Impacts of Human Activities on Spinner Dolphins (*Stenella longirostris*) in Their Resting Areas

Results from volunteer monitoring between March 2006 and October 2008

Final Report to the

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By

Jan Östman-Lind

Kula Nai`a Wild Dolphin Research Foundation, Inc.
P.O. Box 6870
Kamuela, HI 96743

Abstract

A substantial part of marine recreation in Hawaii focuses on viewing and swimming with spinner dolphins, a nocturnal species that rests near shore during the day, in protected bays and coves throughout the Island chain. This practice started on the Kona Coast, Island of Hawaii, some 20 years ago, where a substantial swim-with-dolphins industry and resident swim-with-dolphins community now has been established. There are also many resident marine conservationists, including many native Hawaiians, strongly opposed to these practices creating a very contentious environment. In an effort to collect information, as well as provide a constructive alternative for this conflict, a volunteer monitoring project was initiated in March 2006. Data were collected on standardized forms with an emphasis on measuring how the dolphins were affected by human proximity and behavior in the resting areas. Thirty-seven community volunteers collected a total of 566 hours of data from three bays, over 251 days, spanning 2.5 years. The dolphins spent most of their time in each bay within zone(s) designed to encompass the core resting area while people, mainly snorkelers and kayakers, primarily spent time in these zones when dolphins were present. When people were present in the core resting areas in Honaunau and Kealakekua Bays, the dolphins displayed more aerial behavior, especially those requiring high-energy including acrobatics and behavior associated with fast swimming. These patterns were evident throughout the day and appeared to discourage rest. An earthquake-generated landslide on the side of Kealakekua Bay resulted in the bay being closed off to human use for 18 days in the middle of the monitoring period, providing a natural experiment without humans near the core resting area. The dolphins responded by returning to behavior patterns close to those observed and described prior to the beginning of the swim-with-dolphin encounters. The data strongly support the establishment of human exclusion zones around traditional spinner dolphin resting areas, to enable the dolphins to get undisturbed rest.

Introduction

Hawaiian spinner dolphins (*Stenella longirostris*) feed nocturnally. They rest in protected bays and coves during the day (Norris and Dohl 1980). The duration of the stay varies with bay, school size and season (Norris et al 1994, Östman 1994). Generally, a spinner dolphin school arrives in a resting area in the early to mid-morning and stays until mid afternoon. While there, the school spends most, if not all, of its time within a core resting area that generally occupies only a small part of the bay or cove.

Early studies of spinner dolphins describe dispersed schools arriving in a resting area, often divided into several subgroups and "with considerable aerial behavior" (Norris and Dohl 1980). Once in the bay, the school gradually subsided into a resting mode, with individuals swimming quietly and close together, without any splashing or other aerial behavior (Norris and Dohl 1980, Würsig et al 1994). The school also generally began to swim back and forth in the resting area in a rather predictable pattern, turning at each end to swim back the way it came. Once in deep rest, a school of anywhere from 30 to 100 individuals tended to spend 3-4 minutes below the surface, mostly swimming slowly just over the bottom in what has been termed the 'carpet formation' (Norris and Dohl 1980, Östman 1994). In between dives the entire school usually spent 20-30 seconds at the surface when all individuals would take several breaths before descending for the next dive.

In the afternoon schools ascended from rest in what has been termed zig-zag swimming, where the entire school oscillated between a more active mode, heading offshore or towards one side of a bay with increasing speed and amount of aerial behavior, and rest, heading back into the bay or in another direction swimming slowly with little or no aerial activity (Norris and Dohl 1980). Zig-zag swimming could go on for 20 minutes or longer. Once the dolphins had left the resting bay they headed towards the feeding grounds, where they spent the night feeding in a highly synchronized fashion (Benoit-Bird and Au 2003). The next morning they again approached shore and headed towards a resting area in a protected bay.

Up to the late 1970's, spinner dolphin contact with humans was limited. Schools might encounter humans along the coastline or in some resting areas, e.g. with people spearing fish or swimming in or near resting areas for exercise, or with people associated with various vessels, including water skiers (Norris an Dohl 1980). Kealakekua Bay was one of the few resting areas where this was described. This spot was also where commercial swim-with-dolphin tours started in the late 1980's.

The onset of swim-with-dolphins tours and subsequent explosion of the industry, as well as the influx of swim-with-dolphin enthusiasts to Hawaii have put increasing pressure on local Hawaiian spinner dolphin populations. An example of this may be seen by examining the website: http://www.joanocean.com/Human-do.html. Many Hawaii residents, including native Hawaiian groups became increasingly concerned. When both the commercial and local swim-with community focused their activities on the spinner dolphins resting area in Kealakekua Bay it became clear to many observers that this was not a sustainable activity, because it appeared as though the dolphins were less and less able to get any rest. The situation became very confrontational, including some physical exchanges on the beach between swim-with proponents and locals that were opposed to swimming with wild dolphins. The local Sea Grant extension agent became involved to mediate between the two sides.

The National Marine Fisheries Service (NMFS) became increasingly involved. Early on, the main swim-with-dolphin tour operator on the Island of Hawaii was charged for violations under the Marine Mammal Protection Act (MMPA). The operator apparently chose to pay the fine that was levied and then moved the operation to less easily observed locations. This operator continues to offer swim-with experiences over 15 years after being fined for harassment and is now only one of many commercial swim-with operators on the island. Few NMFS enforcement activities have been successful since then, and there is currently almost no enforcement presence on the island. At this point, these tours are so prevalent that eight to ten boats may leave Honokohau Harbor on any given day primarily offering swim-with tours, just along the northern part of the Kona Coast. Since the late 1980's commercial swim-with-dolphin tours have spread to the rest of the State of Hawaii (Appendix 1).

While numerous community and working group meetings have been held in the Kona area over the last 15 years addressing issues including swim-with-wild-dolphin activities, there had been little direct community training or involvement in monitoring efforts. This changed in 2003 when the Kula Nai`a Foundation offered a training course for boat captains and staff of marine tour companies to, among other things, promote conservation measures for the spinner dolphins.

In 2005, efforts began to obtain more quantitative information on how swim-with activities might affect the dolphins, and to provide an opportunity for community members to get a better understanding of the issues surrounding this activity. Thus, a community-based monitoring program was initiated to document the effects of swim-with-wild-dolphin activities in critical spinner dolphin resting habitat on the Kona Coast. Core resting areas had already been identified in previous studies (Norris and Dohl 1980, Norris et al. 1994, Östman 1994, Forrest 2001, Östman-Lind et al 2004, Courbis and Timmel 2008 – data from 2002), and the first training meeting took place in February of 2006. Monitoring began in March in Kealakekua Bay and was extended to Honaunau Bay in September of 2006. At the same time, the community group *Ka 'Ohana o Kona Hema* started an independent monitoring effort in Honaunau, including monitoring of human activities around the dolphins. These two independent monitoring efforts were coordinated in the fall of 2007.

The first monitoring effort was carried out between March 11, 2006 and May 10, 2007, and preliminary results were presented to the local Community in south Kona in October 2007. That presentation inspired several new volunteers to join the effort. As a result the second round of monitoring, carried out between November 3, 2007 and October 25, 2008, was expanded from the initial two bays, to an additional three bays, Kauhako Bay (off Hookena), Honokohau Bay, and Makako Bay. Thus by 2008, five spinner resting bays were being monitored.

The monitoring was designed to address a series of questions with the goal of evaluating the idea of setting aside human exclusion zones in all the main resting bays. The exclusion zones were designed so that normal human use not intended to interact with the dolphins would be minimally impacted, while at the same time the spinner dolphin core resting areas would be protected.

Methods

The following were the main questions addressed with this study:

1. How are the spinner dolphins using each resting bay?
    a. How much time do they spend in each bay?
    b. Are they spending most of their time in a bay within the core resting area?
2. How are people using each resting bay?
    a. Is the main human use by swimmers/snorkelers, kayakers, and/or motorboats?
    b. Are human use patterns affected by the absence/presence of spinner dolphins?
    c. Are humans in the core resting area when the dolphins are not in the bay?
3. When approaching, how close are people coming to the dolphins in the resting areas?
4. Does the time of day have an impact on the human use patterns?
5. Are the dolphins affected by human attempts to interacting with them, and if so how?
    a. Do dolphins behave differently when people are present, compared to absent?
    b. Does the distance between humans and dolphins affect dolphin behavior?

The monitoring effort of five bays on the Kona Coast varied in terms of coverage, including beginning and ending dates, frequency and duration of monitoring sessions, as well as in the

information that was recorded. This report includes information from the 5 bays on the Kona Coast that were monitored during this project (Figure 1). However, most of the data in this report comes from three of these bays, Honaunau, Kealakekua and Honokohau. For the other two bays, Kauhako and Makako, the data that were provided could mainly be used to measure occupancy rate.

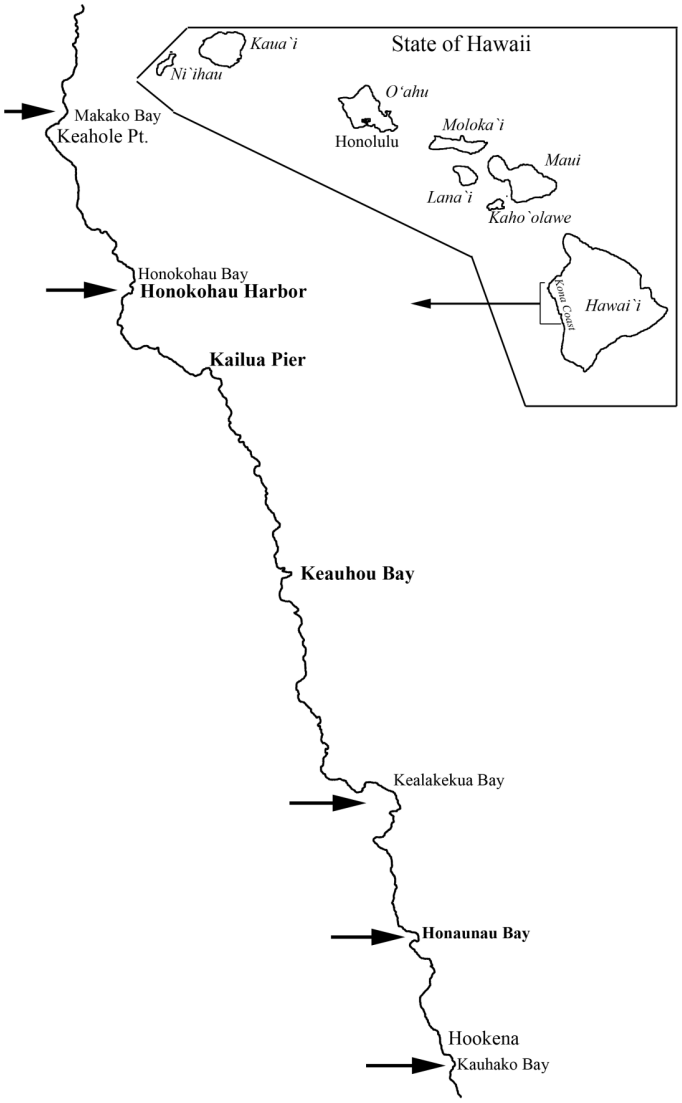

Figure 1. Central Kona Coast on the Island of Hawaii, showing the five bays (arrows) monitored during this project. Harbors and launch ramp locations are indicated with bold place names. The inset shows the main islands of the state, indicating the location of the Kona Coast.

Study Areas

The three main study areas were very different, in terms of both size and physical layout (Table 1, Figure 2). By area, Kealakekua Bay is over 9 times larger than Honaunau and almost 8 times larger than the study area in Honokohau Bay. In addition, the main human uses of the three

areas differed significantly. Users access Kealakekua Bay (Figure 2a) primarily via vessel, either on a charter vessel arriving from the north, or by kayak rented along the main road from Kona or from one of the unofficial kayak rentals at *Napo`opo`o* Wharf. A relatively small number of people drive to the bay by car to go swimming and/or snorkeling from the beach. Honaunau Bay on the other hand, is primarily accessed by snorkelers from shore (Figure 2b). People enter the water at a place called "two-step", allowing easy access in and out of the water. In addition, tour vessels bring people to the bay from harbors to the north, and a few small fishing vessels are launched from trailers at the launch ramp by the bay. There is also a very active canoe club based in Honaunau. Honokohau Bay (Figure 2c) is mainly used for accessing Honokohau Harbor, the main small boat harbor and boat launching point on the Kona Coast, from which a variety of charter vessels operate, including big-game fishing, SCUBA diving, snorkeling, and whale and dolphin watching boats, as well as a submarine that is towed out to its dive site every morning and towed back each evening. The harbor is also used by sail boats, kayaks, outrigger canoes, jet skis and small rental boats. Vessels enter and exit the harbor via a boat channel that cuts through the middle of the study area. There are also several mooring buoys used primarily by large party catamarans, dive and snorkel charters, and a small beach where some swimmers enter the water.

In each of the historical spinner dolphin resting bays, the animals spend most of their time within a small, defined area (Würsig et al 1994, Courbis and Timmel 2008), labeled the core resting area (Östman-Lind et al 2004). In Kealakekua Bay, this is right up against the Pali, or steep cliffs in the northeastern part of the bay. In Honaunau, it is located in the deeper, northern part of the bay, and in Honokohau Bay it is located between the harbor entrance and a green buoy, some 430m offshore, and includes parts of the boat channel (Figure 2).

Table 1. Comparison of relevant physical characteristics of Kealakekua, Honaunau and Honokohau Bays, and the average conditions estimated during the monitoring sessions.

	Kealakekua	Honaunau	Honokohau
Longest distance across bay from observation point (yds):	~1,800	600	600
Distance across mouth of bay (yds)	1670	550	450
Depth (width) of bay (yds)	800	380	450
Total area of Bay (acres)	193	21	25
Mean Estimated Distance to dolphins from observer (yds)	609	168	316
Range(yds)	100-1600	45-525	100-600
Mean Sea State (Beaufort scale)	2.0	1.3	1.3
Range (Beaufort scale)	1 - 4	0 - 2	0-3

Observations Zones

To establish how both dolphins and humans used these resting bays, and to enable a description of possible shifts in human use when dolphins were present, most bays were divided into six zones such that one zone mostly incorporated the spinner dolphin core resting area (Figure 2).

At least five additional zones were defined around this core resting zone. To describe the more complex use patterns of Honokohau Bay, eight zones were defined.

