not), and/or other conditions (*e.g.,* temperature may differ). It may also be that the type of activity directed by humans toward dolphins in Kauhako Bay is disturbing enough to evoke strong reactions by dolphins more often than in the other two bays. Almost all traffic in Kauhako Bay was swimmers and almost all swimming was directed at approaching and attempting to interact with dolphins. Therefore, although traffic levels were lowest in that bay, the activities were the most consistently dolphin-directed. Further, this bay is smaller than Kealake'akua Bay, so fewer swimmers may be able to create more disturbance. There are significantly more swimmers present in Kauhako Bay when dolphins are present (Courbis 2004, 2007). This is not the case in Kealake'akua Bay or Honaunau Bay (Courbis 2004, 2007), supporting the idea that swimmers are drawn to Kauhako Bay to swim with dolphins.

Reduction in entry and exit aerial behavior could have a variety of causes. One possibility is that dolphins may have learned that aerial activity reveals their presence to people waiting to swim out and interact with the group. This idea is supported by Forest's (2001) finding that dolphins were more active in the morning when no humans were present than when humans were present. Östman-Lind *et al.* (2004) reported that most human activity around spinner dolphin schools in Hawai'i was observed in the morning when the schools were finding and entering rest areas. They also found peaks in human/dolphin interaction later in the afternoon, when dolphins typically leave bays. Reduced entry and exit activity may be a way to avoid the morning and afternoon "rush hours" in human approaches to dolphins. These changes in spinner dolphin aerial behavior patterns may affect their ability to rest and to adequately prepare for the evening hunt.

In addition to behavior patterns, activity levels of spinner dolphins in Kealake'akua Bay have changed over time. The frequency of aerial activities per hour per dolphin decreased from 2.232 in the 1970s (Norris *et al.* 1994) to 1.792 in 1993–1994 (Forest 2001) to 0.750 in our 2002 study. We suspect that this reduction in frequency of aerial behaviors is related to the reduction in entry and exit behavior.

Forest (2001) suggested that the reduction she found in aerial behavior might indicate diminished energy levels. She reported that the most athletic aerial activities, spins, and flips, were the least common in her study. Such athletic aerial behaviors were the most common in our study, so a reduction in energy levels may not be the primary cause of reduction in activity levels. Possibly, dolphins have reduced activity during mild disturbance, such as kayaks passing by without approaching the dolphins, or at times of day when swimmers are most likely to approach them, such as when dolphins enter or exit the bay. By reducing activity at these times, the dolphins can potentially avoid attracting attention. The idea that cetaceans might reduce behavior to avoid detection has also been forwarded by Richardson *et al.* (1995), who suggested that there might be a link between bowhead whales' inconspicuous behavior during migration and human activity. However, dolphins will engage in energetic aerial activity during incidents of more intense disturbance, for example, when we observed dolphins arcuate leaping away from a closely approaching swimmer in Kealake‘akua Bay on 1 May.

Mean group size in Kealake‘akua Bay was also similar to previous studies (Norris *et al.* 1994, Forest 2001, Timmel 2005). However, Östman-Lind *et al.* (2004) found a 26% reduction in group size in Hawai‘i from studies in 1989–1992 to their study in 2003 (1 yr subsequent to our study), suggesting recent changes. There are no previous studies with which to compare the group sizes in Honaunau or Kauhako Bays. Östman-Lind *et al.* (2004) also reported shifts in usage of two bays north of our study site, with increased presence in a previously low use bay, and decreased presence in a previously high use bay. They also reported a change in dolphin location preference within one bay. Doty (1968) reported that spinner dolphins in Kealake‘akua Bay were found mainly near Manini Point on the south side of the bay. Norris *et al.* (1994) reported that dolphins tended to frequent the northern part of the bay near the cliffside observation site. We observed dolphins mainly in the northwestern portion of the bay (Courbis 2004, 2007). These changes in preference could be precursors to abandonment of the bay as vessel traffic continues to increase.

Because rest is one of the most important activities for spinner dolphins in Hawaiian bays, changes in resting patterns are potentially biologically important. Although Norris and Dohl (1980) describe rest as very quiescent, only occasionally punctuated by aerial behavior, in our study, there was some aerial activity during times when the group was at rest. Unlike during Norris and Dohl's (1980) study, dolphins never went without aerial behaviors for large portions of the day during our observations. Interruption of rest by approaching vessels and swimmers was frequently observed during our study and rarely observed during Norris and Dohl's (1980) study. Others have also reported disturbance of spinner dolphins at rest. For example, Würsig (1996) reported that spinner dolphins in Kealake‘akua Bay prematurely curtailed resting during repeated boat and swimmer approaches.

