Historical Evidence of Whale/Vessel Collisions in Hawaiian Waters (1975 – Present)

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EXECUTIVE SUMMARY

- The main Hawaiian Islands are the principal wintering grounds of North Pacific humpback whales. Although, their numbers are recovering, humpback whales continue to face a variety of anthropogenic threats. Arguably the most visible impacts are from collisions with vessels. One of the mandates of the Final Recovery Plan for the Hawaiian humpback whale is to investigate vessel collisions and assess the degree to which this threat impacts the population.

- The Hawaiian Islands are quite isolated in the Pacific and are highly dependent on vessel traffic for many forms of commerce. It is to be expected that some collisions between vessels and whales take place in Hawaiian waters. To date very little analytical attention has been paid to incidents locally, which makes it difficult to gauge the severity of the issue from both a conservation and safety standpoint.

- This study examines the occurrence of whale/vessel collisions in Hawaii from two perspectives. First, the available historical information is presented on the number and location of collisions described in media reports and government records since 1975. Secondly, the experiences and opinions of local mariners on the issue of whale/vessel collisions is analyzed based on responses obtained from questionnaires disseminated to professional mariners across the State.

- Twenty-two whale/vessel collisions were publicly reported between 1975 and 2003. Maui had the highest incidence of collisions, while Kauai had the lowest. There was an increase in the number of reported collisions over the period examined. Only two incidents were reported between 1975 and 1984, six between 1985 and 1994, and thirteen between 1995 and 2003.

- Approximately 150 questionnaires were distributed in person and via email to experienced mariners in the Hawaiian Islands. Fifty-eight (58) completed questionnaires were returned via mail or email.

- 31 out of 58 respondents (53.4%) answered that they were aware of one or more collisions taking place between a vessel and a whale during the period between 1998 and 2002. Of these, almost two thirds (64.5%) reported that they knew of 1-2 incidents. Nine (29.0%) knew of 3-5 incidents, 1 (0.03%) knew of 6-8 incidents and 1 reported knowing about more than 12 incidents. By and large the most incidents were reported occurring in the Maui, Molokai and Lanai region.

- The majority of respondents implicated medium sized boats ranging from 31 to 60 feet in length with top speeds between 10 and 30 knots. Large (61-100 ft) boats were also frequently involved, whereas small (< 31 ft) and very large (> 100 ft) vessels comprised only 16% of all reports combined.

- 45 (78.9%) respondents expressed at least some level of concern over the issue of whale/ship collisions in Hawaii. One third (33.3%) indicated they were "very" concerned about the issue, close to half (45.6%) said they were "somewhat" concerned and approximately one fifth (21.1%) replied they had no concerns at all.

- 51 respondents expressed an opinion about the percentage of whale/ship collisions they believe get reported. Almost half (24 respondents; 47.1%) estimated that less than one quarter of incidents get reported to the media or local authorities, 8 (15.7%) answered 26-50%, 5 (9.8%) answered 51-75% and 14 (27.5%) believed reporting was close to 100%.

- 56 respondents offered an opinion regarding whether/how improvements could be made to the reporting process of whale/ship collisions. The most common suggestion was to allow anonymous reports to be made. Also popular were suggestions for a public awareness campaign and the establishment of a toll-free hotline for reporting. 12 respondents (21.4%) felt no improvements were needed.

- The results presented indicate that whale/vessel collisions in Hawaiian waters are occurring with increased frequency and will likely continue to increase unless steps are taken to actively mitigate the problem.

- There are likely a number factors contributing to the increasing rate of incidents. Probably the most significant is that the number of humpback whales wintering in Hawaiian waters has been steadily increasing over the past three decades. Another likely factor is the parallel increase in the number of vessels transiting through and/or occupying areas preferred by whales, such as the a west Maui region where the whale population is among the densest in Hawaii.

- Since collisions were reported for both slow and fast moving craft, it suggests that, in at least some situations, the whales were either not aware of the vessel's presence or could not resolve it's proximity and/or vector of travel based on the available acoustic cues.

- Additionally, because behavioral processes related to reproduction are the primary pre-occupation of humpback whales while in Hawaii, some individuals may simply be less reactive to distraction from nearby human activities than they would be under other circumstances.