The zones in Kealakekua and Honaunau Bays were defined so that most of the core resting area was inside zone "B", although it extended into zone "A" in both bays. For Honokohau Bay, The resting area spanned zones "D", "E" and "F", with zone "E" being defined as the main boat channel for entering and exiting the harbor. In addition, several mooring buoys were present in zones "C", "F" and "H", mostly used by commercial dive and snorkel boats.

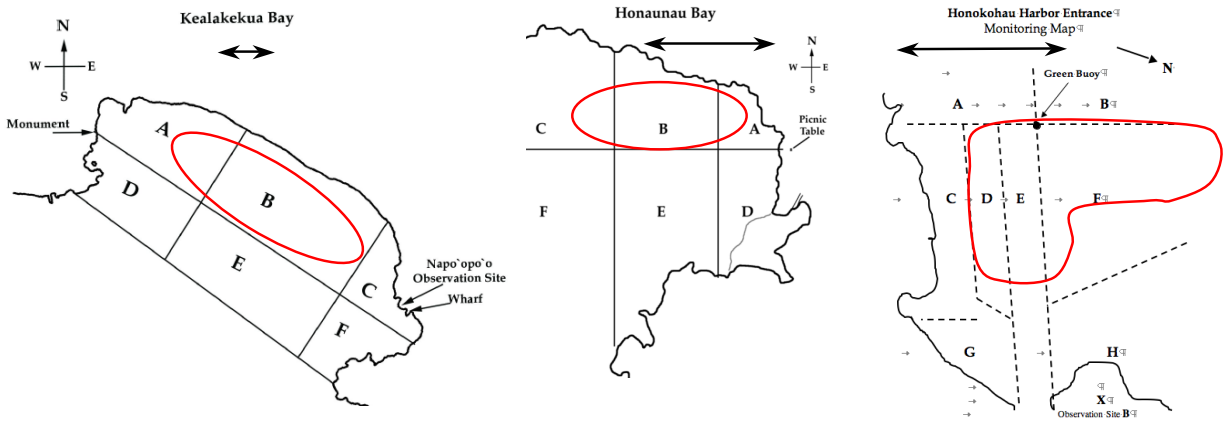

Figure 2. Monitoring maps of a) Kealakekua, b) Honaunau and c) Honokohau Bays. Each bay was divided into zones (see text). The approximate spinner dolphin core resting area is indicated for each resting bay with a red line. The size of each bay is indicate by a double headed arrow spanning 250m.

To identify the zones, the observers were assisted by demarcating landmarks and other natural and man-made objects. Thus in Kealakekua Bay, the three zones (A-C) in the inner part of the bay were separated from the outer zones by a sight line from the Captain Cook Monument to the tower of Kahikolu Church – both land marks visible from the bay and thus useable by kayakers and swimmers to determine their position. The observation site was located near this line making it relatively easy to separate the three inshore zones from the three offshore zones. The imaginary line running NE to SW, separating zones "B" and "C", and "E" and "F" originated at a pile of large boulders on shore (also the landmark for the a line separating the two zones established by the State of Hawaii for fishery management purposes) and continued offshore past one of two moored vessels moored approximately where this line intersected with the line between the church tower and the monument. Distinguishing the imaginary line running NE to SW and separating the two zones (A and D) farthest away from the observation site was more challenging and had to be estimated with the help of a landmark (a bush near the waterline) where this imaginary line originated.

In Honaunau Bay, the main imaginary line separating the three northern zones (A-C) from the southern zones (D-F) originated from the picnic table where the observer were sitting during their monitoring period making it easy to distinguish these zones from each other. The two

imaginary lines running north to south also had clear landmarks (specific rocks at the shoreline) where they originated.

In Honokohau Bay the observation site was located north of the harbor entrance near a sightline going out to a green buoy 430m offshore of the harbor entrance demarking the northern edge of the boat channel. This, together with the steady traffic of vessels mostly in the boat channel, helped to designate the zone for each vessel and swimmer. The imaginary line separating zones "H" and "F" ran along the edge of a coral reef, where several underwater mooring buoys were located.

Monitoring Protocol

The monitoring protocol was the same for all bays except for Honokohau Bay, where some additional data were collected to be reported separately. The protocol was adapted from protocols used by scientists studying spinner dolphins along the Kona Coast since the late 1960's (Norris and Dohl 1980, Norris et al 1994: p. 357-58, Östman 1994, Driscoll 1995, Forest 2001). Four main types of data were collected, on the hour and half hour:

(a) a 10-minute scan to systematically search the study area for the presence of dolphins until they were sighted. The 10-min time frame served to provide a minimum effort in locating the dolphins. Once the dolphins were sighted 10-min scans were discontinued unless the dolphins left the area or 'disappeared';

(b) a Boats and People Snap-Shot (to count the number of human users by zone) for five user groups, Swimmer/Snorkeler; Kayak; Hawaiian Canoe; and Motor Boat in two size categories, up to 7.5 meters (≤ 25 feet) and 8.0m or more (≥ 26 feet). The number of people on vessels was not counted unless the people entered the water;

(c) a 5-min Activity Scan was done as soon as the dolphins were first sighted and then continued on the hour and half hour. Following Norris et al. (1994) all dolphin aerial behavior were categorized and counted for five minutes, as an indication of dolphin activity level. The zone the dolphins were using during the scan was also recorded. Behaviors were categorized into the following categories: Acrobatic: Spin, Flip, Spin-Flip, Breach; Slap/Splash: Body Slap, Head slap, splash (unknown body part used); Fast Swim: porpoise, leap (distance in air ≥ body length), jump (distance in air < body length); Fluke Slap (inverted and upright). Behavior counts were also separated into two dolphin categories: calves, defined as animals ≤ ½ adult length; and non-calves, including adult and sub-adult individuals. Unless specified, the calf data was not included in the analysis.

(d) a Human Proximity and Interactions tally, where people were categorized by user group (see b above) and tallied into one of five categories based on their proximity to the dolphins during the activity scan: (i) Interacting – <10m (and almost always actively pursuing the dolphins), (ii) 10-50m, (iii) 51-100m, (iv) 101-200m, (v) > 200m.

Data Sheets

The data sheets from the 2006-07 monitoring effort were modified based on the feedback from that effort. Thus, two main data sheets were developed: one to be used initially and until any

dolphins were sighted (No Dolphin Seen), and a second to be used after dolphins had been sighted (Dolphins Present). Each form was designed to minimize the number of pages of paper needed for a typical 2-hour monitoring shift (Appendix 3 & 4).

The "No Dolphin Seen" form had a header section and five additional sections to record the results of a 10-minute scan (intensely searching the area for dolphins) immediately followed by a "Boats & People Snap-Shot" section. The five repeated sections allowed for a complete observation record every half hour and were enough for a complete 2-hour monitoring effort where no dolphins were sighted. The header section requested the following information: Date, Time on Site, Observation Station, Observer, recorder, Sea State (using the Beaufort Scale), initial sighting information, if dolphins were sighted, and any comments.

Once dolphins had been sighted, observers switched to the "Dolphins Present" form which had a header section and three additional sections: an "Activity Scan", a "Human Proximity and Interactions" section, and a "Boats & People Snap-Shot" section. This enabled a complete record every half hour of the activity level of the dolphins, which zone(s) they used, the proximity of all people within 200m of the dolphins, as well as information on how many people were using the entire bay by zone. The form required one side per half hour. In addition to the information requested on the "No Dolphin Seen" form, the header also requested the following information: distance from the dolphins to the observer; distance from the dolphins to the nearest point on land; number of subgroups; number of Calves (defined as ≤ ½ adult size); and three School size estimates: Minimum, Maximum and Best Guess.

Volunteer Training

Volunteers were trained on two occasions: once in a classroom setting where the forms and all monitoring categories were introduced and again at the respective field sites. In the field, everyone was familiarized with the demarcations for all zones. A laser range finder (Bushnell Yardage Pro 1000) with a 1000m range was used from the observation station to determine distances to known objects such as specific rocks, moored vessels, and/or buoys and other markers around each bay to help with distance estimates and locating zones. All volunteers were doing their estimates in yards (0.9m), since this was the measurement unit they were most familiar with. However, since all distance estimates were done by eye and a 10% error rate could be easily expected, all estimates were treated as meters for analysis purposes. Each observer had a map of their study area, showing the observation station and the layout of the zones (Figure 2). All terminology was defined and each observer received an electronic and/or hard copy of the Monitoring Protocol, providing step-by-step instructions for how to do the monitoring, including filling out each form.

Additional volunteer observers were added during the study and were trained by more seasoned volunteers. Occasional site visits were also performed while monitoring was in progress, to check on how the monitoring was done, answer any questions and help with any other logistics. The laser range finder was also used again to check on distance estimates.

Data entry

The data collected between March 2006 and May 2007 was entered into excel spreadsheets by the PI. However, as this was very time consuming the data was often entered several weeks or months after it had actually been collected, preventing the opportunity for immediate feedback on observations. This unfortunately resulted in some data loss. As a result, starting in the fall of 2007, all volunteers were asked to enter their own data into excel spreadsheets. They were provided with pre-formatted spreadsheets in a workbook format, complete with step-by-step instructions, including sample data entered from filled-out dummy datasheets, which were also provided as PDF files. Observers submitted their most recent data via email, initially on a weekly basis and then every few weeks, providing another opportunity for regular feedback. A few observers were not able to provide their data this way, so their data were entered by other volunteers.

The Earthquake and Subsequent Bay Closure

On Sunday October 15, at 0705 hours an earthquake, measuring 6.7 on the Richter scale and centered near Kiholo Bay on the northern Kona Coast, shook the Island of Hawaii for 58 seconds. One of the effects of this earthquake was a landslide from the Pali (cliffs) on the eastern shore of Kealakekua Bay. After the main earthquake and subsequent aftershocks occasional rocks continued to fall into the bay, causing the State of Hawaii Department of Land and Natural Resources (DLNR), in cooperation with the US Coast Guard, to close off the inner portion of the bay for about three weeks. The offshore boundary of the closed portion of the bay was a line from the Captain Cook Monument to the *Hikiau Heiau*, approximately all waters within 229m (250 yards) of the Pali (see dashed white line in Figure below), including 56% of zone "B". A Department of Conservation and Resource Enforcement (DOCARE) vessel was stationed in Kealakekua Bay to enforce this closure from October 26, 2006 at least through the end of the year. On November 2, the closed area was modified to run at a distance of 91m (100 yards) seaward of the shoreline along the entire face of the Pali (see solid orange line in Figure below), including 26% of zone "B".

As a result, this natural event created a serendipitous experiment for this study, since all swim-with activities ceased from October 15 until November 2, when observers began recording swimmers and vessels in the study area again. The community monitoring continued with three days of monitoring, on October 19 (Th), 21 (Sa), and 26 (Th), while no people or vessels were in the bay. This time period is referred to as the "Complete Closure" period. The period following the complete closure is referred to as the "Partial Closure" period.

Analysis, Statistical Tests and P-Values

Only data collected when sea state was ≤ Beaufort 4 and swell size did not impede monitoring were analyzed. Unless otherwise stated, all statistical tests presented here were chi-square tests. Significance levels are presented in the figures, using standard indicators for P-values: * < 0.05, ** < 0.01; *** < 0.001; N.S. indicate Non Significant values. The lack of a P-value or N.S. indicates insufficient data for meaningful statistical testing, with expected values < 5.0. Some P-values close to significance, but > 0.05 are presented in the text.

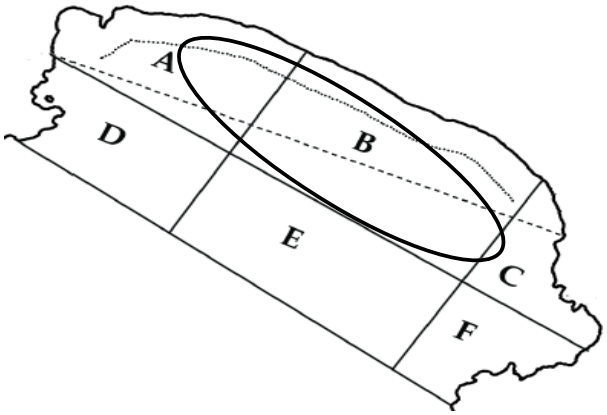

Figure 3. Post-earthquake closure of Kealakekua Bay. In addition to the six zones (A-F) and the ellipsis indicating the approximate core resting area, two lines limiting human use after the earthquake are also indicated. During the complete closure, people could not cross a line (dashed) approximately 250yds (229m) from the Pali (cliffs) along the NE coastline. During the partial closure, no one could get closer than 100yds (91m) to the Pali (dotted line).

Results

Community-Based Monitoring – Effort

This report is based on the analysis of data collected during volunteer monitoring of spinner dolphin resting areas from Mar 11, 2006 – Oct 25, 2008. Community volunteers monitored the spinner dolphin resting areas from shore in four bays (Appendix 2). A total of 566 hours of data were collected from three of the bays over 251 days (Kealakekua: 318 hrs over 146 days; Honaunau: 158 hrs over 74 days; Honokohau: 91 hrs over 31 days). In addition some information are available from Kauhako Bay, Hookena, where 56 hours of data was collected over 20 days. A large amount of data were collected in the three main bays (Appendix 2), including 970 10-minute scans, 368 5-minute activity-scans, and 1253 snapshots. In addition the Honokohau Bay monitoring protocol rendered 1670 vessel survey records.

The monitoring effort was based on when volunteers were available (Figure 4a-c). Thus Honaunau was primarily covered between September 2006 and May 2007 and again between November 2007 and October 2008 (Figure 4a). Kealakekua Bay was monitored from March 2006 through April 2007 and again between November 2007 and July 2008 (Figure 4b). Honokohau Bay was monitored between February and October 2008 (Figure 4c). Kauhako Bay was mainly monitored from December through mid-March (Figure 4d).

On a weekly basis, the main effort was focused on two weekdays, Monday, Thursday and on Saturday, to compare weekends with weekdays. Each volunteer tended to sign up for one or more timeslots on a particular day, again making the coverage of each bay dependant on when volunteers were available. Honaunau was primarily covered on Thursday mornings between 0600 and 0800 hours, and on Mondays between 0800 and 1000 hours and between 1400 – 1600 hours (Figure 5a). Kealakekua Bay was monitored from 1400 - 1600 hours on Mondays and from 0800 – 1200 hours on Thursdays and Saturdays (Figure 5b). Honokohau Bay was

monitored from 0600 through 1200 hours on some Mondays, between 0800 and 1400 hours on some Thursdays, and throughout the day between 0600 and 1600 hours on Saturdays (Figure 5c). Kauhako Bay was mainly monitored in the mornings (0800 - 1200 Hours) on some Tuesdays and Thursdays (Figure 5d).

