

**THE OCCURRENCE AND BEHAVIOR OF WHALES AND DOLPHINS
NEAR KALAELOA BARBERS POINT HARBOR: A STUDY TO ASSESS
THE POTENTIAL INTERACTIONS WITH PROPOSED HARBOR
MODIFICATION ACTIVITIES**

Prepared for:

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1.0 – EXECUTIVE SUMMARY

- Kalaeloa Barbers Point Harbor (KBPH) was constructed as a joint Federal and State project between 1982 and 1985. Since the harbor's opening, present and potential users have indicated the need for harbor improvements to accommodate ships larger than originally anticipated. The improvement project that has been proposed involves deepening the harbor's basin and constructing a jetty on the north side of the harbor's mouth.
- Resident and transient pods of dolphins and whales known to occupy the leeward coast of Oahu could be affected by the proposed plans. Potential threats include noise pollution, degradation or loss of habitat, and disturbance of regular behavioral cycles. A study to investigate the abundance, distribution and behavior of cetaceans in waters adjacent to the harbor is required to comply with Federal requirements relating to the Marine Mammal Protection Act and the Endangered Species Act.
- The objectives of this study are to:
 - Identify the species of cetaceans most likely to be present in the affected area.
 - Map their patterns of distribution.
 - Estimate their frequency of occurrence near the harbor on a day-to-day basis.
 - Establish their general patterns of behavior while in the area.
 - Evaluate the potential impact of the proposed activities on the species identified.
- Data were collected in two phases over a three-month period between February 13th and May 14th, 2001. Phase I focused on defining the daytime distribution and behavior of dolphins and humpback whales in the area. Phase II examined nighttime patterns of occurrence of dolphins and their prey, the mesopelagic boundary community (MBC).
- A line-transect method using a vessel was employed to survey the study site during daylight hours. Active sonar and passive acoustic sampling were used to detect both local densities of the MBC and the presence of foraging dolphins.
- A total of 18 sightings of humpback whale pods were made during 20 surveys. Of these, 6 (33%) occurred north of the harbor entrance and 12 (67%) were seen to the south towards Barbers Point. The average size of a pod was 1.33 whales (N = 18; SD = 0.49). Significantly more whales were sighted in the afternoon than in the morning. Daily abundance estimates for whales in the study area are 6.7 whales between mid February and mid March, 14.4 whales between mid March and early April, and 3 whales per day during the second half of April and into May.
- Spinner dolphins were observed in the study area on 45% of surveys. The daytime occurrence of spinner dolphins was limited almost exclusively to the northern end of the study site, near Kahe Point. The average number of animals observed per sighting was 43 (N = 9; SD = 29). At Kahe Point, spinner dolphins were generally either resting or descending into rest. Two sightings were made south of Kahe Point in the late afternoon when animals were traveling towards Barbers Point. The only other species of dolphins that were observed were spotted dolphins. One sighting was made at the southern end of the study area, just off Barbers Point.
- Nighttime active and passive acoustic sampling revealed that dolphins occur more often and in larger groups north of the harbor than in front of it or to the south. Dolphins tend to feed offshore

in the evening hours and move inshore as the night progresses. Dolphins were detected most often near the harbor shortly before and after midnight, when their food resource was most abundant there.

- There is evidence to suggest that shallow banks like the ones off Barbers Point and Kaena Point have an aggregating effect on whales. It could be that whales travelling along the comparatively narrow strip of shallow water near the harbor entrance are either in transit to or from these two banks.
- The construction activities proposed could pose a potential concern for whales because of two factors: sediments suspended in the water column for extended periods and noise levels produced by dredging and other industrial equipment. Computer models of turbidity contours resulting from dredging operations suggest that sedimentation will be localized enough that whales will only need to make minor adjustments in their travel path to avoid them. Acoustic interactions with dredging noises are more difficult to predict, but data in the literature from other species and sources of noise suggest that whales could react to received noise levels above 115 dB re 1 μ Pa.
- Maximum rms sound pressure levels (SPLs) recorded in dredging operations on soft sediment in Alaska at a range of 150 m were 124 dB re 1 μ Pa at 163 Hz. However, these can be expected to be louder at KBPH where the substrate is mostly made up of hard coral rock. The levels predicted are not high enough to pose any threats of physiological damage to the whale's auditory system, but at close range (< 1 km) could be loud enough to mask the songs of conspecifics in the distance.
- The noisiest part of the jetty construction process will be when rocks for the jetty's core are dumped in the water from trucks. No data are available on what the levels might be, but if they equal or exceed those predicted for dredging then a behavioral or avoidance response by whales is possible.
- The increased turbidity levels projected for waters near the harbor (within 0.5-1 km) will most likely not be of much consequence to spinner dolphins during the day. Kahe Point, where the dolphins are expected to spend most of their time, is sufficiently distant from the harbor that an increase in turbidity there is very unlikely. Dolphins have a sophisticated sonar system, so impaired navigation or predator detection will probably not be an issue for them at night when they occur closer to the harbor.
- Dolphin hearing is not very sensitive at the frequencies expected from dredging. Although dolphins will hear the sounds even several kilometers away, these should not present a significant nuisance to them except at close range (< 1 km). Most likely, the only times spinner dolphins will be exposed to elevated noise levels will be while traveling by the harbor in the morning and afternoon, and then again around midnight when foraging nearby. Avoidance of the area as a result of annoyance by the noise cannot be ruled out. If such reactions do occur, there could be biological consequences. In the worst case scenario, these might include a reduced net access to food, greater competition for the remaining available food resource, and possibly elevated stress levels that could affect reproductive cycles. Other species of dolphins that might feed on the MBC near the harbor at night could be similarly affected.
- Based on Federal definitions of the word "harassment", the daily estimated number of marine mammal that might be impacted by the proposed work are as follows. Humpback whales: 5 to 8

between mid-February to mid-March, 12 to 17 between mid-March and mid-April, and 1 to 5 between mid-April to early May. Spinner dolphins: 43 (± 29). Spotted dolphins: 0 to 20. Bottlenose dolphins: 0 to 10.

- To mitigate the impact of the proposed activities on marine mammals, and thus reduce or eliminate the take of certain species, three possible preventative steps can be taken.

Avoid any dredging or construction activities during the peak periods of the whale season between February and April. Or...

Restrict dredging to the confines of the harbor's basin during whale season to lower received sound levels near the outer entrance of the channel where whales occur. Sound levels could be monitored and limited to a pre-determined threshold value. A reasonable threshold would be the greater of either 115 dB re 1 μ Pa or 10 dB above normal ambient levels. And...

Cease dredging activities at night between 10:00 PM and 2:00 AM. Not dredging during the hours coinciding with the peak occurrence of the MBC near the harbor would ensure unrestricted access to the dolphin's food resource.

- Adopting a combination of strategies 1 & 3 or 2 & 3 would eliminate the major concerns relating to marine mammals about the proposed project. Minor concerns, like altering dolphin travel routes near the harbor can probably not be addressed without a monitoring effort to detect dolphins at least 1-2 km away from the dredging/construction site and a plan to stop operations until they've moved away. If such a plan were not feasible, these concerns would then need to be accepted as part of the overall environmental cost vs. economic benefit equation.

2.0 – INTRODUCTION

Kalaeloa Barbers Point Harbor (KBPH), located on the southwest corner of Oahu, is a commercial harbor providing port facilities for deep-draft vessels. It was constructed as a joint Federal and State project between 1982 and 1985. Since the harbor's opening, present and potential users have indicated the need for harbor improvements to accommodate ships larger than originally anticipated. The improvement project that has been proposed involves deepening the harbor's basin from a current depth of –38 feet below mean lower low water (mllw) to –45 feet below mllw, and the harbor's entrance channel from –42 ft below mllw to –48 ft below mllw. In addition, a 450-foot jetty will be constructed along the north side of the mouth of the harbor to reduce existing cross currents that make navigation challenging during large surf events.