In conclusion, the changes in aerial behavior patterns in Kealake‘akua Bay since previous studies suggest that spinner dolphins in that bay are reducing entry and exit aerial behavior while increasing the amount of aerial behaviors performed during the midday rest period. Although we cannot directly link the increases in vessel and swimmer traffic in Kealake‘akua Bay to these changes in aerial behavior, it is likely that vessel and swimmer activity is at least synergistically involved in causing these changes. Whether these changes are affecting the survival and fitness of spinner dolphins is unknown. Further, although the mean number of swimmers and vessels using Kauhako Bay is lower than the mean numbers using Kealake‘akua and Honaunau bays, this activity is directed almost entirely at swimming with dolphins and may be the cause for the elevated dolphin activity levels and the shorter periods of time dolphins spend in that bay. This suggests that the level of swimmer and vessel traffic alone is insufficient to determine whether dolphins are being impacted by traffic.

We think further research is needed to determine impacts of swimmers and vessels on spinner dolphins in Hawaiian bays. We have submitted for publication a study complementary to our study, describing theodolite tracking of spinner dolphins and swimmers and vessels in Kealake'akua Bay (Timmel *et al.* in press). We recommend that a directed study of swimmers and dolphins in the northern part of Kealake'akua Bay be conducted because this is where tour operators bring people to swim and because dolphins spent most of their time near this part of the bay during our study (Courbis 2004). Acoustic monitoring could be used to determine if there have been changes in acoustic behavior over time as well since spinner dolphins have been previously recorded in Kealake'akua Bay (*e.g.*, Watkins and Schevill 1974, Norris *et al.* 1994). Although controlled experiments on behavior, such as those described by Bejder and Samuels (2003), are not really possible in the three bays we studied because dolphins are never present without swimmers or vessels, continued opportunistic studies similar to ours, but over longer periods of time, should be conducted. As new regulations are enacted, behavior should be monitored to determine if these regulations coincide with any restoration of previous behavior patterns. Also, the largest difficulty in correlating behavior to human activity is the myriad motivations for behavior aside from disturbance. Possibly a study that specifically attempts to determine how closely, quickly, loudly, and from what directions a swimmer or vessel can approach before there are overt reactive behaviors from dolphins would help establish approach guidelines for at least the most disturbing human activities. Continued comparison with historical data and direct assessment of how many people tour operators are bringing into the bays would also improve evaluation of tourism pressure. Renewed efforts at photo-identification may also be useful in assessing whether animals are using multiple bays and if they return to specific bays multiple times. This could also provide insight into calving and mortality rates.

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Literature Cited

Altmann, J. 1974. Observational study of behavior: Sampling methods. Behaviour 49:227–267.

Au, D., and W. Perryman. 1982. Movement and speed of dolphin schools responding to an approaching ship. Fishery Bulletin 80:371–379.

BEJDER, L., AND A. SAMUELS. 2003. Evaluating the effects of nature-based tourism on cetaceans. Pages 229–256 *in* N. Gales, M. Hindell and P. Kirkwood, eds. Marine mammals: Fisheries, tourism, and management issues. CSIRO Publishing, Victoria, Australia.

BEJDER, L., A. SAMUELS, H. WHITEHEAD, N. GALES, J. MANN, R. CONNOR, M. HEITHAUS, J. WATSON-CAPPS, C. FLAHERTY AND M. KRÜTZEN. 2006*a*. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology 20:1791–1798.

BEJDER, L., A. SAMUELS, H. WHITEHEAD AND N. GALES. 2006*b*. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. Animal Behaviour 72:1149–1158.

CONSTANTINE, R., D. BRUNTON AND T. DENNIS. 2004. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. Biological Conservation 117:299–307.

COURBIS, S. 2004. Behavior of Hawaiian spinner dolphins (*Stenella longirostris*) in response to vessels/swimmers. M.Sc. thesis, San Francisco State University, San Francisco, CA. 188 pp.

COURBIS, S. 2007. Effect of spinner dolphin presence on level of swimmer and vessel activity in Hawaiian bays. Tourism in Marine Environments 4:1–14.

DANIL, K., D. MALDINI AND K. MARTEN. 2005. Patterns of use of Maku'a Beach, O'ahu, Hawai'i, but spinner dolphins (*Stenella longirostris*) and potential effects of swimmers on their behavior. Aquatic Mammals 31:403–412.

DELFOUR, F. 2007. Hawaiian spinner dolphins and the growing dolphin watching activity in Oahu. Journal of the Marine Biology Association UK 87:109–112.

DEPARTMENT OF COMMERCE. 2005. Protecting spinner dolphins in the main Hawaiian Islands from human activities that cause "take," as defined in the Marine Mammal Protection Act and its implementing regulations, or to otherwise adversely affect the dolphins. Federal Register 70:57923–57926.