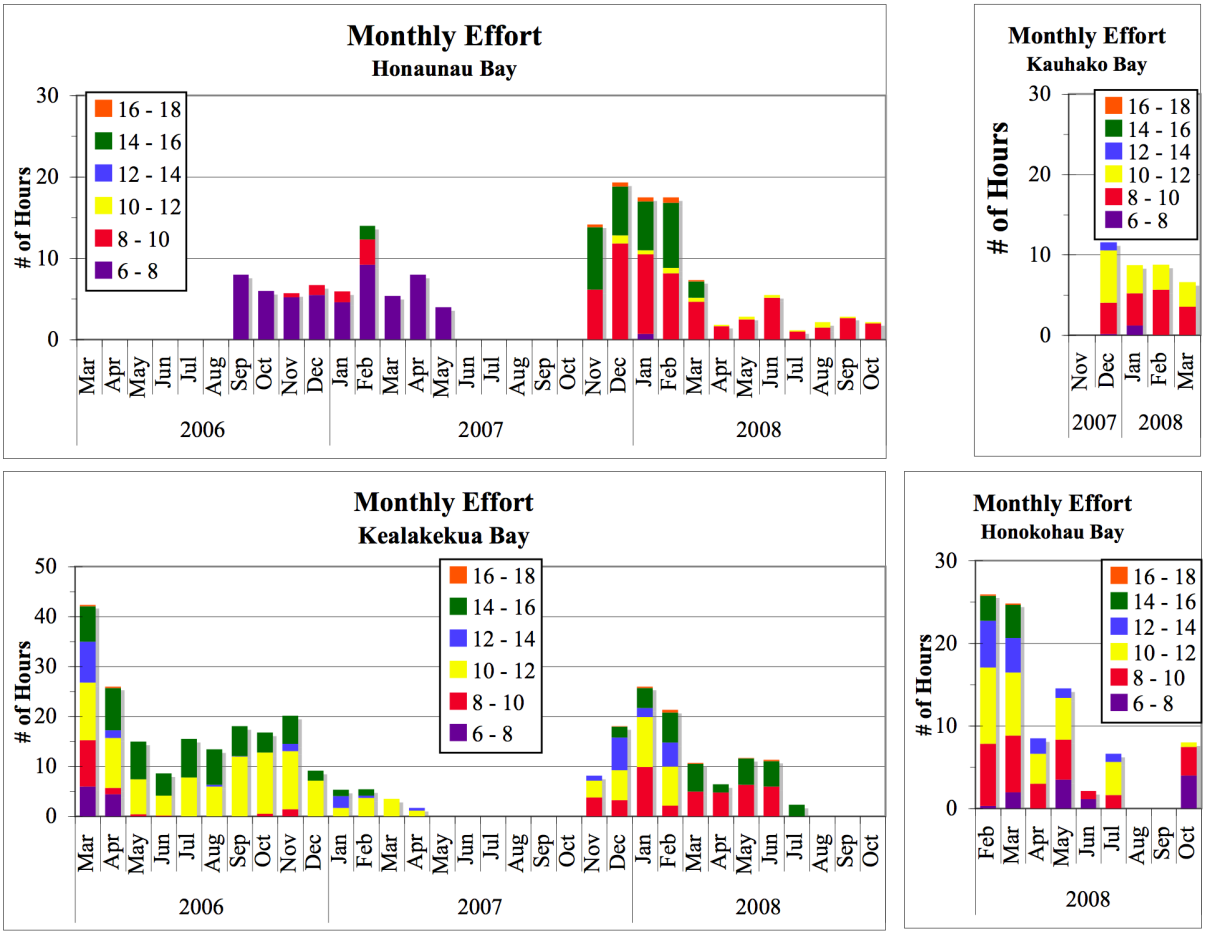

Figure 4. Monthly monitoring effort of a) Honaunau Bay, b) Kealakekua Bay, c) Honokohau Bay, and d) Kauhako Bay, showing the overall effort by month and the monthly break-down by time of day. Observer teams of one or more observers covered one or more two-hour timeslot per week.

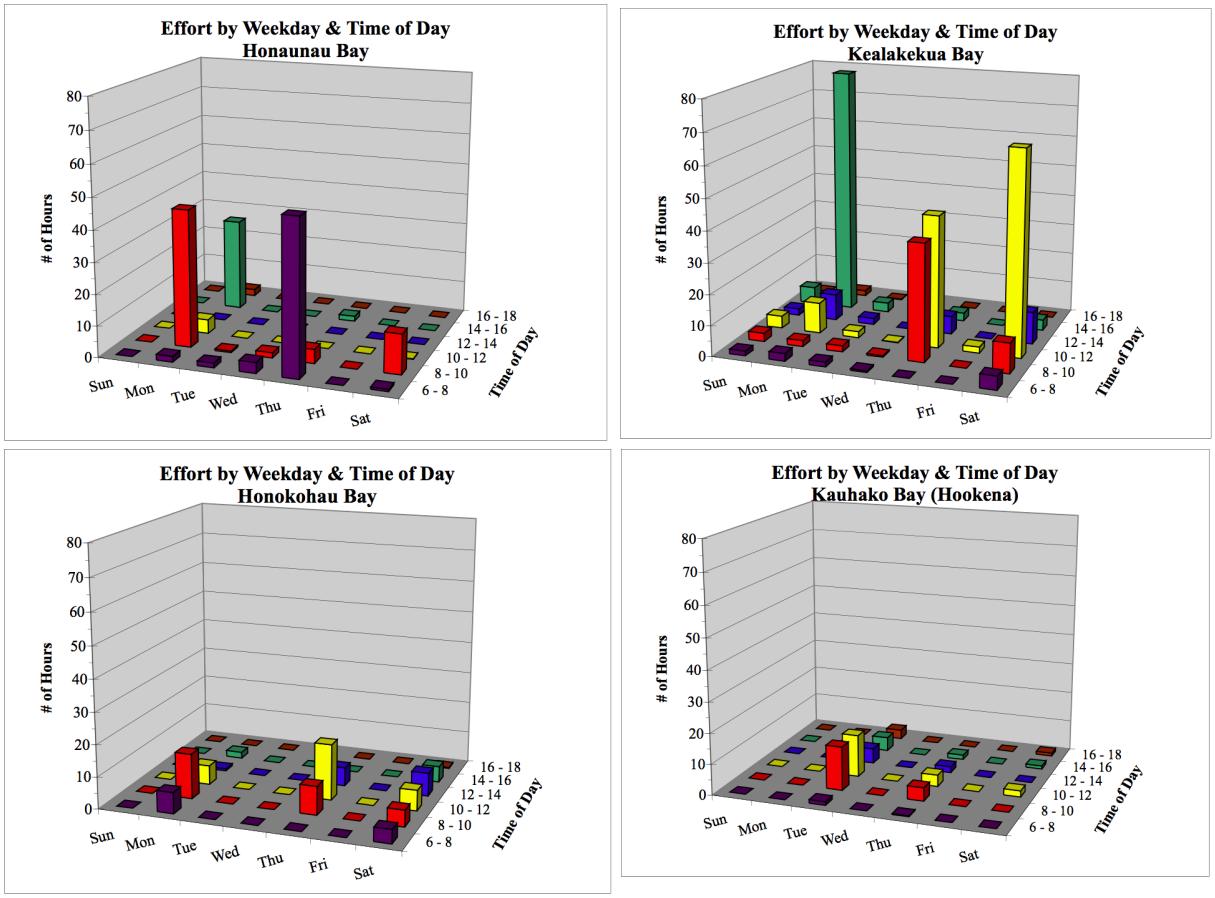

Figure 5. Monitoring effort by day of the week and time of day for of a) Honaunau Bay, b) Kealakekua Bay, c) Honokohau Bay, and d) Kauhako Bay.

Dolphin Use of Each Bay

The amount of time the dolphins were seen varied greatly between bays and time periods. On average, the daily occupancy rate, i.e. the proportion of days the dolphins were sighted within each bay, was the lowest (14%) for Honaunau Bay and the highest (58%) for Honokohau Bay (Figure 6). Since the coverage of each bay generally was from two to six hours, it is also instructive to look at the hourly occupancy rate (proportion of hours dolphins were sighted). This was lower than the daily rate for all bays but showed a similar relationship between the bays (Figure 6).

When spinner dolphins were in the three main resting bays covered in this study, they spent the majority of their time within the zone(s) designed to encompass the core resting area. Dolphin zone use was recorded during the activity scans. However, since the activity scans were 5 minutes long, the dolphins could spend time in more than one zone during a scan. The total zone use percentage for each of the bays thus exceeded 100% (Honaunau: 155%, n=59; Kealakekua: 107%, n=334; Honokohau: 132.9%, n=85), indicating that the dolphins were most likely to spend time in more than one zone during an activity scan in Honaunau, the smallest bay, and the least in Kealakekua, the largest bay. The zone designed to encompass most of the core resting

area was zone "B" for Honaunau and Kealakekua Bays, and zones "D" – "F" in Honokohau Bay (Figure 2), where the dolphins were recorded during 65.8%, 73.6% and 85.5% of the activity scans respectively (Figures 7a-c). In Honaunau Bay zone "A" was also a very important part of the core resting area where dolphins were recorded during 47.4% of all activity scans. For Honokohau Bay it is particularly noteworthy that the dolphins spent time in the main boat channel designed to access the Harbor during 43.5% of the activity scans.

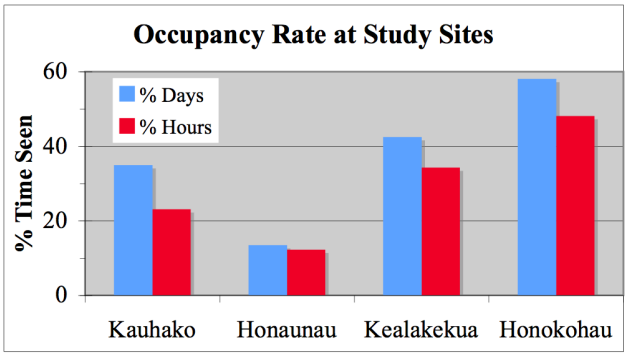

Figure 6. Occupancy rate for four bays on the Kona Coast, showing the proportion of days and hours covered by the monitors when dolphins were sighted in each bay.

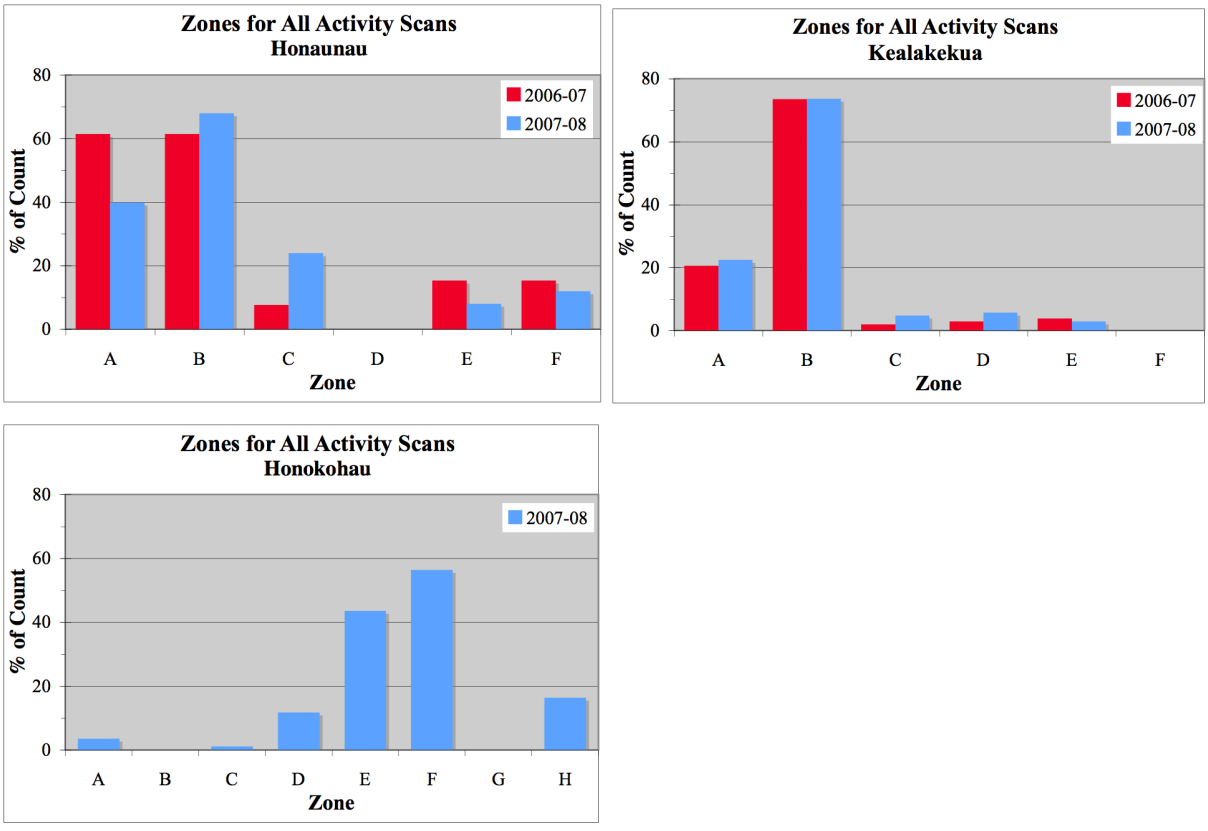

Figure 7. Zone use by spinner dolphin schools in three resting bays, as measured during 5-minute activity scans for a) Honaunau, b) Kealakekua, and c) Honokohau Bays. As each

scan was five minutes long, spinner dolphin schools could spend time in more than one zone. The total percentage per bay therefore exceeded 100% in all bays.

Human Use of Each Bay

The human uses of each spinner dolphin resting area monitored during this study included most user groups: swimmers/snorkelers entering the water from land, kayakers and an occasional Hawaiian canoe, people on tour boats originating from Honokohau Harbor, Kailua Pier, or Keauhou Harbor, rental boats from one of the two harbors, and local fishermen launching their vessels from one of the launch ramps on the Kona Coast, including at the two harbors and in Honaunau bay.