The modifications planned for the harbor raise concerns about the impact dredging and construction activities will have on nearby populations of marine mammals. Hawaii's waters are home to 23 species of marine mammals of which 22 are cetaceans and one is a pinniped (the endangered Hawaiian monk seal, *Monachus schauinslandi*). Of these 22, four (the blue whale, *Balaenoptera musculus*, the fin whale, *Balaenoptera physalus*, the humpback whale, *Megaptera novaeangliae*, and the sperm whale, *Physeter macrocephalus*) are listed as endangered under the Endangered Species Act (ESA) while the rest are protected under the Marine Mammal Protection Act (MMPA). Hawaii's marine mammals are a valuable resource to the State, generating between 19 and 27 million dollars each year in direct, indirect and induced tourist revenue associated with whale and dolphin-watching activities (Barr et al., 2000).

Resident and transient pods of dolphins and whales known to occupy the leeward coast of Oahu could be affected by the proposed plans. Potential threats include noise pollution, degradation or loss of habitat, and disturbance of regular behavioral cycles. Two species of special concern are the spinner dolphin (*Stenella longirostris*) and the humpback whale, both of which are thought to occur regularly near the harbor's entrance. Due to insufficient data available to assess with certainty the occurrence pattern of marine mammals in the area, a study was requested to investigate the abundance, distribution and behavior of all cetaceans in waters adjacent to the harbor. This information is necessary in order to comply with Federal requirements relating to the MMPA and ESA. This report presents the results of a study that was conducted by Oceanwide Science Institute (OSI) to address these requirements. The objectives of this report are to:

- Identify the species of cetaceans most likely to be present in the affected area.
- Map their patterns of distribution.
- Estimate their frequency of occurrence near the harbor on a day-to-day basis.
- Establish their general patterns of behavior while in the area.
- Evaluate the potential impact of the proposed activities on the species identified.

This report will begin by describing the methods used to gather the required data, then present the results that were obtained, and finally discuss the implications of the proposed plans on cetaceans occurring in the area. The report will conclude by providing some recommendations for minimizing adverse impacts.

3.0 – METHODS

Current plans for the harbor's modification call for construction activities to take place 24 hours a day for up to two years at or near the harbor's entrance. As a result, it was necessary to conduct a study that would establish the occurrence of cetaceans in the area both during the day and at night. To this end, data were collected in two phases over a three-month period between February 13th and May 14th, 2001. Phase I focused on defining the daytime distribution and behavior of dolphins and humpback whales (*Megaptera novaeangliae*) in the area. Phase II examined nighttime patterns of occurrence of dolphins suspected to be foraging near the harbor and their prey resource. In addition, data were also collected opportunistically during off survey (or "off-effort") periods. These were times when research was taking place not directly related to the present study, but which coincided with the time period and location of interest. Hawaiian monk seals, although not specifically targeted, were noted if sighted. The study's design and research methodology was coordinated and agreed upon with officials from the National Marine Fisheries Service (NMFS) to meet all requirements for marine mammals protected under the MMPA and section 7 of the ESA.

3.1 – Phase I: Daytime surveys

A line-transect method using a vessel was employed to survey the study site during daylight hours. A saw-tooth transect route was adopted with a shallow inshore leg parallel to the coast and 6 transverse legs that covered waters from 25 to 800 ft deep. Inshore waters were purposely oversampled because of concerns about spinner dolphins resting close to shore. The study site was defined as a 17.5-km² area stretching 3.9 km to the south, 4.1 km to the north and 2.8 km to the west of the harbor's entrance (Fig.1). A total of 20 daytime transects were made. Of these, 10 were conducted in the morning hours between 7:00 AM and 11:00 AM and 10 in the afternoon between 12:00 PM and 5:00 PM. The transect route was randomly navigated either clockwise or counter-clockwise an equal number of times over the course of the study period. Each survey took approximately 2 hours to complete.

The survey vessel used was the *Meleana*, a 32' motor boat powered by a 120-hp diesel engine. It has an observation platform 16 feet above the waterline and operates at a cruising speed of approximately 7 knots. Each survey's crew consisted of 3 individuals: two observers and a boat driver/data recorder. The two observers were stationed on the starboard and port side of the vessel's flying bridge and scanned the waters 90° to either side of the vessel's bow. The boat driver navigated the vessel along the transect from the cockpit below using a course pre-programmed into a Global Positioning System (GPS). The boat driver also collected positional and environmental information every 10 minutes, as well as sighting information when prompted by the observers (see Appendix 1). Communication between the observers on deck and the boat driver/data recorder in the cockpit was achieved via two-way radios. Depth information was obtained from a Furuno FCV-582L depth finder. Surveys were only conducted while under Beaufort sea state 3 or less. Survey legs during which sea state conditions were worse and/or more than half of an observer's field of view was obstructed by glare were not included in the final analysis of the data.

When a sighting was made the vessel was slowed from a survey speed of 7 knots to approximately 3 knots. The observer who made the sighting reported the species, the number of animals sighted, their bearing relative to magnetic north (using a ViewScope's digital compass) and an estimated distance from the vessel. To account for individual biases in the ability to estimate distances, each observer was calibrated by testing him or her with known distances to buoys at various ranges (measured using GPS positioning). By correlating estimated distances with true distances obtained from computer charts, a regression plot with a calibration function was created for each observer.

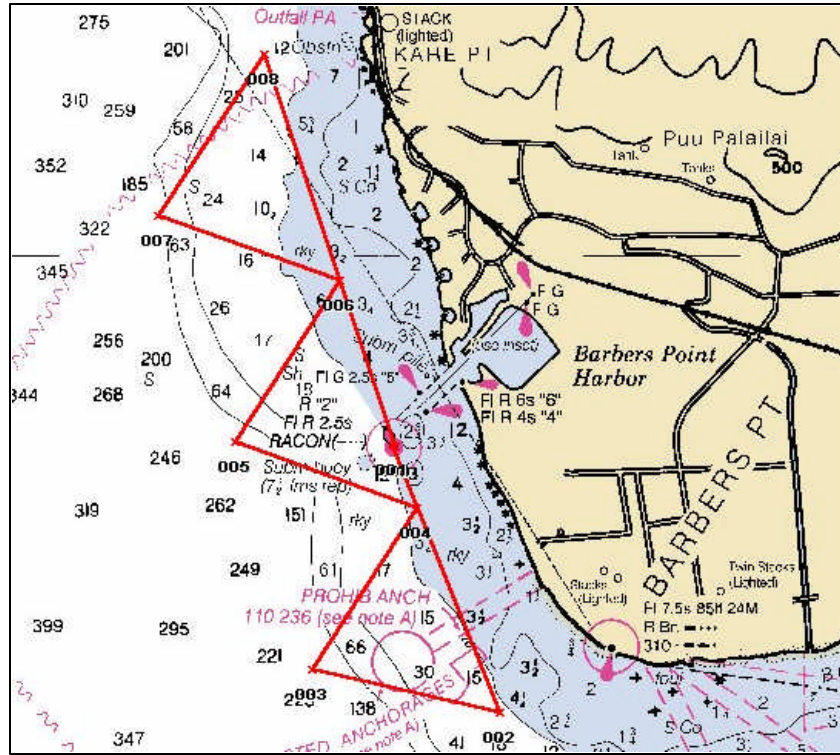


Figure 1 – Transect route followed during daytime surveys. Soundings are in fathoms.

Following a dolphin sighting, the animals were approached and their behavior sampled using a method previously described in Lammers et al. (2000). An index of activity was calculated to establish the behavioral state of the animals. This index ranges from a zero for alert and socially active groups of dolphins to a six for groups of subdued and restful animals. Whales were never purposely approached closer than the 100-yard limit dictated by Federal law. When a whale’s initial sighting was within 100 yards the vessel was stopped until the whale moved away. For whales close enough to observe for several minutes behavior was classified using the criteria listed in Appendix 1.