- Because the findings presented indicate that certain areas are more problematic than others, it appears important that an understanding of whale distribution and habitat use patterns become an integral part of any future management effort.

- Information on collisions is presently quite scattered and not comprehensive. Therefore, no data management system exists that could be used to gauge the effectiveness of any future mitigation efforts. Establishing a centralized database with a publicized means to accept anonymous reports is likely the most effective way to address this problem.

INTRODUCTION

Humpback whales (*Megaptera novaeangliae*) are a cosmopolitan species found in all the world's oceans. Their propensity to seek out shallow or coastal areas makes them vulnerable to human activities that either impact their habitat or directly affect them physically or behaviorally. This report focuses on the impacts of vessel collisions on the North Pacific population of humpback whales wintering in Hawaiian waters.

Like many whale species, most humpback whales are seasonally migratory (Chittleborough, 1965; Dawbin, 1966; cf. Mikhalev, 1997). Summer months are spent feeding in high-latitude, nutrient rich cold waters. Winter and spring months are spent in low latitude warm tropical seas. While on the wintering grounds behavior appears primarily related to mating practices and birthing, although both mature and immature whales of both sexes make the migration (Dawbin, 1966; Craig, 2001). Females on the wintering grounds are rarely sighted alone (Craig et al., 2002), and are either accompanied by a calf and/or one or more male escorts (Herman & Antinoja, 1977). Competitive groups consist of multiple escorts, some of which vie for a position closest to the female, presumably for mating and/or mate guarding purposes (Baker & Herman, 1984; Clapham, 1996; Tyack & Whitehead, 1983). Males may also produce long complex vocalizations termed "song" (Payne & McVay, 1971). The function of whale song remains speculative but is undoubtedly related to some aspect of the mating system (Medrano et al., 1994; Frankel et al., 1995; Darling & Berube, 2001; Helweg et al., 1992). The main Hawaiian Islands are the principal wintering grounds of North Pacific humpback whales (Herman, 1979; Baker & Herman, 1981; Baker et al., 1986; Calambokidis et al., 2001).

Humpback whales are an endangered species. Their numbers were dramatically reduced to perhaps 5% of their original estimated worldwide population levels of approximately 120,000 primarily as a result of intensive whaling during the first half of the 20th century (Johnson & Wolman, 1985). Calambokidis et al. (1997) estimated the number of North Pacific humpbacks at approximately 6,000 compared with an estimated 15,000 in the unexploited stock (Rice, 1978). Although, recent data suggests that the Hawaii population has been steadily increasing (Mobley et al., 1999), humpback whales continue to face a variety of anthropogenic threats (e.g., pollution, underwater noise, habitat degradation, entanglement, etc.) (NMFS, 1991). Arguably the most visible impacts are from collisions with vessels. One of the mandates of the Hawaiian Islands Humpback Whale National Marine Sanctuary's (HIHWNMS) Revised Management Plan is to characterize and monitor how vessels impact whales (NMS, 2002).

Injuries resulting from boat strikes on cetaceans may be broadly classified into two forms, blunt trauma injures and propeller wounds (Laist et al., 2001). Blunt impact trauma often results in fractures of heavy bones such as skulls, jaws, or vertebrae. Massive bruising can also occur. Propeller wounds typically result in deep cuts or parallel slashes into the blubber on the dorsal surface and tailstock of the whale. Additionally, whales may be struck and caught on the bows of large ships and carried into port. However, humpback whales tend to be less susceptible to this type of injury than other more sleek rorquals like fin whales, sei whales, and blue whales (Laist et al., 2001).

Injuries due to blunt trauma and propeller wounds vary in severity, ranging from no apparent effect to minor injury, severe injury, or death. Both non-fatal and fatal injuries have been documented among humpback whales wintering in Hawaiian waters. Deakos et al. (1999) reported a humpback whale calf in Maui waters with a severe wound to its dorsal surface. Subsequent observations of the whale breaching and swimming with its mother that season, as

well as on its own the following year, indicated that it had survived the injury and recovered (Deakos, pers comm.). In contrast, Osmond and Kaufman (1998) documented a single humpback whale with the caudal area of its vertebral processes displaced dramatically from a suspected boat strike. The whale was emaciated and had difficulty moving. The severity of the injury and the reported presence of several tiger sharks nearby the whale indicated that its survival was unlikely.