To quantify the human use of each bay, the number of people or vessels per user group was counted in each zone, either directly after a 5-min activity scan when dolphins were present or after a 10-min scan when they were absent from the bay. The monitoring data suggest that the human use of each bay was highly affected by the presence of spinner dolphins. Data from three of the bays, Kealakekua, Honaunau and Honokohau, were extensive enough for statistical analysis.

Kealakekua Bay

The human use of Kealakekua Bay can be divided into three parts, (1) use by swimmers, and (2) use by kayakers entering the bay from the beach and wharf at *Napo`opo`o* on the south shore of the bay, and (3) the visitors brought to the north end of the bay, near the Captain Cook monument, by tour boats originating from harbors to the north of the bay (Figure 1). The tour boats included one company that brought about 100 people at the time on a 18m long catamaran that was moored in the northwest corner of zone "A" and several companies that brought from six to 20 people on 6-8m long hard-bottom inflatable vessels left drifting along the northwestern coastline of zones "A" and "D". The swimmers in zones "A" and "D" were not counted during this project, since these zones were about 1.5 kilometer (km) away from the observation station, on the opposite side of the bay, making it very difficult to get an accurate count. However, all swimmers in those zones were brought on vessels, and all vessels in these zones, including kayaks, were counted and are part of the numbers reported below.

A total of 389 snapshots were collected in Kealakekua Bay when spinner dolphins were not present and 210 when they were. The human use of zone "B" increased dramatically when the spinner dolphins were present in Kealakekua Bay compared to when the dolphins were absent. There were both significantly more swimmers and kayakers in zone "B" (Figure 8a. and 8b.). The mean number of swimmers per scan increased 5-fold and the number of kayakers more than doubled in zone "B" when the dolphins were present. The increase can be attributed to both swimmers and kayakers moving into zone "B" from adjacent zones, with a significant decrease in swimmers in zones "E" and "F" and a significant decrease in kayakers in zones "D", "E" and "F". The observers also reported more swimmers entering the water from the beach in zone "C" when dolphins were present, explaining the increase in number of swimmers in that zone. There were too few (7 out of 28) Hawaiian canoes recorded in Kealakekua Bay when dolphins were present for statistical analysis of zone use, but it is noteworthy that the 15 records of Hawaiian canoes in zone "B" were all recorded at times when no dolphins had been sighted (Figure 8b.).

Both small (≤ 7.5m) and large (≥ 8.0m) motorboats were recorded mostly in the two zones ("A" and "D") near the Captain Cook Monument, 80.5% and 87.5% respectively for the two size classes (Figure 8c.). However, there was a slight increase in motorboats of both size classes in zone "C" when dolphins were present and a significant decrease in the number of smaller motorboats in zone "D" when dolphins were present.

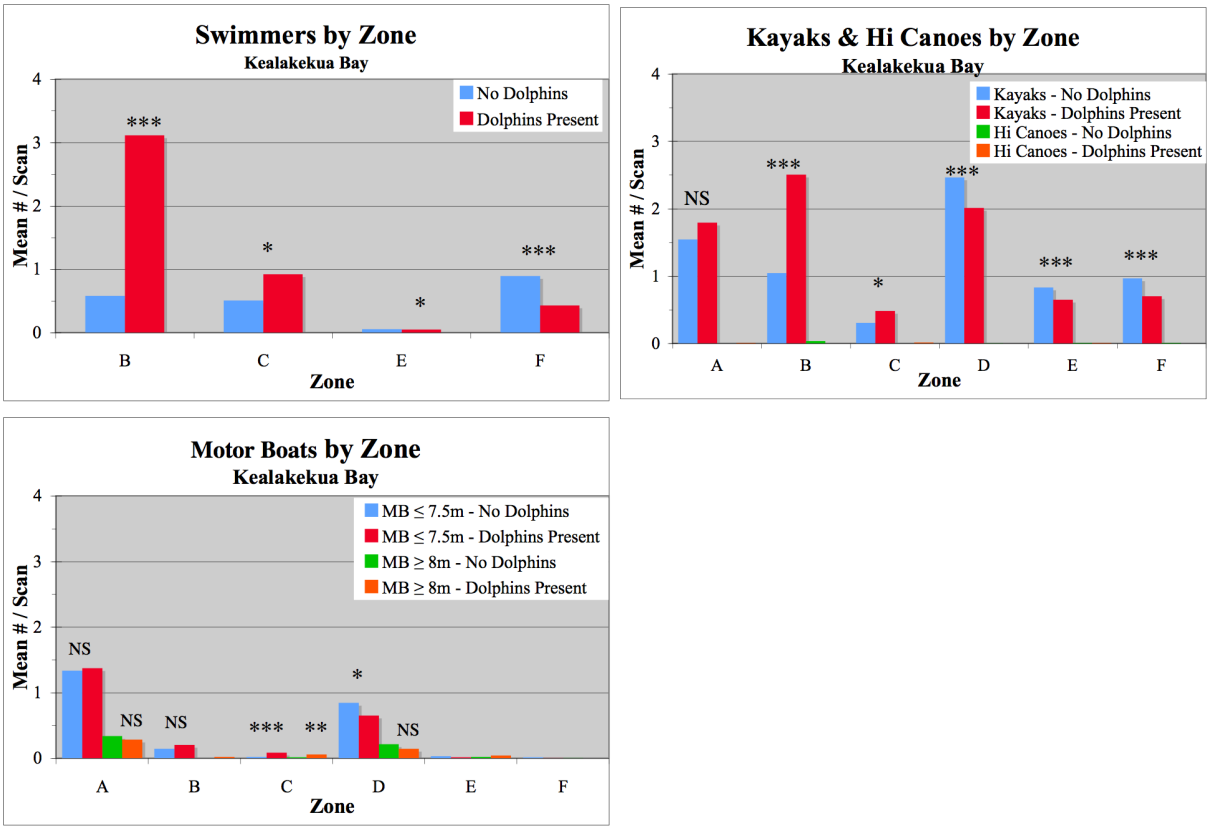

Figure 8. Human zone-use in Kealakekua Bay, comparing snapshots when spinner dolphins were present with snapshots when they were not observed in the bay, for a) swimmers, b) kayaks and Hawaiian canoes, and c) motorboats of two sizes. Zones "A" and "D" were not scanned for swimmers (see text). Significant differences between "dolphin present" and "no dolphins" bars in the same zone are indicated using standard statistical notation. See methods section for further information.

A further analysis of the human use of zone "B" by time of day shows that the pattern of more swimmers and kayakers being recorded there in the presence of dolphins was most striking during the morning hours although it tended to continue throughout the day. The number of swimmers recorded in zone "B" when dolphins were present peaked during the 0800 hour (0800-0859) while the number of kayakers peaked during the 1000 hour (Figure 9). The presence of dolphins correlated with an influx of 7 times more swimmers and 11 times more kayakers into zone "B" during the 0800 hour, and a 3-times increase in both swimmers and kayakers during the 0900 hour. There continued to be about twice as many kayakers in zone "B" when dolphins were present throughout the day (Figure 9b).

When dolphins were not present, fewer swimmers were counted in zone "B". An average 1.8 swimmers per scan during the 0800 and 2.4 swimmers per scan during 0900 hour. During these hours several people were generally standing on land waiting for the dolphins to arrive in the bay. For the rest of the day one swimmer was recorded in this zone in less than every third scan.

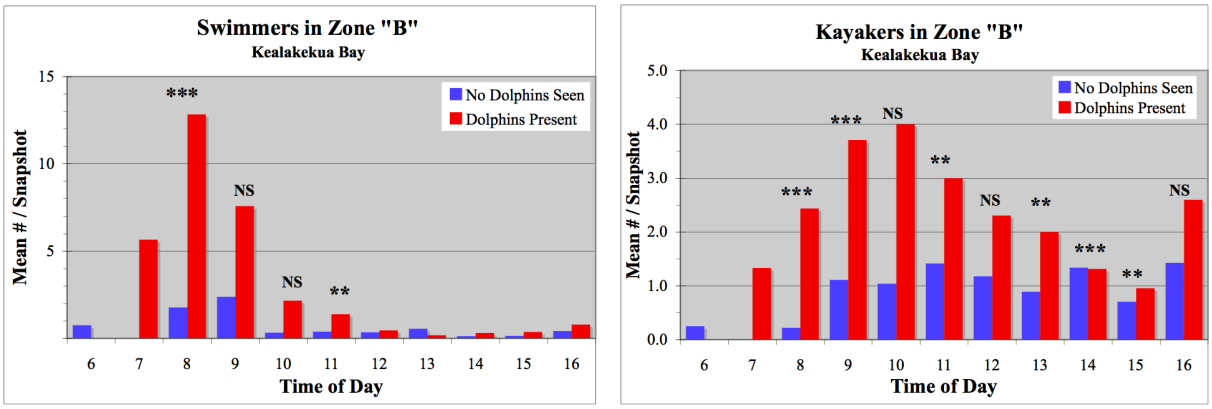

Figure 9. Human use of zone "B" by hour in Kealakekua Bay comparing snapshots when spinner dolphins were present versus absent in the bay for a) swimmers, b) kayaks. Significant differences between bars during the same hour are indicated using standard statistical notation. See methods section for further information..

Honaunau Bay

The human use of Honaunau Bay has three main components. Most people entered the water from land, entering at or near "two-step" into zone "D". Several snorkel tours brought people (about 6-15 people per vessel) to the reef along the southwestern part of zone "E", and there was a boat ramp used to launch small 3-4m fishing boats into the middle of zone "D". These vessels headed more or less due west, exiting the area through the middle of zones "E" and "F".

The main human presence in Honaunau bay was in the form of swimmers. When dolphins were present the number of swimmers increased in zone "B" and decreased in the surrounding zones "D" and "E" (Figure 10a). On average, there was a 9-fold increase in swimmers in zone "B" when dolphins were present, while the number of swimmers dropped by 18% in zone "D" and over 70% in zone "E". There was not enough vessel-data available when dolphins were present for statistical testing, and even when the data was combined for all vessel types it was only possible to test the data for zone "E" statistically. It showed no significant difference between snapshots when dolphins were absent vs. present (Figure 10b).

The analysis of human use of zone "B" by time of day was limited by the very low occupancy rate in that bay, making the number of observations when dolphins were present very low. However, the over all pattern was similar to that found in Kealakekua Bay, with swimmers mostly observed in this zone when dolphins were present in the bay during all time periods that were monitored (Figure 11). There were significant differences in number of swimmers for the 0700 and 0800 hours, when the presence of dolphins brought a 34-fold and 4-fold increase in swimmers respectively. Similarly, although not statistically significant, the presence of dolphins were associated with many-fold increases in the number of swimmers in zone "B" for the 0900

(10-fold), 1000 (21-fold), 1400 (6-fold), and 1500 (8-fold) hours. During the 1600 hour, 11 swimmers were recorded over 13 snapshots with no dolphins present in the bay.

When dolphins were not present in Honaunau Bay, very few swimmers were counted in zone "B". On average one swimmer was counted every three scans and there was no peak in the morning, as was observed in Kealakekua Bay.

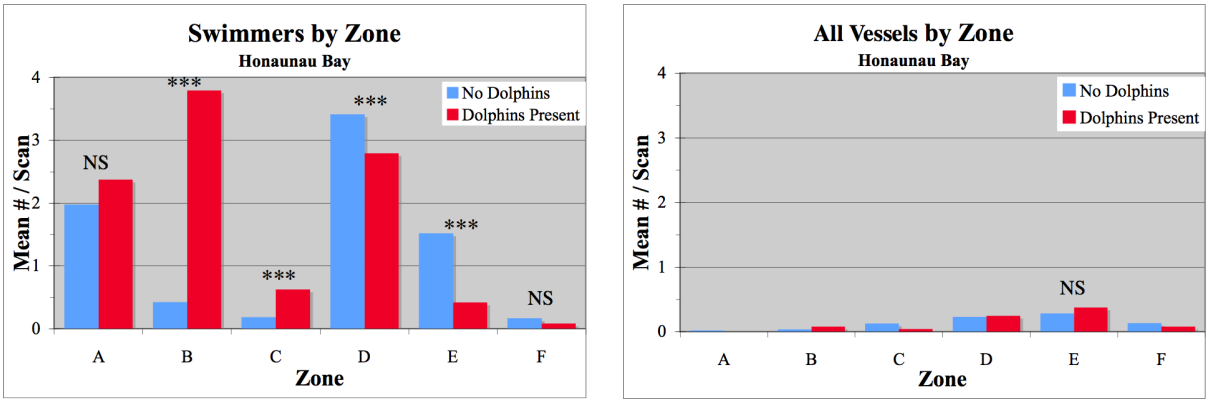

Figure 10. Human zone use in Honaunau Bay, comparing snapshots when spinner dolphins were present versus absent in the bay for a) swimmers and, b) all vessel-data combined. Significant differences between bars in the same zone are indicated using standard statistical notation. See methods section for further information..

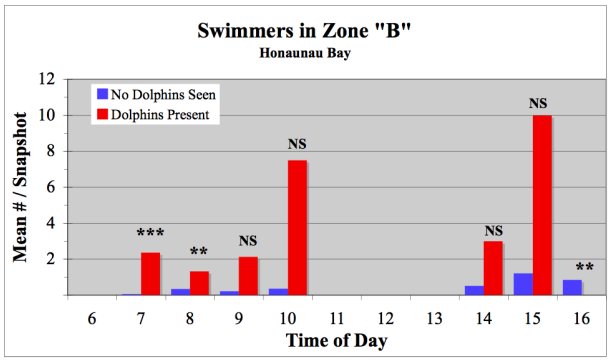

Figure 11. Human use of zone "B" in Honaunau Bay, by time of day, comparing snapshots when spinner dolphins were present versus absent in the bay. Significant differences between bars during the same hour are indicated using standard statistical notation. See methods section for further information.

Honokohau Bay

The human use of this area was dominated by the vessel traffic entering and exiting Honokohau Harbor. However, there were also other human uses. There is a small beach in the eastern end of zone "C" (Figure 1c), where some swimmers/snorkelers enter the water. There are also three mooring buoys in zone "C" just west of this beach, which are often used by snorkel tours and large party catamarans with water slides. Zone "H" is mostly taken up by a coral reef frequented by both dive and snorkel tours that use four mooring buoys located in zones "F" and "H". Only

one of these moorings is in the area depicted on the monitoring map (Figure 2c), with the remaining moorings just to the NNW of this area.