3.2 – Phase II: Nighttime surveys

Hawaiian spinner dolphins were considered to be of special interest in this study because a resident population occurs year-round in the near-shore waters off the Waianae coast (Lammers, 2000). During the day, spinner dolphins seek sheltered, shallow coastal waters for protection from predators while they socialize and rest (Norris et al., 1994). At night, they forage on small species of fish, squid and shrimp that make up the mesopelagic boundary community (MBC). From dusk until dawn they search and follow the MBC as it rises closer to the surface and migrates horizontally towards shore (Benoit-Bird et al., 2001). This cycle of foraging and resting along Leeward Oahu is repeated daily.

The inability to sight animals at night ruled out the survey approach taken in Phase I to assess the nighttime occurrence of dolphins or whales near the harbor. The approach used instead was to employ active sonar and passive acoustic sampling to detect both local densities of the MBC and the presence of foraging dolphins. Whales are not known to feed in Hawaii and there is no evidence presently available to suggest that their nighttime behavior and distribution differs from the day, so they were not considered in this phase.

Active sonar data from both the MBC and spinner dolphins off the south Waianae coast were collected using a Computrol, Tournament Master Fishfinder NCC 5300, modified to read directly into a laptop computer. The envelope of returning echoes was digitized at a sampling rate of 10 kHz using a Rapid System R1200. Data acquisition was triggered by the outgoing signal and data were collected in blocks of 2048 points, representing 156 m of vertical space. The echosounder used a 200 kHz outgoing signal with a pulse length of 130 μ s. The transducer producing a downward-pointing signal with a 10 degree cone was towed 6-7 m behind the vessel, approximately 1 m below the surface of the water. See Benoit-Bird et al. (2001) for calibration methods.

Passive acoustic sampling was conducted by towing a broadband (flat to 150 kHz) hydrophone with a sensitivity of -210 dB re 1 μ Pa approximately 30 m behind the vessel. Received signals were amplified by 50 dB and highpass filtered at 2 kHz using custom-built electronics and monitored using headphones and an LED meter. When a signal believed to belong to a dolphin was detected the position of the vessel was recorded from the GPS.

Night surveys were conducted on five occasions between May 1st and 10th, 2001. Two 8-km transects oriented parallel to the shoreline were each surveyed for one hour beginning at 6 PM and ending at 12:30 AM while traveling approximately 2.6 m/s (5 knots). One transect was located approximately 2.8-3.0 km from shore, while the other was located 1.0-1.3 km from the shoreline. Previous work had demonstrated that the nightly vertical and horizontal migration of the MBC is spatially and temporally symmetrical about midnight (Benoit-Bird et al., 2001), so it was deemed unnecessary to conduct surveys between midnight and 6 AM. The position, depth, and signal strength data from the echosounder was mapped in ArcView's Geographic Information System with 3-D Analyst in order to determine the horizontal and vertical distribution of mesopelagic animals and spinner dolphins. Individual echoes were color-coded by target strength to separate spinner dolphins and mesopelagic animals. The dorsal aspect target strength at 200 kHz of individual spinner dolphins is within 2 dB of -27 dB, regardless of the dolphin's depth. The predicted dorsal aspect target strength for a 2 m fish, equivalent in length to the average spinner dolphin, is -20 dB (Love, 1970), significantly higher than that measured for spinner dolphins.

The relative abundance (analogous to catch-per-unit-effort) of spinner dolphins was calculated as the percent of sampling time that dolphins were observed. We considered individual animals observed acoustically within 30 seconds of each other to be part of the same group and calculated the observation time as the total time from the first sighting in the group until the last. Sightings of a single animal were assigned an observation time of 15 seconds. Because abundance is not based on counting of animals but rather percentage of sampling time dolphins were observed, multiple returns from the same animal within a short time of each other had little effect on the calculated relative abundance. Because of the vessel's speed, 2.6 m/s, it is unlikely that the same animal would be seen at distant times during the same transect. The relative abundance of mesopelagic organisms was calculated as the percent of the outgoing signals that returned with organisms present (Benoit-Bird et al., 2001; MacLennan & Simmonds, 1992).

3.3 – Off effort data collection

An ongoing study of spinner dolphin behavior coincided with the work described here. The focus of this second study was on spinner dolphin movement patterns along the Waianae coast and on their social acoustic behavior. As part of this work, spinner dolphin groups were tracked visually for several hours at different times of the day. The methods used are described in Lammers et al., 2000. Data that

are relevant to the objectives of this study are included here, as they add to our understanding of the spinner dolphin's use of the area.

4.0 – RESULTS

4.1 – Phase I

The two species of cetaceans most frequently encountered during daytime surveys were humpback whales and spinner dolphins. Their patterns of occurrence and behavior are discussed in detail below.

4.1.1 – Humpback whales

On 20 surveys humpback whale pods were observed 22 times. Of these, 4 were deemed re-sightings of the same animal(s) and therefore were not considered in the final count of 18. Two sightings were recorded on 6 surveys, one sighting on 5 occasions and no sightings were made on 9 surveys. Thus, one or more pods of whales were observed in the study area during 55% (11/20) of surveys. Figure 2 shows the location of all the sightings that were made. Of the 18 whale pods observed, 6 (33%) occurred north of the harbor entrance and 12 (67%) were seen to the south towards Barber's Point. A total of 25 individual whales were counted during the study period. The average size of a pod was 1.33 whales (N = 18; SD = 0.49), although this may be an underestimate because distant pods may have been undercounted. Of the 18 pods observed, six were classified as traveling either north or south parallel to the coast, two were observed engaging in long dives of five minutes or longer, two were surface active (breaching, tail slapping or fluke slapping) and the behavior of eight others was undetermined.

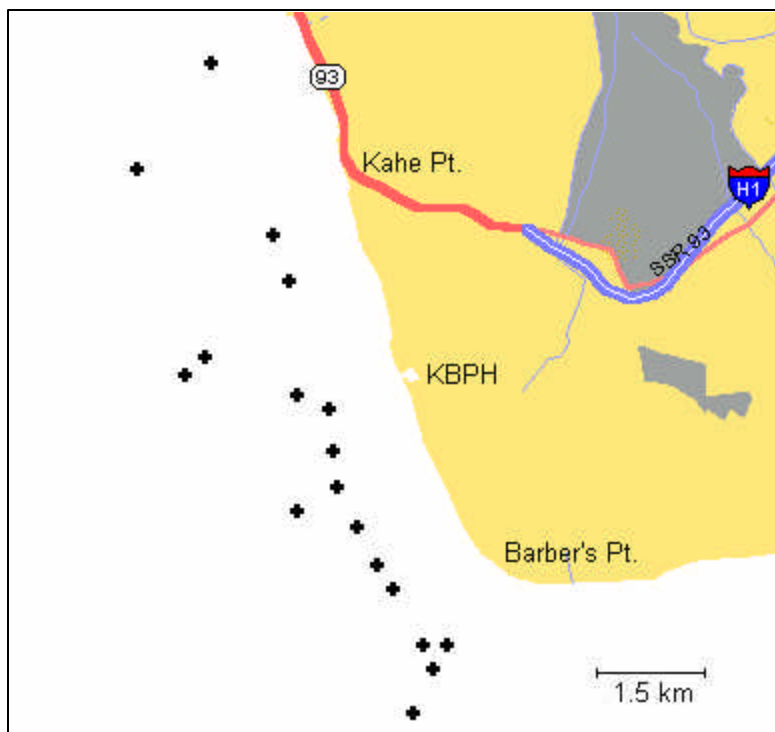


Figure 2 – On effort whales sightings. Each cross represents a whale pod.

To represent the frequency of sightings as a function of time spent surveying, we divided the study into three periods. The “early” period includes 7 surveys made between February 13th and March 8th, the “middle” period includes 7 surveys conducted between March 13th and April 3rd and the “late” period represents 6 surveys made between April 21st and May 14th. Figure 3 shows a graph of the number of whales (not pods) sighted per hour spent surveying during each period. Whales were sighted most frequently (1.2 whale/hr) during the latter part of March and beginning of April (the middle period). If we assume that these values are representative of the frequency of occurrence of whales, then during a 12 hour day we would estimate 6.7 whales to occur on average per day in the study area between mid February and mid March, 14.4 whales per day between mid March and early April, and 3 whales per day during the second half of April and into May (the last whale sighting was on May 1st). However, this assumption is only valid if whales are primarily transiting through the area, which the behavioral data tend to suggest is the case.