The earliest historical record worldwide of a humpback whale strike may be from Gilmore (1959) who speculated that reports of "flukeless" humpback whales off California in the 1950's were caused by ship strikes. To date, only two reports have been produced that review vessel collisions with humpback whales. Wiley et al. (1994) examined records of humpback whale strandings along the U.S. Atlantic coast between 1985 and 1992 (most were in the vicinity of Chesapeake Bay). They reported that 30% (6 of 20) of stranded individuals had injuries caused by vessels. Laist et al. (2001) conducted a much more comprehensive study on whale/vessel collisions worldwide, which included humpback whales along with several of the other great whale species. Their study compiled and analyzed records of motorized boat strikes from historical sources, whale stranding records and anecdotal accounts from boats involved in collisions occurring principally along the coasts of the U.S. Atlantic and Gulf of Mexico, the British Isles, Italy, France, and South Africa, but also including some data from Alaska and Antartica. Although historical records revealed that boat strikes on fin whales (*Balaenoptera physalus*) were most common, collisions with humpback whales (along with right whales, gray whales, and sperm whales) were considered relatively common.

There is some evidence that ship collisions may impact individuals of a species differently depending in part on their age/class, body size, and activity at the time of the collision. From their U.S. stranding data, Laist et al. (2001, Table 2) reported lengths for 9 of the 10 struck humpback whales. An examination of this data revealed two whales below 8 m in length, six whales between 8 and 9 m, and one whale 11.1 m long. In all likelihood, these whales were sexually immature, probably 3 years of age or less (Stevick, 1999). Of the 10 whales listed, three had evidence of propeller wounds and eight had evidence of fractures, dislocations, skeletal damage or blunt trauma. Sex was determined for nine of the whales, six were female and three male. These data suggest that younger whales may be more susceptible to collisions with vessels, perhaps because they typically spend more time at the surface, are less visible, are closer to shore (Herman et al., 1980; Mobley et al., 1999; Smultea, 1994) or due to a combination of these factors. In any case, habitats preferred by calves and juvenile whales may be areas of greater risk of vessel collision, especially if these are also areas of high vessel traffic.

From the anecdotal records examined by Laist et al. (2001), 8 of 32 (25%) collisions with the great whales in which the species was confidently identified involved strikes on humpback whales. Two additional records noted that the injured whale was probably a humpback. An examination of these records indicates that collisions involved several types of vessel including 2 passenger cruise ships, 4 whale-watch boats, 2 coast guard cutters, and 2 fishing vessels. Vessel sizes ranged from 10 m for a private sport-fishing vessel to 730 m for a passenger ship. All incidences occurred in the high latitude feeding grounds in the Atlantic, Pacific, and Southern oceans. With respect to the kinds of injuries sustained, one whale was reported killed, three were categorized as severely injured, three were considered minor, one was not apparent, and two were not classified. Seven of the nine collisions in which the velocity of the vessel was recorded or estimated indicated speeds exceeding 10 knots at the time of impact. Vessel speeds

reported with high precision (i.e., not estimated) indicated that collisions resulting in death or severe injury were typically greater than 14 knots.

One of the limitations of the data reviewed above is that they primarily pertain to the feeding areas of humpback whales or to areas along their migration route. Because humpback whale behavior during the breeding season differs dramatically from that on the feeding grounds, more focused studies on the threat of collisions on the wintering grounds are warranted.

Because the Hawaiian Islands are quite isolated in the Pacific they are highly dependent on vessel traffic for commerce, both in terms of importation and exportation. Additionally, boats represent an important means of transportation and are a major source of revenue for the local economy as the primary tools of the sightseeing, diving, fishing, and whale watching industries. As the number of whales in Hawaii continues to increase together with the number of vessels operating in whale habitats and the size and speed of ships, it is to be expected that some collisions will take place (NMFS, 1991). However, to date very little analytical attention has been paid to incidents locally, which makes it difficult to gauge the severity of the issue from both a conservation and safety standpoint.