The primary focus of the monitoring effort for Honokohau Bay was the inner part of the bay, encompassing the core spinner dolphin resting area. The purpose of the monitoring was to assess how the vessel traffic in and out of the harbor affected the dolphins. This unfortunately meant that very few "Boats and People Snap-Shot" observations were recorded when dolphins were absent, limiting the possibility of statistical testing on this aspect of the data due to too low expected values. However, by combining the data on vessel traffic and reducing the number of categories it was possible to make a few statistical comparisons.

There were fewer swimmers in the area in front of the harbor mouth when dolphins were present as compared to when dolphins were absent. When dolphins were absent, swimmers were primarily observed in zones "C", "F", and "H", the zones where boat moorings are available and with easy beach-access into the water from land (Figure 12a). When dolphins were present in the bay, the number of swimmers decreased significantly in zones "C" and "H" to 34% and 6% respectively of the numbers when no dolphins were present. The number of swimmers also decreased to 34% in zone "F", although this was not statistically significant ($P = 0.09$). One swimmer was recorded in zone "D" and two in zone "G" when dolphins were present. There were no records of swimmers in zone "E", the boat channel, during a regular scan although swimmers were observed there on a few occasions when dolphins were present during non-scan times.

By combining the data on all vessel types it was possible to test the vessel use of zone "E" statistically. The number of vessels in this zone increased 7-fold when dolphins were present (Figure 12b). By further combining the vessel data, it could be shown that the number of vessels using the three zones encompassing the core resting area ("D", "E", "F") increased 4-fold overall when dolphins were present, while the use of the three remaining inshore zones surrounding the core resting area ("C", "G", "H") decreased to 80% of the numbers when dolphins were not present (Figure 12c).

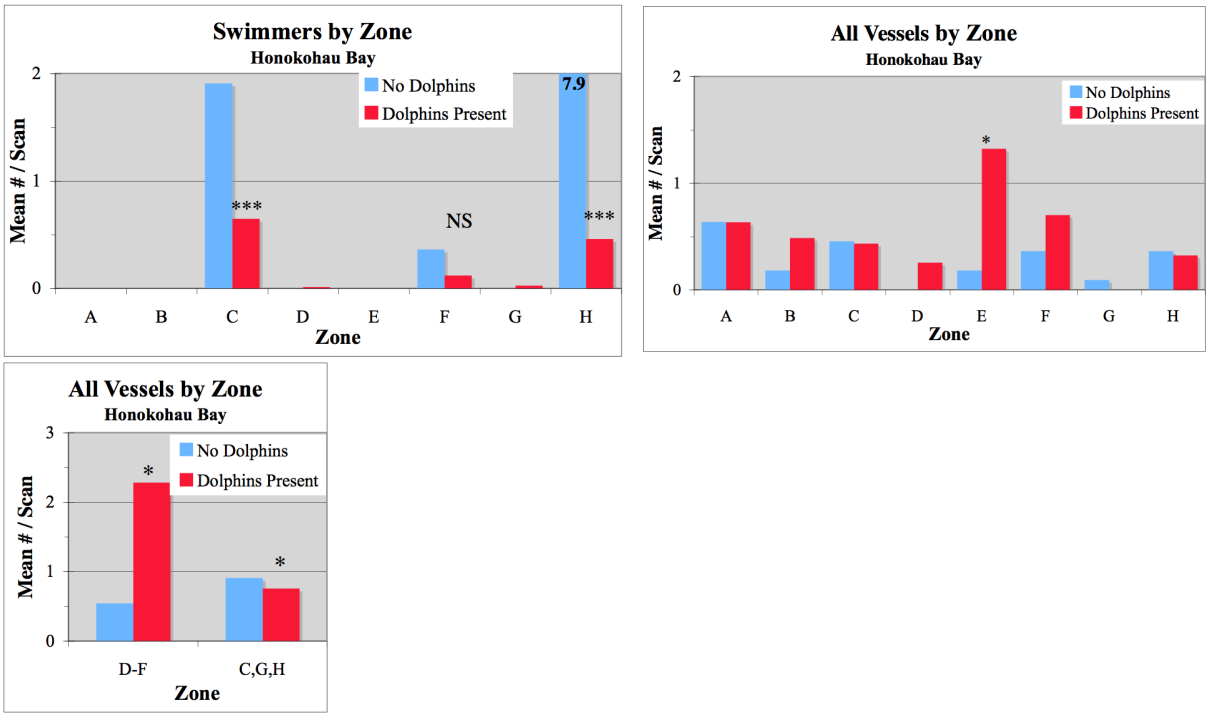

Figure 12. Human zone-use in Honokohau Bay, comparing scans when spinner dolphins were present versus absent for a) swimmers, b) all vessel-data combined, and c) all vessels comparing the three zones (D-F) encompassing the spinner dolphin core resting area with the remaining inshore zones (C,G,H). Significant differences between bars in the same zone are indicated using standard statistical notation. See methods section for further information.

Human Distribution Relative to the Dolphins

In addition to investigating the human use within each bay when dolphins were absent or present, monitoring data was also collected on human distribution relative to the dolphins when the dolphins were in each bay.

In Kealakekua Bay, it was primarily swimmers and kayakers that moved close to the dolphins (Figure 13a). On average, 1.9 swimmers were within 10m actively pursuing, attempting to interact with the dolphins with another 1.7 swimmers within 50m and 0.8 between 50m and 200m. For kayaks, 0.6 were within 10m with an additional 1.4 kayaks within 50m and 0.9 between 50m and 200m. Thus, on average, 3.6 swimmers and 2.0 kayakers were within 50 meters of the spinner dolphins during each of 171 activity scans, with additional swimmers and kayakers nearby.

In Honaunau Bay, only swimmers were observed close to the dolphins. On average, 3.0 swimmers were within 10m of the dolphins actively trying to interact with them. Another 3.2 swimmers were within 50m, and a total of 9.5 swimmers were within 200m of the dolphins during each of the 21 activity scans that were done (Figure 13b).

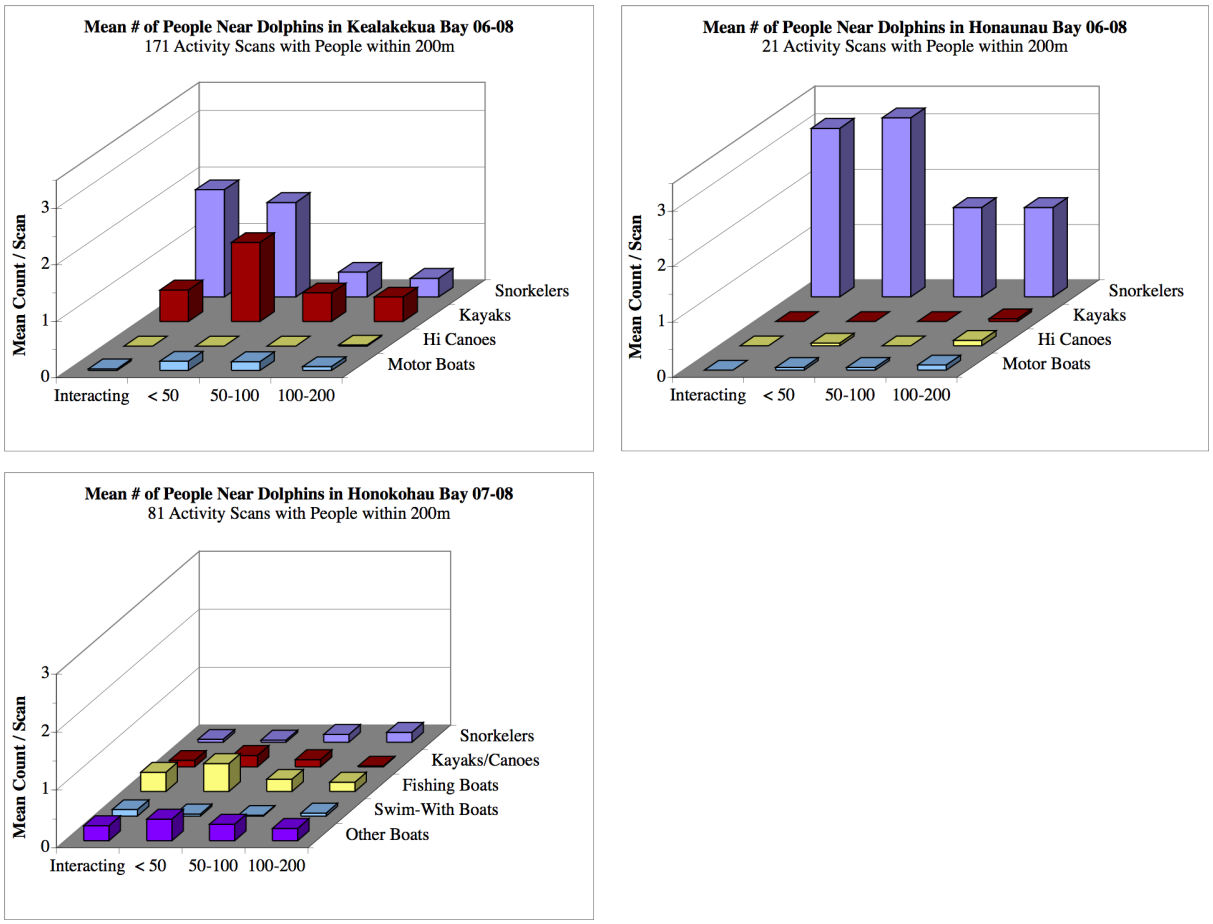

Figure 13. Distribution of people relative to the dolphins during 5-min activity scans in a) Kealakekua Bay (n=171), b) Honaunau Bay (n=21), and c) Honokohau Bay (n=81).

The picture was quite different in Honokohau Bay where on average only 0.4 swimmers and a total of 3 vessels were within 200m of the dolphins (Figure 13c). This number includes vessels that were entering and exiting the harbor through the boat channel (zone "E"). The majority (64%) of all vessels transited straight through the dolphin resting area without changing speed or direction.

Measuring Dolphin Reactions

Aerial Behavior by non-calves

To measure how the dolphins reacted to the human attention in the resting areas, their aerial behaviors were counted during 5-min activity scans. Only behaviors attributed to an adult or sub-adult, non-calf dolphin (calves defined as < ½ adult length), are reported in this section. The human proximity to the dolphins was also estimated at the end of each activity-scan, making it possible to correlate the two. If the nearest people (swimmers or people in vessels) were more than 200m away, the dolphins were considered to be by themselves for the purpose of this study.

Aerial Behavior Relative to Human Proximity

To estimate how the amount of aerial behavior was affected by human proximity, all aerial behavior measured during the activity scans were attributed to the nearest distance category where people were recorded for purposes of analysis. That is, if there were swimmers and/or kayakers both between 50-100m and 100-200m away from the dolphins during an activity scan, for this analysis all aerial behavior were attributed to the 50-100m distance category.

The frequency of aerial behavior per activity scan was positively affected by human proximity in all bays (Figure 14). This trend was the clearest in the two smaller bays (Honaunau and Honokohau), while the highest average of aerial behavior per scan in Kealakekua Bay was for the 10-50m category (5.1), followed by the 0-10m category (3.9). Conversely, the lowest number of aerial behavior per scan was recorded when the closest humans were 100m-200m away, including one activity scan in Honokohau Bay (n_{tot}=42) when no aerial behavior were recorded, one activity scan in Honaunau Bay (n_{tot}=27) when three aerial behaviors were recorded (2 fluke slaps and a jump), and 12 activity scans in Kealakekua Bay (n_{tot}=171) when an average 1.0 aerial behavior were recorded per scan. Regression analysis on the same data set, with the distance for each category set to the middle of the range, rendered significant correlation coefficients for

It is important to note, however, that a sizable proportion of aerial behaviors were displayed when the closest people were 50-100m away. When adjusted for sample size, the proportion of aerial behavior recorded when the closest people were at this distance were 23% for Honaunau Bay, 21% for Kealakekua Bay, and 12% for Honokohau Bay.

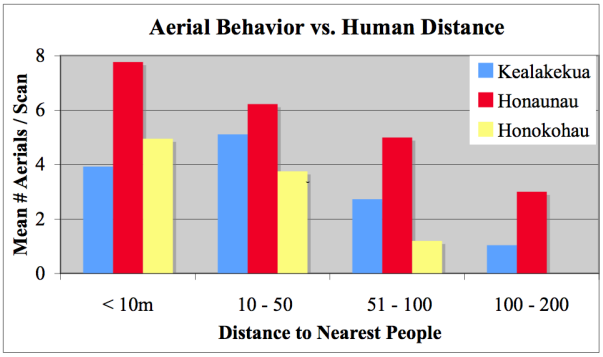

Figure 14. Mean number of aerial behavior recorded per activity scan relative to human proximity. Human proximity was measured as the closest distance category where humans were observed.

Aerial Behavior Relative to Time of Day

To assess whether time of day influenced the frequency of aerial behavior, the data was divided into 3-hour time bins, with the exception of the last monitoring hour of the day. This also ensured that there would be enough data per category for statistical analysis. Therefore, there were four time bins (0600-0859, 0900-1159, 1200-1459, 1500-1559) for Kealakekua and Honaunau Bays (where monitoring sometimes occurred after 1500 hours) and three time bins for Honokohau Bay (where the last observations were always done before 1500 hours). Furthermore, since the majority of all aerial behavior occurred when people were within 100m of

the dolphins (Honaunau 91%, Kealakekua 98%, Honokohau 89%), the following analysis focused on the aerial behavior recorded when people were ≤ 100m, comparing them to aerial behavior seen when the dolphins were by themselves (people > 200m).

In Kealakekua Bay significantly more aerial behaviors were recorded when people were within 100m of the dolphins during all time periods except 1200-1400 (Figure 15a), although the difference in this time period was almost significant (P = 0.063). Between 0600-0800 all aerial behavior occurred in the presence of people, and this was also the case for the 0900 hour. In Honaunau, aerial behavior was only recorded on two of the five days when dolphins were present without people, once when the dolphins were milling off a point in the far part of zone "C" (Figure 2b.) and once in weather too rough for people to swim and the dolphins were seen surfing the waves. All other aerial behaviors recorded in this bay were observed with people within 100m of the dolphins (Figure 15b). The majority of aerial behavior recorded during mid-morning and early afternoon in Honokohau Bay were also recorded with people within 100m of the dolphins, while the opposite was the case in the early morning (0600-0859) time period when most aerial behaviors were recorded with people more than 200m away (Figure 15c).