The occurrence of whales at night in the area cannot be evaluated because little is known about their nocturnal behavior. However, of the 25 whales counted 18 (72%) were seen in the afternoon and only 7 (28%) during morning surveys, a statistically significant difference ($\chi^2 = 4.84$; DF = 1; p = 0.028). This suggests that time of day is a factor influencing the occurrence of whales in the area.

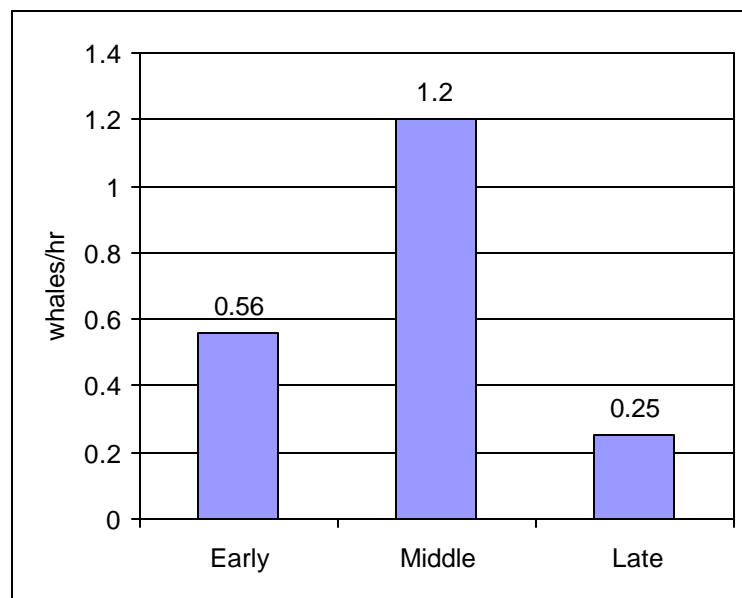


Figure 3 – Number of whales sighted per hour surveyed during the early, middle and late periods of the study.

4.1.2 – Spinner dolphins

Spinner dolphins were observed in the study area on 45% (9/20) of surveys. Figure 4 shows the location of all the sightings made. The occurrence of spinner dolphins was limited almost exclusively to the northern end of the study site, near Kahe Point. Sightings were made with approximately equal frequency during both morning and afternoon surveys (4 and 5 times, respectively). The number of animals observed per sighting ranged between 2 and 90. The average was 43 (N = 9; SD = 29). All but one sighting were of animals in waters less than 100 ft deep ($\bar{x} = 49.8$; SD = 30.5).

Behaviorally, the spinner dolphins encountered were more active on average in morning than in the afternoon. Mean behavioral indices calculated were 3.56 (N =4; SD = 0.79) and 4.23 (N = 4; SD = 1.23), respectively. At Kahe Point, spinner dolphins were generally either resting or descending into rest (see Norris et al., 1994). Two sightings made south of Kahe Point in the late afternoon were of animals traveling towards Barbers Point.

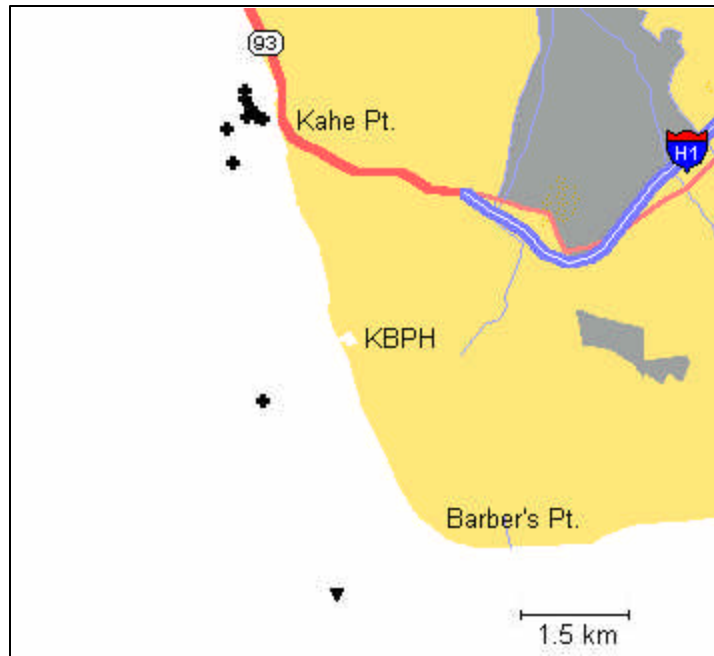


Figure 4 – On-effort sightings of dolphins. Crosses represent spinner dolphins. The triangle represents a pod of spotted dolphins.

4.1.3 – Other species

Although species like bottlenose dolphins (*Tursiops truncatus*), false killer whales (*Pseudorca crassidens*), pilot whales (*Globicephala melaena*), melon-headed whales (*Peponocephala electra*) and pygmy killer whales (*Feresa attenuata*) are known to occasionally occur in the area (Lammers, pers. observ.; NMFS – Protected Species Program letter to Department of the Army dated 10/5/01), the only other species of cetaceans that were observed in this study were spotted dolphins (*Stenella attenuata*). One sighting was made at the southern end of the study area, just off Barbers Point (Fig. 4). Approximately 20 animals were observed at 10 AM on February 19th slowly moving southward along the edge of the Barbers Point bank. The behavioral state of these animals was not clear, but their location and length of dives suggest they might have been feeding at the time.

Hawaiian monk seals, though not common, have been reported to occasionally occur on the leeward coast of Oahu. However, no sightings were made during the present study.

4.2 – Phase II

The data obtained using both active and passive acoustic sampling cannot be converted to actual number estimates of animals occurring in the study area at night because it is not possible to say what

percentage of the animals in a group were detected by the sonar or what proportion were acoustically active. However, relative comparisons between locations and time periods are justified. Abundance estimates are based on the number of returning echoes believed to be from dolphins and the frequency of dolphin sounds detected. Although visual confirmation of the dolphin species detected only occurred on a handful of occasions, it is assumed that most echo returns came from spinner dolphins. Spinner dolphins are the only local species of dolphin known to rely almost exclusively on the MBC for food.

Unlike the visual sighting data presented in Phase I, the acoustic data can more difficult to interpret in its raw form. Therefore, to illustrate the relative abundance of dolphins as a function of location and time, the results are presented by dividing the study area into six quadrants. These quadrants can be thought of as a 2 x 3 matrix with columns representing inshore and offshore waters and rows separating the study area into northern, central and southern sections. The results of this analysis can be seen in figure 5.