This study examines the occurrence of whale/vessel collisions in Hawaii from two perspectives. First, the available historical information is presented on the number and location of collisions described in media reports and government records since 1975. Secondly, the experiences and opinions of local mariners on the issue of whale/vessel collisions is analyzed based on responses obtained from questionnaires that were disseminated to professional mariners across the State. In each case, trends are reported that give insight into the severity of the issue and provide guidance for mitigation and management strategies.

METHODS

The historical occurrence of whale/vessel collisions in Hawaiian waters was investigated by searching through print media archives, government records and the scientific literature for accounts of past incidents. Print media sources examined via microfiche and/or web-based archives included: *The Honolulu Advertiser*, *The Star Bulletin*, *West Hawaii Today*, *The Maui News*, *The Hawaii Herald Tribune*, *Hawaii Fishing News* and *The Garden Isle*. Some of these sources did not come into existence until after 1975, so their databases were searched beginning with the first archives. The government records that were examined included the 'Whale Incident Log' maintained by the Hawaiian Islands Humpback Whale National Marine Sanctuary, stranding and incident records from the National Marine Fisheries Service (NMFS) and information gathered via personal communication with the National Oceanic and Atmospheric Administration's (NOAA) Office of Law Enforcement.

The second approach capitalized on the wealth of information residing with experienced members of Hawaii's maritime community. To access this information, a questionnaire (see the Appendix) was developed and distributed to mariners at several of the major harbors across the islands. Questionnaires were personally disseminated to mariners who indicated interest in participating in the survey. Each questionnaire included a cover letter describing the purpose of the study and an assurance that all responses would be kept confidential and anonymous. A stamped return envelope was also provided. The harbors where the questionnaire was distributed included: Port Allen and Nawiliwili Harbor on Kauai; Kewalo Basin, Honolulu Harbor and Ko'Olina Marina on Oahu; Lahaina Harbor and Maalaea Harbor on Maui; and Kawaihae Harbor,

Honokohau Harbor and Kailua Bay on the Big Island. Each harbor was visited at least twice, typically once in the morning and once in the afternoon.

RESULTS

Historical records of whale/vessel collisions

Between 1975 and 2003 twenty-two (22) whale/vessel collisions were publicly reported. Maui had the highest incidence of collisions, while Kauai had the lowest (Fig. 1). There was an increase in the number of reported collisions over the period examined. Only two (2) incidents were reported between 1975 and 1984, six (6) between 1985 and 1994, and fourteen (14) between 1995 and 2003. The following is a brief summary of each incident as it was reported in the local print media, government records and/or the scientific literature:

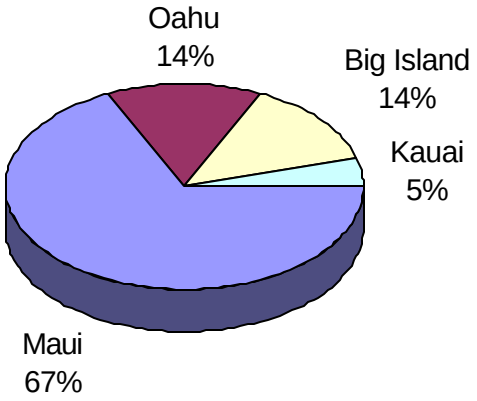

Figure 1 – Occurrence of whale/vessel collisions by island between 1975 and 2003

1979, date not specified: Off Maui. A whale researcher reported that a humpback whale calf dove below her rubber boat, accidentally picking up a pontoon. No further details given. Reported in an April 1st, 2002 Star Bulletin article.

February 2nd, 1981: 1.5 miles off Puako, Hawaii an adult whale breached immediately in front of a trimaran sailing vessel, coming down between the center and starboard pods. The forward section of the side pod was broken off. No specific injuries were noted on the whale. At the time of the incident the vessel was traveling at 7 knots. Reported in West Hawaii Today and the HIHWNMS Whale incident log.

January 1st, 1987: Off Kona, Hawaii a diving charter boat collided with a whale while traveling at "full throttle" (speed not specified), leaving skin and blubber on the driveshaft. The extent of the injuries to the whale was unknown. Reported in the HIHWNMS Whale incident log.

March 26th, 1988: Off Molokini, Maui a 24-ft vessel traveling at 30 mph struck an adult whale. The whale hit under the boat's stern. It was thought to have been unharmed and was seen swimming away. Reported in the Maui News and the HIHWNMS Whale incident log.