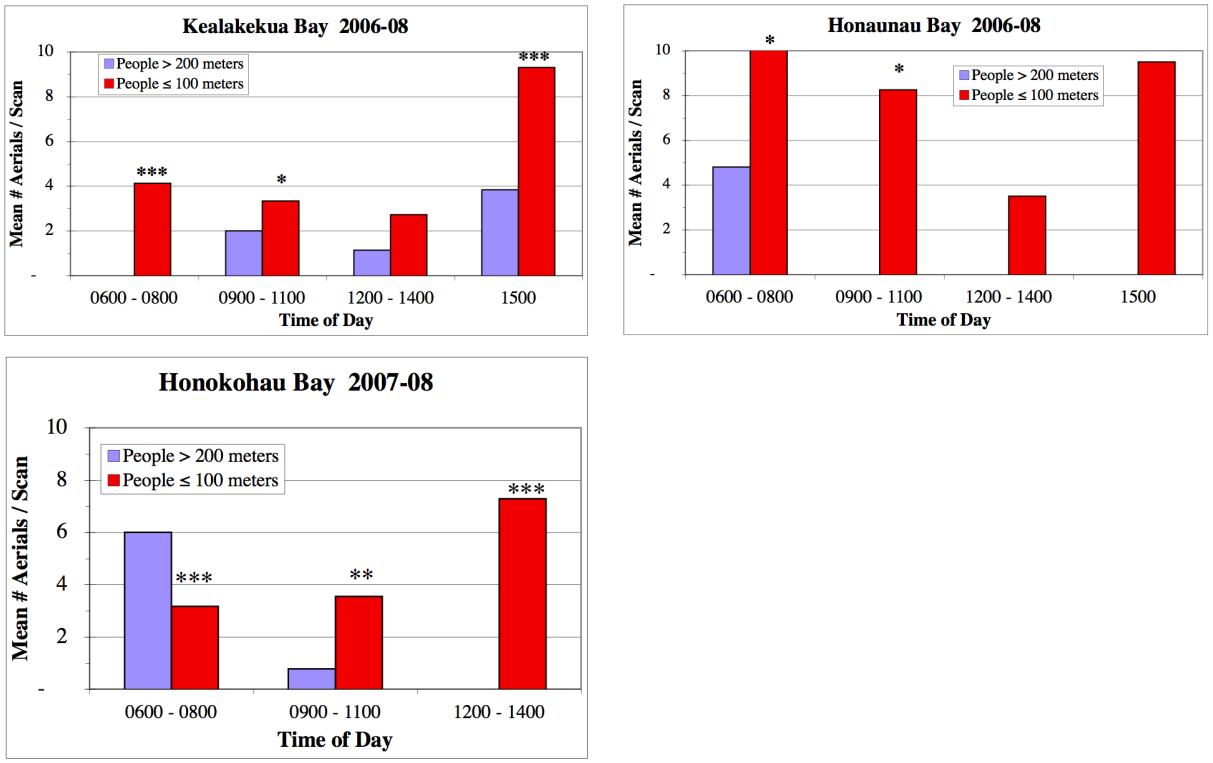

Figure 15. Comparing the mean number of aerial behavior when people were within 100m of the dolphins, versus over 200m from the dolphins in a) Kealakekua, b) Honaunau, and c) Honokohau Bays. Significant differences between bars in the same time period are indicated using standard statistical notation. See methods section for further information.

Aerial Behavior by Category

The aerial behaviors were lumped into three main categories for this part of the analysis, acrobatic behavior, slaps/splash, and fast swim. However, as one of the observers covering

Kealakekua Bay during the 2007-08 study recorded large numbers (3209) of porpoising behaviors (one of the behaviors in the Fast Swim category), representing 99.5% of all fast swimming behaviors recorded for that bay that season, this behavior was graphed and analyzed separately from the other fast swim behaviors for that bay. The number of activity scans, i.e. the sample size, varied by bay with 110 activity scans recorded in Kealakekua Bay (22 with people > 200m from the dolphins and 88 with people ≤ 100m), 18 in Honaunau Bay (1 with people > 200m and 17 with people ≤ 100m), and 91 in Honokohau Bay (23 with people > 200m and 68 with people ≤ 100m).

The majority of aerial behaviors were recorded when humans were closer than 100m to the dolphins, for most behavior categories in the three bays (Figure 16). The mean number of acrobatic and fast-swim behaviors were significantly higher in all bays when people were within 100m of, compared to more than 200m from, the dolphins. People ≤100m brought a 3-fold increase in acrobatic behavior and 2.5-fold increase in non-porpoise fast-swim behaviors in Kealakekua, a 3.2-fold increase in acrobatic behavior and all fast-swim behaviors in Honaunau, and a 5.3-fold increase in acrobatic behavior and a 5.1-fold increase in fast swimming in Honokohau. The number of slaps/splash behaviors, however, remained statistically unchanged.

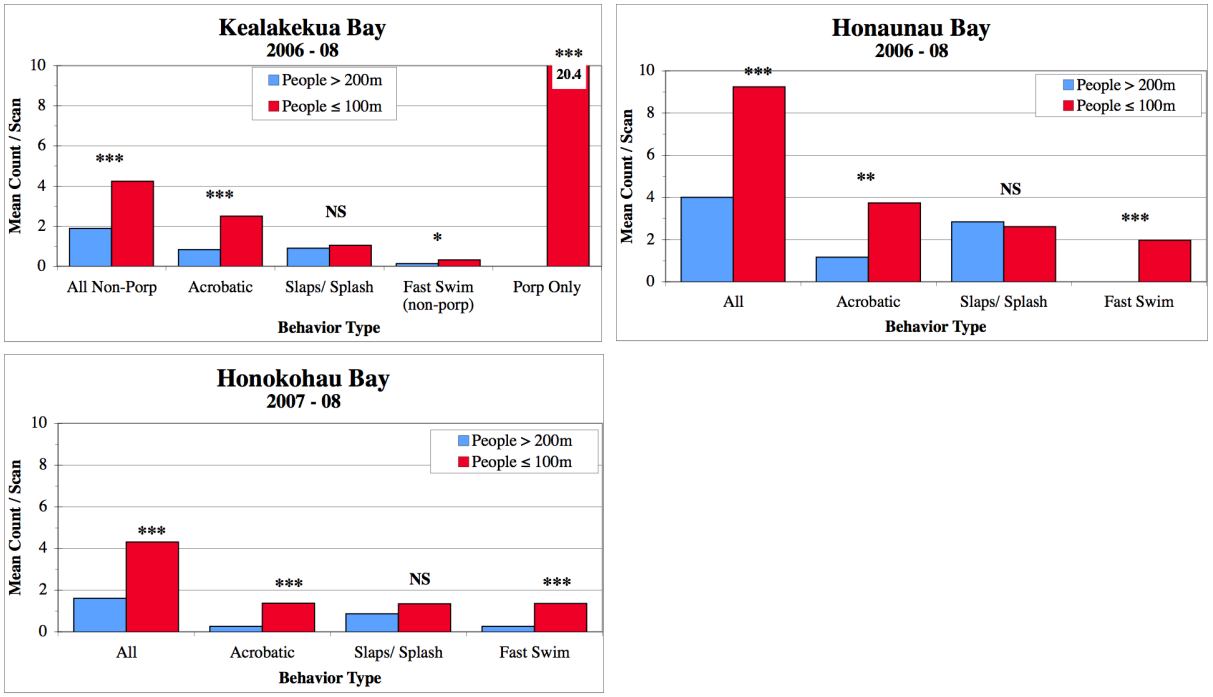

Figure 16. Average aerial behavior count during two conditions, people and vessels >200m from the dolphins vs. people and vessels ≤100m of the dolphins in a) Kealakekua, b) Honaunau and, c) Honokohau Bays. Significant differences between bars for the same behavior type are indicated using standard statistical notation. See methods section for further information.

Effects of Human Exclusion from Kealakekua Bay

During the complete closure period following the earthquake on October 15, 2006 monitoring was conducted on three days (October 19, 21 and 26), thus providing too small of a sample size

for statistical comparisons with the time periods before and after. However, spinner dolphins were present in the bay on all three days, for an occupancy rate of 100%, compared to 39.3% before the earthquake and 31.8% between the time people were allowed back into the area again and April 12, 2007.

Twelve activity scans were conducted over the three monitoring days during the complete closure time all between 10:14 and 11:45. These activity scans can therefore best be compared to the scans conducted during the 0900-1159 hours before the earthquake and after the complete closure period (Fig. 17). The dolphins' behavior changed during the human exclusion period after the earthquake, with a significant reduction in both acrobatic behavior and slaps and splashes. The sample size was not adequate for a statistical analysis of the fast swimming and maneuvering behavior, although the smallest mean (0.08 – 1 record in 12 scans) was recorded during the complete closure period.

After the closure area was reduced from encompassing approximately 56% of zone "B" to about 26%, the frequency of acrobatic behavior increased to once again be significantly higher than during the complete closure. The frequency of slaps and splashes on the other hand did not change significantly (P = 0.33). It should also be noted that the total proportion of all acrobatic and fast swim behavior was only 27% during the complete closure period compared to 53% before and 88% after.

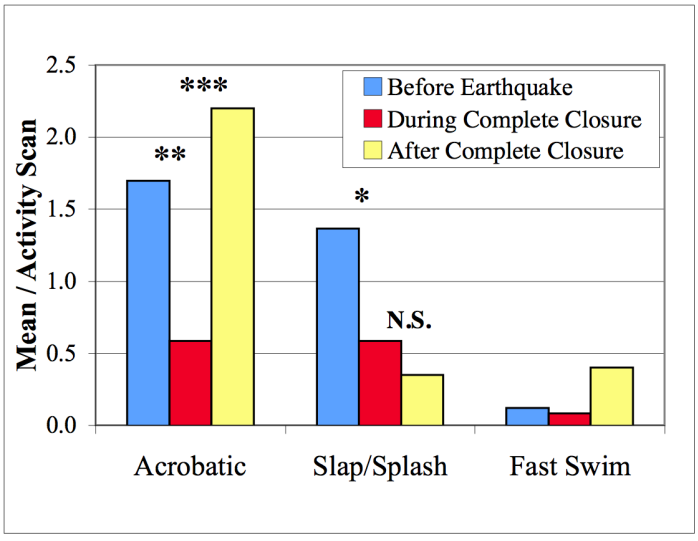

Figure 17. Mean number of aerial behavior during the 0900-1100 hours in Kealakekua Bay before, during and after the complete closure period. Significant differences between bars for the same behavior type are indicated using standard statistical notation. See methods section for further information.

Aerial Behavior by Calves

In addition to the aerial behavior attributed to adults and sub-adults, i.e. non-calf dolphins, behaviors attributed to calves were noted in a separate column for each activity scan. These behaviors only represented 11% of all recorded behavior. However, their distribution over the

study provided additional information on the effects of human presence on the behavior of the dolphins.

Most (33 of 64) of the calf aerial behavior recorded in Kealakekua Bay between Mar 2006 and May 2007 were recorded during the complete closure period, including 50% of the spins and 100% of the spin-flips and fluke slaps. Thus 51.6% of the calf aerials were recorded in the twelve activity-scans taken during the complete closure period, representing only 9.9% of all activity scans. This represents an average 2.8 calf aerials/scan compared to 0.3 calf aerials/scan for the rest of the study. Therefore, the number of recorded calf aerial behavior was more than nine times higher than expected during the complete closure time, compared to the rest of the monitoring period ($P= 7 \times 10^{-29}$).

Fluke Slaps

During the 10:45 activity scan on October 21, 2006, two series of fluke slaps were recorded, 15 assigned to an adult and 21 assigned to a calf. These are the only long series of fluke slaps recorded for Kealakekua Bay during the entire study. No other fluke slaps were recorded during the complete closure period and all other fluke slaps were recorded as one to three per activity scan, except for one scan where 5 slaps were recorded.

Discussion

Overall, spinner dolphin schools spent the majority of their time in each bay within the zone ("B") designed to encompass the majority of the core resting area, indicating that these zones represented a good approximation of where the dolphins choose to spend their time in each bay. For Kealakekua Bay it also compares well with early descriptions of how the spinners used the bay between 1968 and 1981 (Norris and Dohl 1980, Norris et al 1994). Timmel et al (2008) repeatedly pinpointed the location of spinner dolphin schools in the bay using a theodolite from a vantage point 69m above sea level, producing a similar use pattern of the bay, although with a higher use of zone "A", at the far end of the bay from the observation station used in this study.

People mostly used the spinner dolphin core resting area in Kealakekua Bay and Honaunau Bay when the dolphins were present. Similarly the zones encompassing the spinner dolphin resting area in front of Honokohau Harbor had significantly more vessel use when dolphins were present while the use of adjacent zones was reduced. The human use patterns in all three bays therefore shifted focus towards the dolphins when they were present, although this shift was much less pronounced in Honokohau Bay. This is consistent with findings by Holland and Meyer (2002) showing that in 1997 the human use of Kealakekua Bay shifted from the two coastlines, the northwest by Captain Cook Monument and the southeast by *Napo`opo`o* beach, towards the middle of the bay when the dolphins were present.

The prevalent human user groups varied with location. In Honaunau Bay, it was almost completely limited to snorkelers, while the main user groups in Kealakekua Bay included both snorkelers and kayakers, with both providing a significant component in terms of human pressure on the dolphins. A large component of the visitors to Kealakekua Bay used kayaks to paddle over from *Napo`opo`o* on the south shore of the bay to *Ka`awaloa* and the Captain Cook Monument on the north shore. When dolphins were not present in the bay kayakers tended to stay offshore of zone "B", paddling the shortest distance, about 1.7 km, from the launch area at *Napo`opo`o* wharf to the monument. Kayakers that were in zone "B" tended to paddle across the bay just inside the offshore border of the zone. This is very similar to what was described by Timmel et al (2008) for the years 2000 to 2002. When the dolphins were present in the bay they were often between 0.5 km from the beach or more, making it very challenging for many visitors to get to the dolphins by swimming. The kayaks therefore enabled people to get close to the dolphins and keep up with them as they moved back and forth across the bay. Once near the dolphins, some would then go in the water and swim with the dolphins using snorkel and fins.