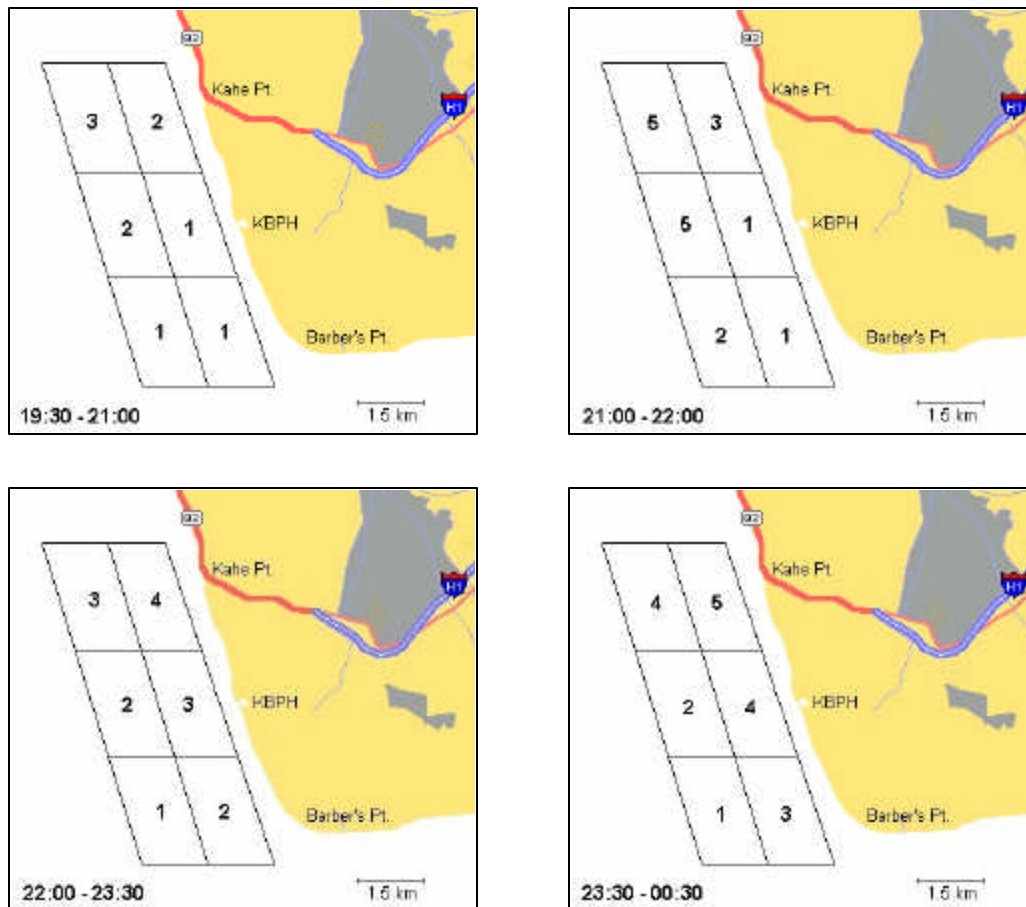


Figure 5 – The relative abundance of foraging dolphins as a function of time and location. The time period is shown in the lower left corner. Relative abundance is represented as follows: 1 = very low; 2 = low; 3 = moderate; 4 = high; 5 = very high.

At all times, animals were seen more often and in larger groups in the northern quadrants than in the central or southern ones. Dolphins tended to feed offshore in the evening hours and move inshore as the night progressed. Figure 6 shows relative abundance as a function of time for dolphins and their

prey resource, the mesopelagic boundary community. Spinner dolphins were always observed in near proportion to their prey. Consequently, dolphins were detected most often in the inshore quadrants near midnight, when their food resource was most abundant there. This is also indicated in the final frame of Figure 5, where dolphins occurred in moderate to very high densities in all three inshore quadrants shortly before and after midnight. A relatively large number of animals were also observed in the offshore central quadrant between 9 PM and 10 PM, where the prey had a second peak in abundance. These patterns are consistent with those observed off the Kona coast of the island of Hawaii (Benoit-Bird & Au, 2001) and the south shore of Lanai (Benoit-Bird, unpublished data).

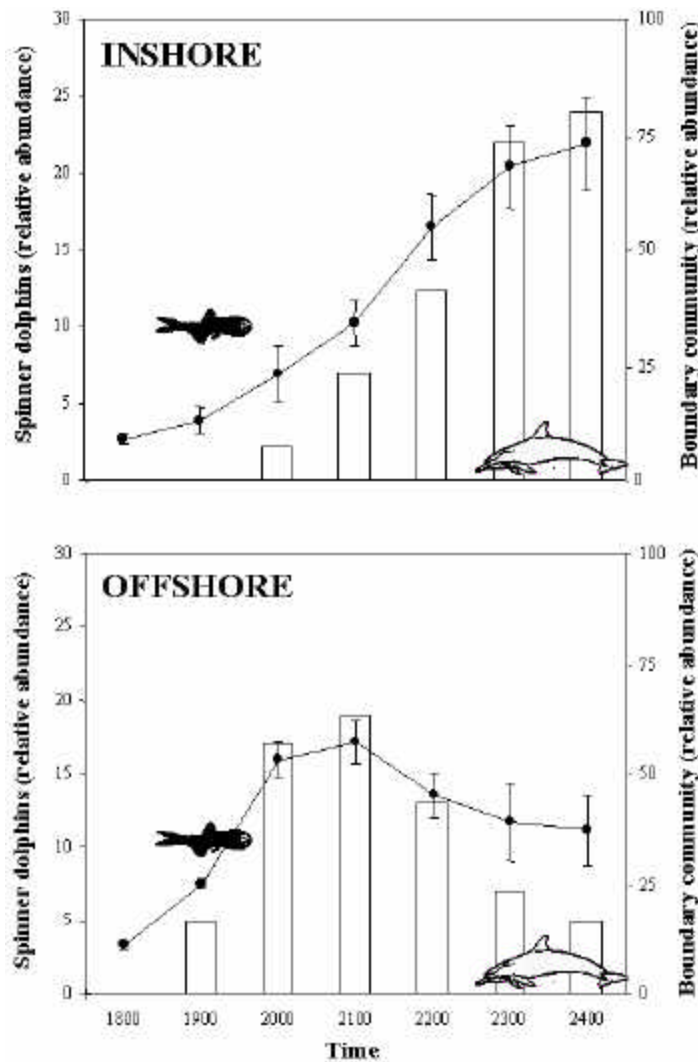


Figure 6 – The relative abundance of the boundary community (lines) and dolphins (bars) as a function of time. Inshore abundance is shown in the top figure and offshore in the bottom figure. Abundance is in units of percent time observed.

4.3 – Off effort data

Groups of spinner dolphins were visually tracked opportunistically between February and May while conducting behavioral and acoustic studies. On six occasions spinner dolphins were encountered while resting at or near Kahe Point and subsequently followed until they began foraging.

Generally, dolphins left the Kahe Point area between 2:30 and 4:30 PM. On four occasions the dolphins moved south towards Barbers Point. Two other times, the animals were followed north, towards Maili Point. Figure 7 is representative of the route normally taken by southbound spinner dolphins. Most of the time, groups tended to travel slowly (< 3 knots) along the coast in shallow waters approximately 30-40 ft deep. On this particular day the animals crossed the harbor's entrance channel near the first marker buoy shortly before 3 PM. They reached the 100-fathom (600 feet) isobath of the Barbers Point bank at around 4:30 PM, at which point they began to spread out and do long dives, suggesting that they had reached their early evening foraging grounds.

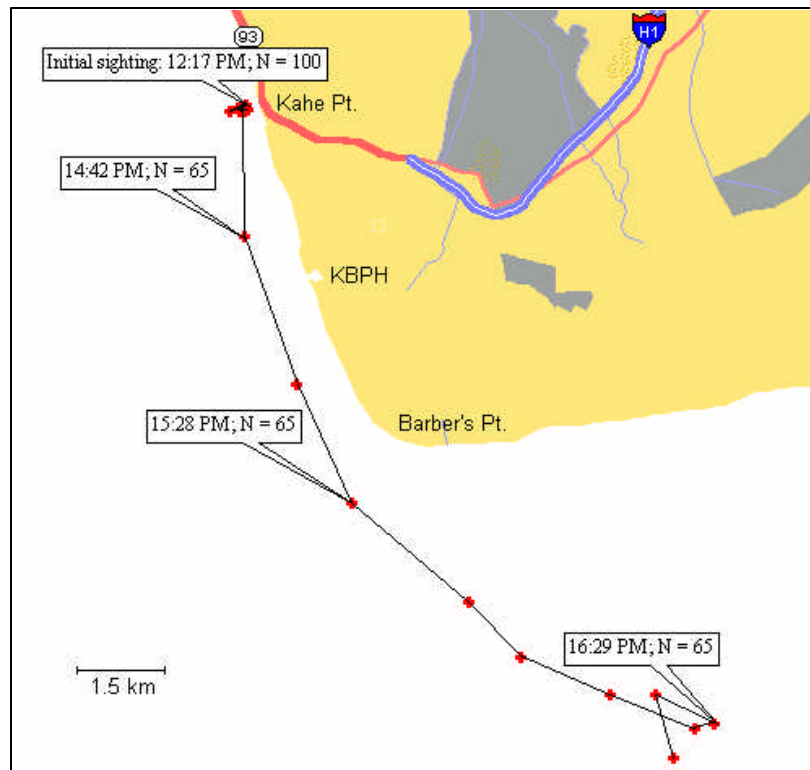


Figure 7 – Spinner dolphin track obtained on May 18th, 2001. Approximately 100 animals were initially encountered at Kahe Pt. shortly after 12 PM. Of these, about 65 remained in the area until 2:30 PM, at which time all remaining animals moved south towards the Barbers Point bank.