DEPARTMENT OF COMMERCE. 2006. Protection of marine mammals; notice of intent to prepare an environmental impact statement. Federal Register 71:57923–57926.

DOTY, M. 1968. Biological and physical features of Kealake'akua Bay, Hawai'i. Final Report to the State of Hawai'i, LG 67-331. No. 8. (unpublished). 210 pp. Available from University of California at San Diego, 9500 Gilman Dr., La Jolla, CA 92093.

FOREST, A. 2001. The Hawaiian spinner dolphin *Stenella longirostris*: Effects of Tourism. M.Sc. thesis, Texas A&M University, Galveston, TX. 91 pp.

JANIK, V., AND P. THOMPSON. 1996. Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. Marine Mammal Science 12:597–602.

LAMMERS, M. 2004. Occurrence and behavior of Hawaiian spinner dolphins (*Stenella longirostris*) along Oahu's leeward and south shores. Aquatic Mammals 30:237–250.

LUSSEAU, D. 2004. The hidden cost of tourism: Detecting long-term effects of tourism using behavioral information. Ecology and Society 9. Available at http://www.ecologyandsociety.org/vol9/iss1/art2/.

LUSSEAU, D. 2005. Residency pattern of bottlenose dolphins *Tursiops* spp. in Milford Sound, New Zealand, is related to boat traffic. Marine Ecology Progress Series 295:265–272.

NORRIS, K., AND T. DOHL. 1980. Behavior of the Hawaiian spinner dolphin, *Stenella longirostris*. Fishery Bulletin 77:821–849.

NORRIS, K., B. WÜRSIG, R. WELLS, M. WÜRSIG, S. BROWNLEE, C. JOHNSON AND J. SOLOW. 1985. The behavior of the Hawaiian spinner dolphin, *Stenella longirostris*. Southwest Fisheries Science Center Administrative Report LJ-85-06C. 218 pp. Available from SWFSC, P.O. Box 271, La Jolla, CA 92038.

NORRIS, K., B. WÜRSIG, R. WELLS, M. WÜRSIG, S. BROWNLEE, C. JOHNSON AND J. SOLOW. 1994. The Hawaiian spinner dolphin. University of California Press, Berkeley, CA.

ÖSTMAN-LIND, J., A. DRISCOLL-LIND AND S. RICKARDS. 2004. Delphinid abundance, distribution and habitat use off the western coast of the island of Hawai'i. Southwest Fisheries Science Center Administrative Report LJ-04-02C. 28 pp. Available from SWFSC, P. O. Box 271, La Jolla, CA 92038.

RICHARDSON, W., K. FINLEY, G. MILLER, R. DAVIS AND W. KOSKI. 1995. Feeding, social and migration behavior of bowhead whales, *Balaena mysticetus*, in Baffin Bay *vs.* the Beaufort Sea—Regions with different amounts of human activity. Marine Mammal Science 11:1–45.

SANTOS, M. 1997. Lone, sociable bottlenose dolphin in Brazil: Human fatality and management. Marine Mammal Science 13:355–356.

SHANE, S., L. TEPLEY AND L. COSTELLO. 1993. Life threatening contact between a woman and a pilot whale captured on film. Marine Mammal Science 9:331–336.

STONE, G., AND A. YOSHINAGA. 2000. Hector's dolphin *Cephalorhynchus hectori* calf moralities may indicate new risks from boat traffic and habituation. Pacific Conservation Biology 6:162–171.

TIMMEL, G. 2005. Effects of human traffic on the movement patterns of Hawaiian spinner dolphins, *Stenlla longirostris*, in Kealakekua Bay, Hawai'i. M.Sc. thesis, San Francisco State University, San Francisco, CA. 77 pp.

TIMMEL, G., S. COURBIS, H. SARGEANT-GREEN AND H. MARKOWITZ. In press. Effects of human traffic on the movement patterns of Hawaiian spinner dolphins, *Stenella longirostris*, in Kealake'akua Bay, Hawai'i. Aquatic Mammals.

WATKINS, W., AND W. SCHEVILL. 1974. Listening to Hawaiian spinner porpoises, *Stenella cf. longirostris*, with a three-dimensional hydrophone array. Journal of Mammalogy 55:319–328.

WÜRSIG, B. 1996. Swim-with-dolphin activities in nature: Weighing the pros and cons. Whalewatcher 30:11–15.

WÜRSIG, B., F. CIPRIANO AND M. WÜRSIG. 1991. Dolphin movement patterns: Information from radio and theodolite tracking studies. Pages 79–111 *in* K. Norris and K. Pryor, eds. Dolphin societies: Discoveries and puzzles. University of California Press, Berkeley, CA.

ZAR, J. 1999. Biostatistical analysis. Simon & Schuster, Upper Saddle River, NJ.

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