Many of the people that swim with the dolphins in Kealakekua Bay belong to a group of residents dedicated to swimming with the dolphins on a regular basis, daily if possible. They were therefore used to swimming from shore and out to the dolphins. Many of the group members moved to Hawaii in the last 15 years, specifically to spend time with the dolphins. During the time of both studies members of this group spent every morning patrolling the three bays on the south Kona Coast (Kealakekua, Honaunau, Kauhako) looking for the arrival of spinner dolphin schools. Once the dolphins were sighted, they would activate a phone tree that quickly brought in a large numbers of group members to swim with the dolphins wherever they were found. In addition, several members of this group generally spent several hours each morning at the end of Napo`opo`o road, by Kealakekua Bay, waiting for the dolphins to arrive.

These people may well be responsible for the increase in the number of people swimming in Kealakekua Bay in the mornings (0800 and 0900 hours) when the dolphins were not present, as they tended to go for a swim before they left the bay. This same bump in swimming activity was not evident in Honaunau Bay, where this group did not spend much time, probably due to the low likelihood of the dolphins spending time there. The observers at Honaunau, however, often made notes of 'drive-byes', when some members of this swim-with group drove by and spent a few minutes scanning the bay for dolphins from the car.

The data for Kealakekua and Honaunau Bays further indicate that the human use of the spinner dolphin resting area was not only affected by the presence of the dolphins, but largely depended on their presence. As long as dolphins were not sighted in these resting bays, the human use of this area was very limited with only an occasional swimmer or vessel seen in that part of each bay. The appearance of dolphins in each bay correlated with a large influx of people into the core resting area causing the number of swimmers and kayakers in Kealakekua Bay to increase an average 7 and 11 times respectively during the 0800 hour, with corresponding numbers for the spinner resting area in Honaunau Bay, although the sample sizes in the presence of dolphins were relatively small in this bay.

Honokohau Bay is another historical spinner dolphin resting area (Norris and Dohl 1980, Östman 1994). However, here the situation was very different from both Kealakekua and Honaunau Bays, with a much smaller overall human pressure on the dolphins, which was completely vessel based. The majority of vessels transited through the area in the boat channel with more or less constant speed and direction with the dolphins mostly milling around in the area.

Effects of Human Activities on the Dolphins

The question that needs to be answered is: Are the dolphins affected by this human activity of swimming with them? The data collected on the dolphins' aerial behavior during this study clearly suggest that the dolphins are affected negatively by the human activities in these bays. Since the dolphins are in these bays primarily to rest and socialize (Norris et al 1994), any disruption of their behavior should be considered a disturbance. To ascertain how deep in rest a school of spinner dolphins is it is useful to consider how a school in very deep rest behaves. A school typically spends 3-4 minutes underwater, swimming slowly in a tight-knit group. The entire school then ascends to the surface as a unit spending about 20-30 seconds, giving every individual a chance to take several breaths, before the entire school once again descends as a unit. No aerial behavior and very few sounds are emitted and the entire school moves in a highly coordinated fashion back and forth in the resting area (Würsig et al 1994, Östman 1994, Driscoll 1995). The behavior is very reminiscent of a large fish school moving as a single organism. The dolphins also spend time in the resting bays socializing with each other, adults strengthening and reaffirming bonds and calves learning adult behavior patterns such as aerial behavior. However, except for calves attempting aerial behavior, relatively few aerial behaviors are performed in these bays, as the dolphins are descending into rest during the morning hours and rest there through the middle of the day (Norris and Dohl 1980)

The behavior of the dolphins when people were within 100m clearly suggests that they were highly affected by the human proximity and activities, which were mostly directed at the dolphins. The intention of the people in these areas is also indicated by their distribution, either

closer than 100m or farther away than 200m, with very few incidences of human presence recorded in between. It is telling that the mean number of aerial behaviors per activity scan was directly correlated with the distance between humans and dolphins.

By breaking down the aerial behavior into categories it became clear that the categories most affected by human presence were the high energy behaviors, including the acrobatic behavior and behavior associated with fast swimming, such as porpoising and leaps, shown to increase swimming efficiency at high swimming speeds (Au and Weihs 1980). The dolphins were thus caused to behave in a manner completely counter to rest by the human proximity and behavior in their resting areas.

It is also unfortunate that this effect, although most prevalent in Kealakekua Bay in the early morning hours, was seen through out every day that the dolphins were present in both Kealakekua Bay and Honaunau Bay. In fact, in Honaunau Bay, all aerial behavior recorded after 0800 hours were recorded while people were within 100m of the dolphins. This unfortunately extends to several other traditional spinner dolphin resting bays on the Kona Coast, including Kauhako Bay, by Hookena, and Makako Bay, just north of Keahole Point. Although, the amount of data that was provided from these two bays were minimal for different reasons, anecdotal information from the people monitoring these bays indicate that the dolphins will not have very much time on their own in either of these bays, as soon as they enter. Courbis and Timmel (2008) found that the number of swimmers in Kahako Bay was significantly higher when spinner dolphins were present, and that "almost all swimming was directed at approaching and attempting to interact with dolphins".

One morning spinner dolphins were directly observed attempting to rest in Makako Bay, on July 12, 2005. The dolphins arrived in the bay a little after 1000 hours. Several vessels that had followed them down the coast arrived with them. Five charter vessels and about 35 snorkelers were around the dolphins with the objective of allowing the snorkelers to see the dolphins underwater. Several boat captains repeatedly pointed out to the people in the water where the dolphins were and directed them to the animals. Some vessels occasionally picked up their customers, took them closer to the dolphins and dropped them back in the water. The dolphins were obviously trying to get to their core resting area but were repeatedly blocked by vessels and people. The result was that the dolphin school was divided into three subgroups that were scattered around the bay. They spent the next couple of hours in the bay constantly pursued by swimmers and vessels. They were even herded by one of the vessels that drove the dolphins right towards the snorkelers it had just deployed a few minutes earlier. When the dolphins finally left the bay, after over two hours of attempting to rest, the school had not been able to descend into a resting pattern at all, not even for a minute or two.

Further evidence of how the dolphins were affected by human activities was provided during the 3-week period after the October 15, 2006 earthquake, when virtually all human activity in Kealakekua Bay was prevented during the complete closure period. The data collected on the three monitoring days during this period showed schools that behaved very differently from before the earthquake. On October 19, four days after the earthquake and during the complete closure, four consecutive activity scans did not produce a single non-calf aerial behavior. On October 21, the activity scan data indicated a school that was primarily in rest mode but where

some levels of social interactions were taking place. The majority of aerial behavior recorded were inverted fluke slaps (termed motorboating by Norris and Dohl 1980), a sexually solicitous behavior usually produced in series of up to 20 or more as opposed to upright fluke slaps, indicating frustration or annoyance, and generally produced only once or twice (Östman 1991, Östman 1994). The comments provided by the observers during the complete closure period also indicated that the schools were primarily resting, swimming back and forth slowly, peacefully, staying down for long periods of time, all indicators of a school in deep rest, or at other times socializing. These were behaviors that were rarely if ever noted during the rest of the study. They may be hinted at by the relatively high number of undefined slaps and splashes recorded when people were more than 200m from the dolphins. The sharp increase in acrobatic behavior among non-calves after the complete closure period also shows a clear correlation between human presence in the bay and the occurrence of these behaviors.

The Long-Term Effects on Dolphins?

The long-term effects of these human activities are less clear, but evidence is accumulating to suggest that there may be serious long-term impacts. Disturbing the dolphins during their resting period can have many negative consequences in addition to the impacts documented here. Preventing them from resting during the day will likely have impacts on their ability to feed at night, as well as avoid predators and protect their young. Courbis and Timmel (2008) suggest that spinner dolphins have changed the way they enter the resting bays on the Island of Hawaii, no longer performing aerial behavior as they enter, but rather moving in quietly in such a way that their entry is often missed. The first sighting of the dolphins is often made only once they are well inside the resting area. Indeed, this is generally how the dolphins were first sighted in Kealakekua Bay during this study.

Hawaiian spinner dolphins have also started to change where and how they rest. They were sighted less frequently in Makako Bay in 2003 than between 1989 and 1993 (Östman-Lind et. al 2004, Östman 1994). In 2003 they had started to use another nearby area to rest along a part of the coastline that was not used by any of the 135 spinner schools followed between 1989 and 1993. Several of the volunteers participating in this project who also kayak regularly described similar observations along different parts of the Kona Coast – finding schools of spinner dolphins milling along parts of the coastline where they never used to be found.

Comparing the occupancy rates, i.e. the proportion of days spinner dolphins were using each resting area, provides another look at the possible long-term effects on the dolphins. Interestingly the timing of the changes is mirroring the spread of the swim-with-wild-dolphin activities along the Kona Coast. The occupancy rate in Kealakekua Bay was much lower (58%) during a 1993-94 study (Forest 2001) compared to previous findings (74% of 113 days - Norris and Dohl 1980, 79% of 364 days- Norris et al 1994). The drop in occupancy rate corresponded with the time in the late 1980's to early 1990's when swim-with-wild-dolphin activities expanded rapidly in Kealakekua Bay. The earlier occupancy rate information was based on a years worth of data (May 1979 - May 1980) when the bay was covered from sunrise to 1800 hours for 364 days, only missing Christmas day (Norris et al 1994). The coverage for the 1993-94 data was similarly extensive (Forest 2001). Thus the drop in occupancy rate from 79% to 58% is highly significant both statistically ($P < 0.001$) and biologically.

Swim-with-wild-dolphin activities began to spread from Kealakekua to the rest of the Kona Coast in the early 1990s, including Honaunau and Kauhako to the south and Honokohau and Makako to the north. By 1995 it was well established north of Honokohau Harbor. This is when several resting areas off Kailua-Kona and further north were affected, including Honokohau and Makako Bays, as well as other areas farther north. Indeed the occupancy rates provided in this and other studies over the years suggest that the overall trend in spinner dolphin occupancy rates of traditional resting bays on the Kona Coast is dropping (Figure 18). Unfortunately, there are no available data between 1994 and 2002.

The only exception to this trend seems to be the resting area in front of Honokohau Harbor. The monitoring of this area suggest that it may be due to the vessel traffic in and out of the harbor, going right through the core resting area and deterring swim-with activities and lingering kayaks. Even the number of vessels directed towards the dolphins was much smaller than in any of the other resting areas.

It thus appears that the predictable vessel traffic through this resting area has created something of a haven, by discouraging dolphin-oriented activities. Most of the traffic in and out of the harbor was by vessels piloted straight through the resting area in a narrow corridor. This is reminiscent of what can be observed in many national parks, where deer and other animals graze on the side of the road apparently undisturbed by cars going by just a few meters away (e.g. Burson et al 2000). As most vessels transiting the dolphin resting area behaved in a predictable way, the dolphins were likely habituated to this traffic. However, this was not the case for all vessels, which will be looked at in more detail in a separate report. As a result the construction of Honokohau Harbor in 1968, which most likely significantly degraded the ability of the dolphins to rest there, ironically appears to have created some of the most preferred conditions, relatively speaking, some 40 years later. Unfortunately, this is mainly a commentary on the level of disturbance that the dolphins are enduring in their resting areas now.

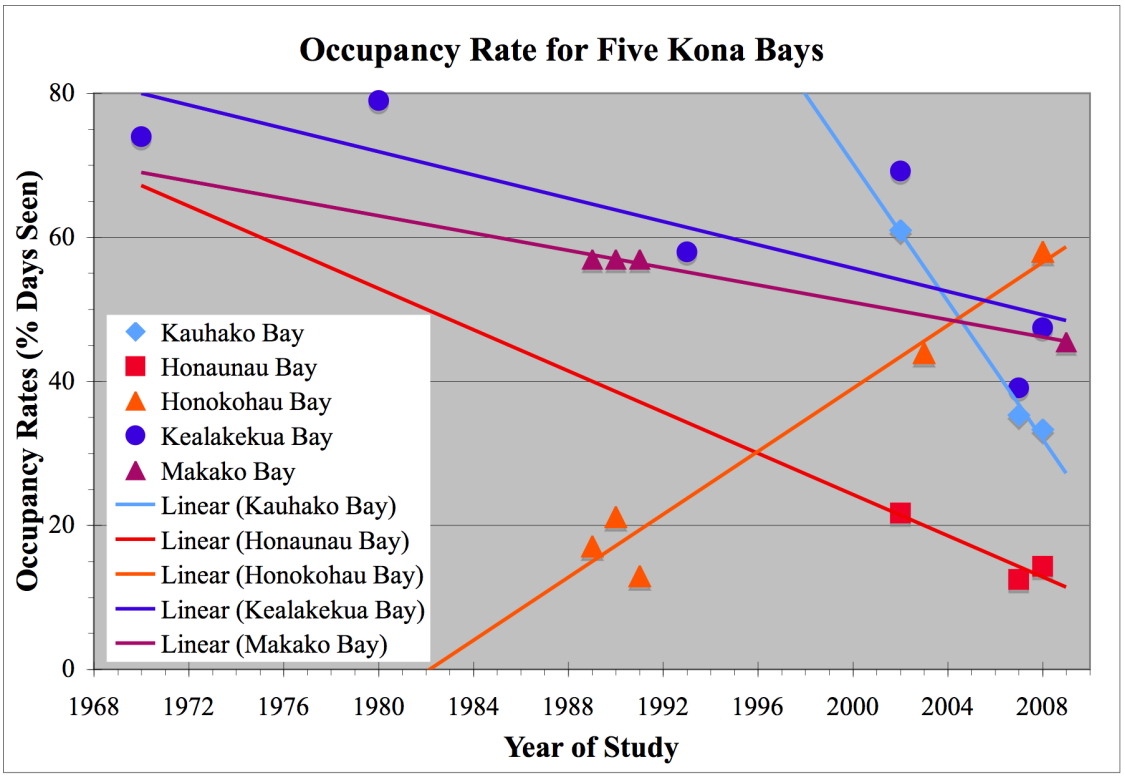

Figure 18. Occupancy rates as calculated for studies in five of the main resting areas on the Kona Coast. 1968-72 data (Norris and Dohl 1980), 1979-80 data (Norris et al 1994), 1989-92 data (Östman 1994), 1993-94 data (Forest 2001), 2002 data (Courbis 2004), 2003 data (Östman 2004), 2006-07 and 2007-08 data (this study – means presented in Figure 6).

It should be noted that the spinner dolphin resting area in Honaunau Bay is very sensitive, as this is a very small bay. This bay had the lowest occupancy rate of the five study areas covered in this study. There is no information available on the occupancy rate of this bay before swim-with-wild-dolphin activities began there. The only other data point, 18.2% during the Spring of 2002 is provided by Courbis (2004) However, it is likely that it was much higher than the 14% noted in this study, and it is possible that it could drop to 0% if nothing is changed.