5.0 – DISCUSSION

5.1 – Humpback whales

5.1.1 – Natural History

The humpback whale season begins in Hawaii towards the end of October, when the first sightings are usually made in the waters around Maui. On Oahu, whales normally begin being sighted consistently in January. The results presented here indicate that whales are moderately abundant in waters adjacent to the harbor until the latter part of April, with a distinct peak in mid to late March. This is roughly consistent with abundance trends observed for the rest of the state (Mobley et al., 1999)

Most of the whales for which a general behavior pattern could be established in this study appeared to be primarily transiting through the KBPH area rather than occupying it for extended periods. Both aerial and vessel survey data show that statewide approximately 74% of whales occur in waters less than 100 fathoms (600 ft) deep (Mobley et al., 1994; Lammers et al., 2000). This is partly explained by a preference on the part of females with calves for the relative protection of shallow coastal waters (Smultea, 1994). The 100-fathom isobath along the study site is between 1.8 and 2.6 km from shore, which contrasts with the area just south of Barbers Point where a shallow bank extends the 100-fathom contour out 6.3 km from shore in some parts. This bank has been shown in a previous study to be a local aggregating feature for whales (Lammers et al., 2000). Another similar, but considerably larger area is Kaena Point, 35 km to the north, where whales also occur in high densities (Lammers, pers. obs.) Thus, it would appear that whales travelling along the comparatively narrow strip of shallow water near the harbor entrance are either in transit to or from these two banks.

5.1.2 – Interactions with proposed construction plans

The construction activities proposed for the harbor entrance might pose a concern for whales because of two incidental consequences: sediments suspended in the water column for extended periods and noise levels produced by dredging and other industrial equipment. Turbid waters are primarily a concern for mothers with newborn calves since decreased visibility could lead to greater risks of separation and/or predation. Humpback whales are periodically exposed to considerably more turbid conditions in the nutrient-rich waters off Alaska where they feed in the summer than in the clear tropical waters of Hawaii. Therefore, the localized turbid conditions expected from dredging operations should not present a serious problem for subadult and adult whales.

Models predicting the average and worst case turbidity conditions resulting from dredging activities at the outer entrance channel indicate that turbidity values exceeding those experienced during large surf events will occasionally extend more than 1200 m southwest of the harbor's entrance (Sea Engineering, Inc., 2000). Based on the whale distribution data presented here, this overlaps only slightly (~ 100-300 m) with the whales seen closest to the entrance during the surveys. Therefore, while not out of the question, it is unlikely that turbidity will have an adverse effect, even for whale pods with young calves. Under the scenarios predicted, turbid conditions will be localized enough that whales will only need to make minor adjustments in their direction of travel to avoid them.

A potentially greater source of disturbance for whales comes from the noise levels that will be produced by dredging and jetty construction operations. Although no data presently exist on the behavioral reactions of humpback whales specifically to dredging sounds, there is sufficient evidence from other species and sources of sound to warrant a cautious approach.

In an experiment on bowhead whales (*Balaena mysticetus*) in Alaska, whales exposed to artificially projected dredging sounds 21-30 dB re 1 μ Pa above ambient noise levels reacted by stopping their feeding activities and moving more than 2 km away from the source of the sound (Richardson et al., 1990). Other bowhead whales subjected to the same levels but from real dredging apparently behaved normally, suggesting that they may have habituated to the steady noise after initially being disturbed by it. Gray whales (*Eschrichtius robustus*) in Baja California provide an example of long-term change in baleen whale distribution as a result of industrial activities, including dredging. Gray whales almost completely abandoned a lagoon during several years with intense shipping and dredging activity (Bryant et al., 1984). Bryant et al. suggested that "the constant

dredging operation necessary to keep the channel open ... may have been the main source of disturbance". Gray whales reoccupied the lagoon after shipping subsided.

A recent draft report characterizing the underwater sounds produced by bucket dredging operations in an Alaskan ship channel reported that at a distance of 150 m from the dredge, the maximum rms sound pressure level (SPL) received when the bucket hit the bottom was 124 dB re 1 μ Pa at 163 Hz (Dickerson et al., 2001). Approximately 1 km away the same sound had a peak rms SPL of 116 dB at 316 Hz and at 2 km it was down to 109 dB at 77 Hz. The levels of other events in the operation such as "bucket digging" were generally comparable or lower to the bottom contact sound. These levels are equivalent, although somewhat lower, to those reported by Richardson et al. (1990). The observed difference may be due to the types of substrates that were involved in each operation (Dickerson et al., 2001). Softer substrates like the mud and gravel dredged in the Dickerson et al study tend to result in less noise. The levels produced while dredging the hard coral substrate in the KBPH basin and channel will almost certainly be several dBs higher than those reported above.

The noise levels and frequencies described for dredging operations fall well within the presumed audible range of humpback whales. Thus, there is little doubt that whales will hear the dredge, even at a distance of several kilometers. The levels are not high enough to pose any threats of physiological damage to the whale's auditory system, but at close range (< 1 km) the noise could be loud enough to mask the songs of conspecifics in the distance. What consequences, if any, this will have on the behavior of whales is difficult to predict. Humpback whales in Hawaii are routinely exposed to loud ambient sounds from vessels and other whales (Au & Green, 2000), so it is possible that they could habituate to the noise (Richardson et al., 1995). Alternatively, transiting animals unfamiliar with the dredging sounds could react by altering their normal travel routes or choosing not to occupy the area. Gray whales migrating along the California coast showed significant responses to a variety of playback noise types resulting from petroleum drilling operations (Richardson et al., 1995). Received noise levels at which gray whales reacted were similar among four sources of continuous noise, and similar to the received levels of drillship and dredge sound to which bowheads react. Table 1 presents the received broadband (20-1000 Hz) sound levels at which various percentages of migrating gray whales were observed to react, as well as the noise level 100 m from the actual source and the range from the source at which 50% avoidance can be expected (Malme et al., 1984).

Table 1 – Broadband sound levels (dB re 1 μ Pa) from a simulated source of drilling noise resulting in varying percentages of avoidance behavior by gray whales. Also shown are the SPL recorded 100 meters away and the range for which 50% avoidance is predicted. Modified from Richardson et al., 1995.

Levels for various percent avoidance:			Actual level at 100 m	Actual range (m) for 50% avoidance
10%	50%	90%		
110 dB	117 dB	122 dB	136 dB	1100 m

Malme et al. (1985, cited in Richardson et al., 1995) investigated the effects of underwater noise from drilling activities on feeding humpback whales. They reported no clear avoidance responses at broadband received levels up to 116 dB re 1 μ Pa. No data exists, however, on how behavioral responses might vary in the humpback's breeding grounds or with respect to dredging sounds. In general, it appears that whales tend to avoid stationary industrial activities such as dredging and

drilling when the received sounds are strong, but not when the sounds are barely detectable (Richardson et al., 1995).

No data is available on the noise levels that will be produced during the construction of the jetty. The noisiest event will occur when the jetty's core rock material (4" to 8"-diameter rocks) is dumped into the water from land by trucks (Mr. Rick Halzel, pers. com.). Placement of the interlocking Core-loc pieces on the surface of the jetty requires a careful process of lowering each piece in place using a land-based crane. No loud underwater sounds should result from this operation. The dumping of rock material at varying intervals, on the other hand, is likely to produce a loud transient sound. If the levels are comparable or higher to the dredging sounds they will be heard by whales. Temporary and impulsive sounds tend to produce more drastic behavioral responses in cetaceans than continuous ones (Richardson et al., 1995). Therefore, if the jetty is built during whale season, a behavioral or avoidance reaction by whales cannot be ruled out.