March 1st, 1990: Off Kawaihae, Hawaii a 19-ft fishing vessel struck a whale as it started up after hauling in a catch. The whale lifted the boat out of the water momentarily. No injuries were noted on the whale, but damage was sustained on the boat. Reported in Hawaii Fishing News, West Hawaii Today and the HIHWNMS Whale incident log.

February 10th, 1994: Off Lahaina, Maui a U.S. Coast Guard vessel spotted a whale of unspecified age or sex with two relatively fresh lacerations on the dorsal fin from a propeller. Reported in the HIHWNMS Whale incident log.

February 22nd, 1995: Off Lahaina, Maui a 65-ft sailing vessel struck a mother/calf pair. A mark was reportedly visible on the mother. Reported in the Star Bulletin, Honolulu Advertiser, the Maui News and the HIHWNMS Whale incident log.

January 16th, 1996: 5 miles off Wailea, Maui an 82-ft twin hull vessel struck an adult male whale. The vessel was traveling at approximately 8 knots when it sighted the whale. The engine was placed in neutral, but the whale pushed the vessel up as it swam under. No mention of injuries or damage to the vessel. Reported in the Honolulu Advertiser and Maui News.

January 18th, 1996: Nanakuli, Oahu. A male calf (4.42 m in length) was found stranded alive and injured in the afternoon and seen at nightfall with portions of the umbilicus attached. It was found the following day. Injuries included propeller wounds on the dorsal side, and cause of death was assumed to be trauma from a propeller strike. Reported in Mazzuca et al., (1998) and the Star Bulletin.

January 21st, 1996: Off Launiupoko, Maui an adult female with a severe spinal deformity and heavily infested with whale lice was sighted with several tiger sharks nearby. The spinal deformity was strongly suggestive of blunt trauma resulting from a collision with a vessel (A. Pack, pers. obs.). The whale had difficulty moving it's caudal peduncle. It was presumed to have died shortly after the sighting. Reported by Osmond and Kaufman (1999), the Honolulu Advertiser and Maui News.

January 22nd, 1996: Off Maalaea, Maui an adult female with a calf was spotted with a fresh piece of flesh gouged out, apparently from a collision with a vessel. Reported in the Honolulu Advertiser and Maui News.

January 1st, 1998: A cetacean presumed to be a humpback whale was struck off Maui (no specific location reported) by an 82-ft twin hull vessel. The whale swam off in unknown condition. Reported in NMFS database.

March 30th, 1998: Off Pearl Harbor, Oahu. A U.S. Navy submarine traveling at 8 knots struck a large cetacean presumed to be a humpback whale. The whale was spotted in front on the ship's bow. The engine was put in neutral, but the whale was struck on its left side. The whale tail slapped then swam away in unknown condition. Reported in NMFS database.

March 25, 1999: Off Maui. Researchers sighted a calf with a fresh, deep wound from a propeller on its back. The calf and mother were re-sighted in the Maui region on three other occasions over a period of 38 days. During this time the calf appeared to make a recovery. Reported by Deakos et al. (1999) in Abstracts of the 13th Biennial Conference on the Biology of Marine Mammals, Wailea, Maui. The following year, the injured whale (now a yearling) was re-sighted in Maui waters (Deakos, pers. comm.).

February 4th, 2000: Off Waimanalo, Oahu. A 20-ft fishing vessel traveling at 8 knots struck a whale. The whale was observed swimming off. Reported in the Honolulu Advertiser.

February 15th, 2001: Off Port Allen, Kauai a juvenile whale breached on top of a stationary 40-ft catamaran engaged in whale watching. The whale swam away apparently unhurt. Reported in the Star Bulletin.

March 15th, 2002: 6.2 miles off Maalaea, Maui a whale struck a stationary 65-ft catamaran engaged in whale watching with its head. The whale followed the vessel as it left the area. No apparent injuries or damage to the vessel. Reported in the Honolulu Advertiser.

March 27th, 2002: Off Lahaina, Maui a calf was reported struck by an undisclosed type of vessel. Witnesses reported seeing scars on the calf's back. Reported by the NOAA Office of Law Enforcement.