The latter part of Figure 18, from about 2000 and on, coincides with an increase in advertisement over the world wide web for swim-with-wild-dolphin experiences in Hawaii and elsewhere. An internet search using the search engine Google, actually a series of searches, increasingly narrowing in on the Kona Coast by progressively adding words to the final search "wild dolphin swim Hawaii tours Kona", but without quotation marks, resulted in 332 hits in November 2002. By October 2004 this search rendered 919 hits. The search was repeated on an intermittent basis, mainly conducted the day before a presentation. Figure 19 shows the results for the most restrictive search (wild dolphin swim Hawaii tours Kona). The number of hits increased drastically in the June 2005 search, when the results for the first time not only included the sites of companies and organizations promoting swim-with experiences, as well as some information cautioning against the practice (e.g. Driscoll-Lind and Ostman-Lind 1999), but also included websites that served to direct people to various companies offering swim-with-wild-dolphin

experiences at certain destinations, including Kona. This coincided with the number of new hits since the last search increasing from an average 0.8/day to 45.6/day. The number of hits has continued to increase through November 2009, although the average number of new hits since the last search appears to have gone down. This may indicate that swim-with-wild-dolphin experiences are currently increasing in other parts of the world – the previous search was done in November 2006, making it less likely that the drop is an affect of the economic down turn starting in late 2008.

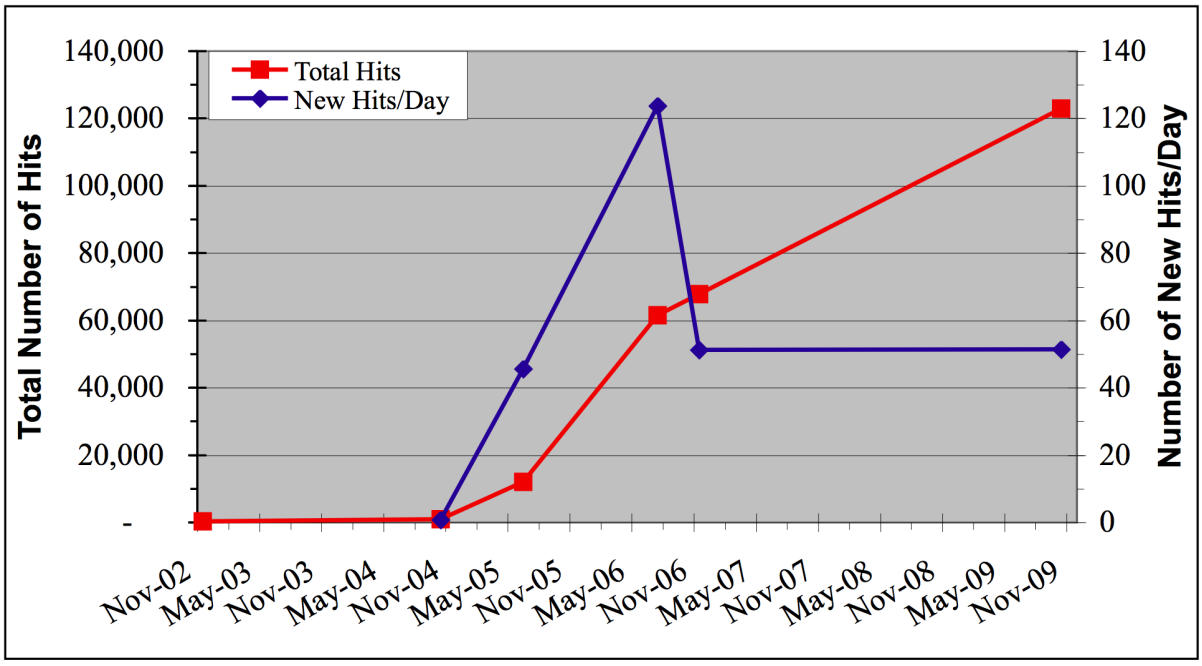

Figure 19. Results of intermittent search on internet search engine Google, using the following search words: wild dolphin swim Hawaii tours Kona. The first two searches, in November 2002 and October 2004 resulted in 332 and 919 hits respectively. The average number of new hits/day for each search is also displayed.

Creating Human Exclusion Zones

The information on the human use of these three bays corroborates a proposal to close off the core spinner dolphin resting areas in each of these bays, with enough of a buffer zone to keep the vessels at least 100 meters away from the core resting area. The proposal originated in 2004 when key stakeholder groups, working in three different Hawaii State-sponsored working groups, discussed how to make the use of Kealakekua Bay more environmentally and culturally sensitive. Each group met several times a month over several months. The group where the proposed human exclusion, or Kapu zone came up dealt with all issues around the use of the waters in Kealakekua Bay, including diving and snorkeling tours, kayaking, and how to deal with all the resources in and around the bay, including the spinner dolphin resting area. The only stakeholder group that chose not to participate was the local swim-with-wild-dolphin community.

Closing off the dolphin core resting area in Kealakekua Bay as a human exclusion zone would have minimal impact on most non-dolphin-directed uses. When the dolphins were not present in the bay, people were only recorded in zone "B" about once every three scans. It could impact a few people that use the bay to swim for exercise, although there are other parts of the bay that can be used for this purpose. The same solution could also be applied to most other spinner dolphin resting areas around Hawaii Island, including Makako Bay north of Keahole Point and Kauhako Bay off Hookena, as well as resting bays on other islands throughout the State of Hawaii.

Honaunau Bay, with its very small size, represented a big challenge, in terms of being able to set aside a human exclusion zone encompassing the spinner dolphin core resting area and still provide somewhere for people to swim and snorkel, and use the launch ramp for kayaks and small motor boats. However, the data on the human use of this bay shows that people did not use the spinner dolphin resting area unless the dolphins were there. This is understandable, as the dolphin resting area is over 20m deep even in the shallowest part and has a sandy bottom with very little for a snorkeler too look at. On the other hand, the southern and eastern parts of the bay has and extensive coral reef. Furthermore, people that grew up in Honaunau some 30-40 years ago saw the northern part of the bay as an area that was left for the dolphins, while people used the rest of the bay (L. Loa Personal Communication). So human use of the northern part of the bay appear to have been initiated recently by people specifically meaning to approach the dolphins.

Viewing Dolphins from Shore – an alternative

The fact that spinner dolphins can be seen from shore makes them likely targets, since people can see them while eating breakfast, driving along the coastline or sitting on the beach. It is however possible to turn this circumstance into a positive experience for both dolphins and people. In Honaunau Bay, for example, when the dolphins were present, they spent time in zone "A" during almost half of all activity scans, sometimes getting as close as 50m from shore, if left undisturbed. This would make it excellent location for a land-based interpretation center, where people could be on land and enjoy the dolphins without disturbing them. Binoculars and real-time underwater sound feeds could be provided, as well as interesting and accurate information. Interestingly, the Pu`u Honua National Historic Park is located on the south shore of this bay. This idea could also be applied to other areas on the Island of Hawaii, such as Hookena (Kauhako Bay) and Makako Bay, and elsewhere in Hawaii where spinner dolphins come close to land areas where interpretation centers could be located.

100 yard (90m) Distance Limit.

The results of this study can also be applied to spinner dolphins outside of the resting areas. The distribution of people relative to the dolphins in both Kealakekua and Honaunau Bays shows that most people closer than 200m to the dolphins actually were within 50m of the animals. In other words, people that were focusing on the dolphins were closer than 50m to the dolphins, the length of an Olympic size swimming pool. The majority of aerial behavior were also recorded when at least some people were this close to the dolphins. However, people farther away than 50m were still associated with an increase in aerial behavior, with 98% of all aerial behavior in

Kealakekua and Honaunau, 100% in Honokohau, recorded when people were within 100m of the dolphins.

It is important to note that the absence of aerial behavior does not necessarily mean that the dolphins were unaffected by human activities in the area. The aerial behaviors used in this study are very useful for land-based observations and for use by relatively untrained eyes, since they are very obvious and can be seen from a long distance. However, there are more subtle surface behaviors that can be used as a gauge on whether the dolphins are being disturbed. One of these is the "High Surfacing", where dolphins surface higher than normal in the water. Although this behavior is a more sensitive indicator, it takes practice to identify and requires closer proximity to the animals than most observers had in this study. However, the dolphins spend 95% of their time below the surface where observations are much more difficult, especially if you do not want to introduce an observer effect. It is therefore prudent to apply the precautionary principle.

The NOAA Fisheries, Office of Protected Species viewing guidelines for non-humpback whale marine mammals in Hawaii*, including spinner dolphins, suggest a 50-yard (46m) distance limit. It is not clear what information this guideline is based on, but it does not appear to be based on scientific data. The data in this study, using aerial behavior as an indicator of disturbance, suggest that these dolphins can be disturbed from farther away. In fact, using the mean number of aerial behaviors per scan recorded when people were within 200m, 29% of aerial behaviors in Honaunau and 36% in Kealakekua Bay were recorded when the closest people, swimmers and/or in vessels, were estimated to be more than 50m away. The data reported here therefore supports extending the distance limit well beyond 50m. It should be pointed out that, as all distances in this study were estimated by eye, the exact distance limits cannot be determined. However, using the precautionary principle, it can be argued that the data presented for both Kealakekua and Honaunau support a distance limit of at least 200m as some aerial behaviors were recorded when the closest people were estimated to be between 100m and 200m from the dolphins. A more pragmatic approach would be to adopt the same distance limit (100 yards or 91m) as is currently applied for marine mammal species covered by the endangered species act (ESA), or promoted by the Alaska regional office of NOAA Fisheries**.

Applying a 100yd distance limit to all dolphin-viewing vessels operating outside the resting areas would reduce the disturbance of these animals as they move along the coastline in the mornings on their way to a resting area. Spinner dolphin schools are very sensitive to how vessels are handled around them as they move along the coast. In certain areas, the entire school can even be stopped in its track by just one vessel located in their path. When following 135 focal schools between 1989 and 1992, I repeatedly saw single vessels, either on a mooring or just drifting close to shore, causing a school of 80-100 animals or more to stop in their tracks and mill 100-200 meters from the vessel for long periods of time until the vessel left, at which time the school continued on their way to a resting area. The people on these vessels will rarely be aware of their impact on the animals, even if they know they are there, as they did not see what

* http://www.nmfs.noaa.gov/pr/education/hawaii/

** http://www.fakr.noaa.gov/protectedresources/mmv/guide.htm

the dolphins did before they arrived, nor after they left. The same is true for people on vessels that quickly approach, or even run straight through a dolphin school.

A 100yd distance-limit would also be embraced by most whale and dolphin watching tour companies. In 2003, as part of a 6-week course on marine protected species, all but one of 16 boat captains and field staff from nine tour companies operating on the Kona Coast, participated in a one-day on-the-water-practicum. All participants were found to overestimate distances on the water, when compared to measurements with a laser-range finder, including captains with many years of on the water experience. The vessel was then taken to 100m offshore of a school of spinner dolphins, slowly moving down the coast in the mid-morning. As the vessel was kept 100m offshore of the main part of the school, paralleling the last subgroup, a few sub-adult and juvenile animals approached the vessel and came to the bow, while the rest of the school, including all adults, remained relatively undisturbed and continued along the coastline. At the time, all course participants agreed that they had never seen a dolphin school behave that way before and they were amazed at the great views of the dolphins and some of the 'new' behaviors they had seen.

Conclusion

The information collected by the community volunteers shows that: a) the spinner dolphin resting areas in both Kealakekua and Honaunau Bays are only used by people when dolphins are present, and the people are there to target the dolphins; b) rather than resting in these areas, the dolphins became much more active when people were within 100m of them, thus loosing valuable resting time; In addition, long-term data on occupancy rates suggest that Honokohau Bay has become the most popular resting area on the Kona Coast, probably because the boat traffic in and out of the harbor is discouraging dolphin-oriented activities, especially by swimmers and people in kayaks. It is not known how lack of rest during the day impacts the dolphins' ability to feed, avoid predators and protect their young at night, but it is likely to impact all these activities negatively. To allow the dolphins to get undisturbed rest, human exclusion zones around the core resting areas have been suggested, and have been embraced by all but one of the resident stakeholder groups using Kealakekua Bay. The data from this monitoring effort also suggest that the current viewing distance promoted by NOAA Fisheries in Hawaii be extended beyond 50m.

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The first phase of this monitoring effort was organized in Kealakekua Bay as part of the State of Hawaii sponsored Makai Watch Program while I was employed as the Big Island Marine Coordinator for The Nature Conservancy. Alycia Bouyounan, Chris Wall, Nicole Killebrew and Nick Magel, from the Audubon Expeditions Institute, part of Leslie University, created the initial momentum for this project by dedicating two full days each to monitoring. Stephen Cornacchia headed up the effort in Kealakekua Bay during 2006, and Ann and Wes Jenkins continued the monitoring effort into May of 2007. Between November 2007 and October 2008, Nora Beck Judd, Steven Cornnacchia and Catherine Wynne collected the majority of the data. They were assisted by Patty Eames, Glen Metheny, Candace Miyatani, Ann Provacs and Marc Vandenplas. Emily Burt anchored the effort in Honaunau Bay between September 2006 and May 2007 and was helped by Jackie Au. Between November 2007 and the end of October 2008 Stephanie Amick, Julie and Regan Steelman, and Lynn Webber covered Honaunau Bay. Nora Beck Judd and Lynn Webber also helped by entering not only their own data onto spreadsheets, but also that of other volunteers. Linda Preskitt helped coordinating this effort from the fall of 2007

Dolphin Quest staff adopted the Honokohau Bay monitoring site and did most of the monitoring there, although they were assisted by other volunteers. Stacia Goecke functioned as a site coordinator, not only collecting a large amount of data, but also entering all the data into excel spreadsheets. The primary monitoring effort was done by Erin Urekew, Stacia Goecke, Sonja Jaramillo, Ross Kellog, Lauren McWilliams, Chatney Okamura, Julie and Regan Steelman and Lauren Thimmons. They were assisted by, Jennifer Clark, Ashley Hayden, Kristen Girard, Lynn Iokepa, Stania Olivera, Jason Owens, and Chase. Kauhako Bay was covered by Marina Kuran and Gary Oamilda. A heartfelt *Mahalo Nui Loa* goes out to all the volunteers that helped collect data for this study. They not only spent numerous hours monitoring the respective bays, but some drove as much as 75 km to get to their monitoring site. The existence of the current database enabling this analysis is due completely to the persistence of this group of dedicated volunteers that spent numerous months monitoring the bays on a weekly basis.

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