5.2 – Spinner dolphins

5.2.1 – Natural History

Unlike whales, which occupy the study site only temporarily each year, spinner dolphins are yearlong residents in the area. The data suggest that during the day spinner dolphins seek out and occupy a very specific area near Kahe Point about 50% of the time. The areas directly north (before Kahe Point) and south (up to Barbers Point) of the harbor's entrance do not appear to be important resting habitats. These areas are more turbid and more exposed to predominant winds, making them less desirable for resting spinners relying on vision to detect predators (for an explanation see Norris et al., 1994). When not using Kahe Point as a resting ground, spinner dolphins will often occupy the area off Nanakuli instead (Lammers, unpublished data). Spinners only occurred adjacent and south of the harbor in the late afternoon on days when they were in transit towards Barbers Point. A similar pattern is probably repeated in the pre-dawn or dawn hours during their return to the more protected waters off Nanakuli and Kahe Point.

Group sizes of spinner dolphins occurring in the study site during the day averaged about 40 animals, but at times could be as high as 100 individuals. At night numbers are more difficult to estimate, but the consistency and frequency of dolphin echoes and signals recorded suggest that even more animals might occur in the area after dark. Additional animals might stem from an offshore population of spinner dolphins, other species of dolphins foraging on the same prey, or both. Nighttime foraging activity was greatest north of the harbor, but was also quite common directly offshore after approximately 9 PM. The peak daily occurrence of dolphins near the harbor on most days is probably between 11 PM and 1 AM, when their prey resource is closest to shore.

5.2.2 – Interactions with proposed constructions plans

The occurrence of spinner dolphins in waters heavily navigated by commercial, industrial and private vessels along the south shore of Oahu (Lammers et al., 2000) suggests that a certain amount of tolerance for nearby human activities exists among these animals. However, whereas vessel traffic is characterized by transient events lasting only a few minutes, the harbor modification work will persist almost continuously for up to two years. The concerns facing spinner dolphins are similar to those already discussed for whales, namely the effect that sediments suspended in the water and noise levels produced by dredging will have on locally occurring animals. Because spinner dolphins are year-

round residents that use the area in question extensively for foraging, socializing and resting, the potential impacts must to be evaluated carefully.

The increased turbidity levels projected for waters near the harbor (within 0.5-1 km) will most likely not be of much consequence to spinner dolphins during the day. Kahe Point, where the dolphins are expected to spend most of their time, is sufficiently distant from the harbor that an increase in turbidity there is very unlikely (see Sea Engineering, Inc., 2000). Spinners traveling past the harbor in the early morning and late afternoon will probably experience turbid conditions at times, but as discussed with whales, they will only need to make minor adjustments in their travel path to avoid them. At night, the situation will be somewhat different. Foraging spinners that follow their prey into waters near the harbor when dredging is taking place will experience more turbid conditions than normal. It is not known how this will affect them or their prey. Dolphins have a sophisticated sonar system, so impaired navigation or predator detection will probably not be an issue for them.

On balance, the localized nature of the sedimentation expected does not seem to justify the assumption that turbidity near the harbor will adversely impact spinner dolphins. At worst, the animals will avoid turbid waters and opt for clearer areas nearby. Any such disruption in their behavior will cease when the project is completed and the water quality returns to ambient levels. No long-term effects should be expected.

A second source of concern comes from the elevated noise levels that will be produced by the dredging and jetty building machinery. Dolphins are acoustically very specialized animals that rely on sound for communication, navigation and predator detection. An increase in ambient noise level has the potential to mask natural acoustic cues used by dolphins and/or create an avoidance reaction to the source of the noise.

The estimated sound pressure levels and frequency characteristics received at different distances from a bucket dredge are presented in the discussion above on humpback whales. Peak frequencies in all cases ranged between 77 Hz and 316 Hz. All hearing tests conducted on dolphins to date indicate that these are not very sensitive frequencies for them (see Au et al., 2001). Although spinner dolphins will hear the dredging sounds even several kilometers away, these should not present a significant nuisance to them except maybe at close range (< 1 km). Spinner dolphin social and echolocation signals are much higher in frequency (between 5 and 150 kHz) and therefore will not be subject to significant masking effects.

The literature contains only one reference to spinner dolphins reacting to construction sounds. Shallenberger (1978, cited in Richardson et al., 1995, p.279) reported that “spinner dolphins reduced their use of a Hawaiian bay after the start of a noisy construction project for a water pipeline.” No further details, however, were provided. Another species, the beluga (*Delphinapterus leucas*) showed less reaction to stationary dredges than to moving barges despite similarities in their sounds (Ford, 1977; Fraker, 1977, as cited in Richardson et al., 1995). It was concluded that “...passage of belugas along a shoreline was temporarily blocked by a dredging operation involving frequent barge traffic, but not by dredging with little barge traffic” (Richardson et al., 1995, p.279).

It seems unlikely that spinner dolphins will alter their daytime use of the Kahe Point area given that the expected received noise levels from dredging and the construction of the jetty (see discussion above) pose neither a physiological threat to their hearing nor a significant source of masking for their signals. Naturally occurring noise levels from snapping shrimp are generally high (> 100 dB re 1 μ Pa) in the shallow waters near Kahe Point, so dredging sounds there will most likely only reach a few

decibels above normal ambient levels. Further offshore from Kahe, where the greatest concentrations of foraging dolphins occur at night, ambient noise will be lower, but so will the dredging sounds. As water gets deeper, all sounds progressively experience more attenuation in amplitude due to increased spherical spreading losses.

Most likely, the only times spinner dolphins will be exposed to elevated noise levels will be when they cross the harbor entrance in the early morning and late afternoon, and then again around midnight when foraging nearby. Given that their own sonar signals reach peak to peak sound pressure levels of 220 dB re 1 μ Pa (Au, 1993) and are much higher in frequency, it is unlikely that their ability to feed in the area will be affected by acoustic interactions between the noise and their signals. However, avoidance of the area near the harbor and other behavioral modifications that result from annoyance by the noise are reactions that cannot be ruled out. If such reactions do occur, there could be associated biological consequences. These might include a reduced net access to food, greater competition for the remaining available food resource, and possibly elevated stress levels that could affect reproductive cycles. These, however, are worst case scenarios. Any such displacement of animals from the area should not persist following the completion of the project when sound levels return to normal.

5.3 – Other cetacean species

The daytime surveys conducted did not reveal any other regularly occurring species of cetaceans in waters adjacent to the harbor. Spotted dolphins were encountered only once several kilometers south of the harbor. Past and ongoing research efforts in the area by Lammers (unpublished data) suggest that spotted dolphins and bottlenose dolphins (*Tursiops truncatus*) occur with some regularity on and along the Barbers Point bank. These animals, however, are rarely seen in the vicinity of the harbor during the day. At night, it may be that these and other species do occur there with greater frequency. The high number of dolphins detected using active acoustic sampling suggests that this might be the case. Spotted dolphins probably feed on the MBC at least in the evening and dawn hours. Bottlenose dolphins probably do not feed on the MBC itself, but could be trophically linked to it via other species that do.

Like spinner dolphins, other dolphin species will hear the dredging activities in the harbor channel. As discussed previously, these sounds are unlikely to result in complications with navigation, foraging and predator detection. It is thus doubtful that either spotted dolphins or bottlenose dolphins will be adversely impacted by dredging and/or construction activities.

5.4 – Estimate of marine mammal impact

The Federal government prohibits any unauthorized activity that has the potential to disturb or harass a marine mammal or marine mammal stock in the wild. “Harassment” is broadly defined as “any act of pursuit, torment or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering” (16 U.S.C. 1362, sec.3(18)(A)). Harassment under part (i) is termed Level A Harassment and under part (ii) is called Level B Harassment.

Assuming that no blasting using explosive charges is to take place during the proposed harbor expansion project, the industrial activities projected do not present any apparent physical or physiological threat to marine mammal species occurring in the area. However, the proposed activities

do have the risk of “disturbing” local marine mammal stocks. Specifically, normal “migration” patterns may be disrupted in the case of humpback whales and spinner dolphins, and regular “feeding” patterns could be affected in the case of at least spinner dolphins, but possibly also spotted dolphins and bottlenose dolphins. Thus, Level B Harassment of these species is likely to take place during the project.

Establishing the number of animals of each species that will be impacted can at best only lead to a rough estimate. Even within species, there will be considerable individual variability in behavior and tolerance towards disturbances. In some cases, assumptions must be made that are only based on limited evidence or data. Table 2 presents the number of marine mammals that can reasonably be expected to occur near the KBPH area on a daily basis. Estimates for humpback whales are based on the number of sightings made per unit time spent surveying (see section 4.1.1). Dolphin estimates are derived from the average number of animals either observed (see section 4.1.2) or suspected to occur in the area during the day and/or night. The values reported for humpback whales do not factor in any potential nighttime occurrence. If the assumption is made that whale traffic is continuous throughout the 24-hour day then these values should be doubled.

Table 2 – Estimated number of marine mammals occurring within a 4-km radius of the harbor entrance. An asterisk (*) indicates that nighttime occurrence is not factored into the estimate due to a lack of data. A chevron (^) indicates that the estimate is mostly based on prior knowledge and experience with the species’ occurrence in the area (not empirical calculations).

Species	Daily takes
<i>Humpback whales</i>	
Mid-Feb to Mid-March	5-8*
Mid-March to Mid-April	12-17*
Mid-April to Mid-May	1-5*
<i>Spinner dolphins</i>	43 (± 29)
<i>Spotted dolphins</i>	0-20^
<i>Bottlenose dolphins</i>	0-10^

6.0 – RECOMMENDATIONS

To mitigate the impact of the proposed activities on marine mammals, three preventative steps should be considered by the project’s planners. These are:

1. Avoid any dredging or construction activities during the peak periods of the whale season between February and April. Maintaining the area free of any disturbance during these three months will prevent any change in the occurrence and behavior of whales and will reduce the overall impact on dolphins by providing them with a temporary “break” from the locally noisy conditions.
2. If option 1 is not feasible, then a second alternative could be to only dredge within the harbor’s basin during the peak periods of the whale season between February and April. Restricting the dredging to the confines of the basin could considerably lower received sound pressure levels near the outer entrance of the channel where whales occur. Exactly by how much the noise would be

attenuated cannot be established without empirical measurements. In lieu of such data, one approach might be to monitor the levels received beyond the channel's entrance buoy periodically to ensure that they do not exceed a pre-determined threshold. Based on the behavioral data presented in the literature, a reasonable threshold would be the greater of either 115 dB re 1 μ Pa or 10 dB above normal ambient levels measured in waters deeper than 100 ft, where most whales occur. If received levels exceed the adopted threshold, dredging could either be stopped or shifted to a "quieter" area of the basin.

3. Cease dredging activities at night between 10:00 PM and 2:00 AM. By doing so, the risk of adversely impacting foraging dolphins nearby will be greatly minimized. This action could be significant since it is not presently clear what biological consequences might result from dolphins avoiding the area while foraging. Not dredging during the hours coinciding with the peak occurrence of the MBC near the harbor would help ensure unrestricted access to the dolphin's food resource.

Adopting a combination of strategies 1 & 3 or 2 & 3 would eliminate the major concerns relating to marine mammals about the proposed project. Minor concerns, like altering spinner dolphin travel routes near the harbor can probably not be addressed without a monitoring effort to detect dolphins at least 1-2 km away from the dredging/construction site and a plan to stop operations until they've moved away. If such a plan were not feasible, these concerns would then need to be accepted as part of the overall environmental cost vs. economic benefit equation.

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DATE: Month/Day/Year.

SURVEY #: The name of the survey (i.e. K1, K2, etc)

BOAT DRIVER: The person responsible for steering the vessel along the transect.

DATA RECORDER: The person responsible for inputting data on paper and/or the computer.

STARBOARD OBSERVER: The person responsible for maintaining continuous watch between 270° and 0° of the vessel's bow.

PORT OBSERVER: The person responsible for maintaining continuous watch between 0° and 90° of the vessel's bow.

OTHER: Wildcard observer maintaining watch towards the back of the vessel and/or relieving others as needed.

LEG #: The study site is composed of 8 transect legs. Indicate which leg the vessel is currently on.

TIME: hr/min/sec derived from GPS.

LATITUDE: degrees.minutes.seconds derived from GPS.

LONGITUDE: degrees.minutes.seconds derived from GPS.

SWELL: The average height of passing swells, from trough to crest.

DEPTH: Approximate depth of water, as determined by the depthfinder.

BFT: Beaufort sea state as determined by the following criteria:

<u>Scale</u>	<u>Condition</u>
0	Smooth and mirror-like.
1	Scale-like ripples without foam crests.
2	Small short wavelets; crests glass appearance and not breaking.
3	Large wavelets; some crests break; foam of glassy appearance; occasional white foam crest.
4	Small waves become longer; fairly frequent white foam crests.
5	Moderate waves, more pronounced long form; many white foam crests; there may be some spray.
6	Large waves form; white foam crests extensive; may be spray.

GLR: Glare on the water, as estimated using the following criteria:

- 0 No glare in observation field.
- 1 Glare in 1-10% of observation field.
- 2 Glare in 11-25% of observation field.
- 3 Glare in 26-50% of observation field.
- 4 Glare in 51-75% of observation field.
- 5 Glare in 76-100% of observation field.

VIS: Visibility rating based on combined Beaufort and glare estimates:

<u>VIS</u>	<u>BFT</u>	+	<u>GLR</u>
Excellent (EX)	0 – 1		0
Very good (VG)	0 – 2		0 – 1
Good (GO)	0 – 3		0 – 2
Fair (FA)	0 – 4		0 – 3
Poor (PO)	0 – 4		0 – 4
Unacceptable (UN)	0 – 5		0 – 5

VESSEL BEARING: Bearing of vessel at the time of the sighting as determined through the rangefinder.

OBSERVATION BEARING: Magnetic bearing to the sighted marine mammal(s) as determined by a digital compass.

DISTANCE: The estimated distance, in meters, between the vessel and the sighted marine mammal(s).

SPECIES: Species code of the marine mammal(s) sighted:

MN = Humpback whale	<i>Megaptera novaeangliae</i>
SL = Spinner dolphin	<i>Stenella longirostris</i>
SA = Spotted dolphin	<i>Stenella attenuata</i>
TT = Bottlenose dolphin	<i>Tursiops truncatus</i>
SB = Rough toothed dolphin	<i>Steno bredanensis</i>
GM = Shortfin pilot whale	<i>Globicephala macrorhynchus</i>
PC = False killer whale	<i>Pseudorca crassidens</i>
BB = Baird's beaked	<i>Berardius bairdii</i>
MD = Blainville's beaked	<i>Mesoplodon densirostris</i>
ZC = Cuvier's beaked	<i>Ziphius cavirostris</i>
US = Unidentified Stenella	
UD = Unidentified dolphin	
UW = Unidentified whale	
UB = Unidentified beaked whale	

NUMBER: Estimation of the total number of animals sighted in a cluster of animals. Recorded as a minimum and maximum estimate within ± 5 (i.e. 15-20).

BEHAVIOR: Observable behavioral patterns (indicate all that apply):

SA = Surface active: Animals show marked surface behaviors such as breaching, leaping, tail slapping, etc.

TR = Travel: Animals moving in a clear direction for duration of sighting.

ST = Stationary: Animals not moving in any clear direction during the duration of the sighting.

LD = Long dives: Animals diving for more than five minutes between surfacings.

COMMENTS: Additional information that may be relevant at that particular time. For whales, presence of calves should be noted here.