February 10th, 2003: Off Maalaea, Maui a whale watching charter boat reported feeling a "bump" as it left the harbor. The vessel stopped and saw a subadult whale surface nearby. The whale was observed for 15-20 minutes, but no visible signs of injury were noted. Reported by the NOAA Office of Law Enforcement.

March 7th, 2003: Off Maalaea, Maui a whale watching charter boat struck a whale while returning to the harbor past sunset. The whale could be seen rolling in the wake. No visible injuries to the whale or damage to the vessel were reported. The vessel was traveling at 16-17 knots when it struck the whale. Reported by the NOAA Office of Law Enforcement.

At least two additional incidents occurring in the late eighties/early nineties were reported by a humpback whale researcher on Maui in a Star Bulletin story on April 1st, 2002. In each case, a whale bumped the research vessel as it was operating in neutral gear. No injuries or damages were reported. Locations were not given.

The reported incidents included cases of humpback whales incurring propeller wounds as well as blunt trauma. Figure 2 shows that of the 14 incidents in which the age class of the whale was specified, nearly 60% involved calves or juveniles.

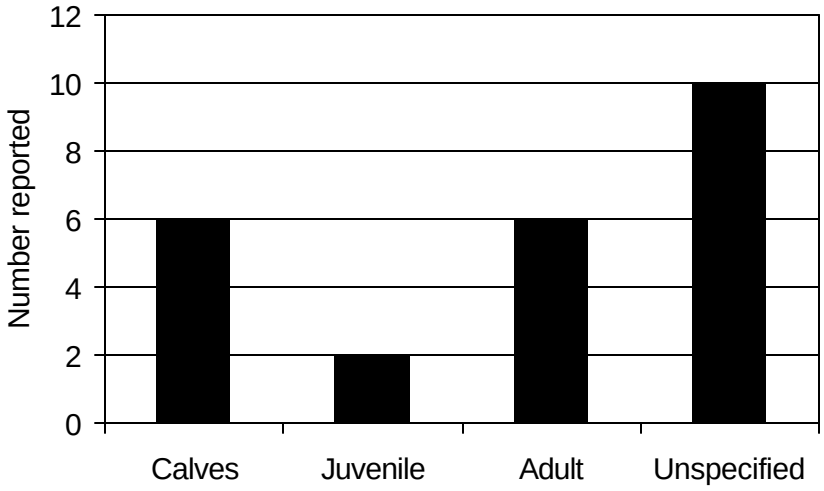

Figure 2. The number of collisions with whales of different age classes in Hawaiian waters (1975 – 2003).

Collision questionnaire responses

Approximately 150 questionnaires were distributed in person and via email to experienced mariners in the Hawaiian Islands. The exact number is not known because electronic questionnaires were also forwarded to an unspecified number of people via intermediaries. Fifty-eight completed questionnaires were returned via mail or email.

It should be noted that participants were not selected randomly from a statistical standpoint because restrictions on when and where we could access appropriate candidates limited our ability to randomize the selection process. Respondents represent a haphazardly selected sample of Hawaii's mariners who chose to respond to our request for information. Consequently, no formal statistical inference has been attempted. The trends described below should be interpreted with some degree of caution and not be assumed to necessarily reflect the experiences and opinions of all of Hawaii's mariners.

Respondent characteristics:

Respondents were classified according to the island(s) for which they had the greatest level of experience, the number of years spent on the water, the primary context of their experience and the size of the vessel they typically operated. In total, 13 respondents identified themselves as being primarily associated with waters around Kauai, 12 Oahu, 17 the Maui, Molokai and Lanai region, 12 the Big Island, and 4 with waters between the islands. The level of experience reported varied considerably, but 91.3% or respondents indicated they had spent 5 or more years in waters around a specific island. The context of the respondent's experience also ranged and in several cases multiple primary contexts were reported (Fig. 3). However, the vast majority

(82.8%) identified themselves as professionals whose livelihood was tied to working on the water. Finally, over half (56.9%) of respondents indicated that their primary experience was with vessels of medium (31-60 ft) size, 19.0% with small vessels (30 ft), 13.8% with very large vessels (> 100 ft), and 10.3% with large vessels (61-100 ft).

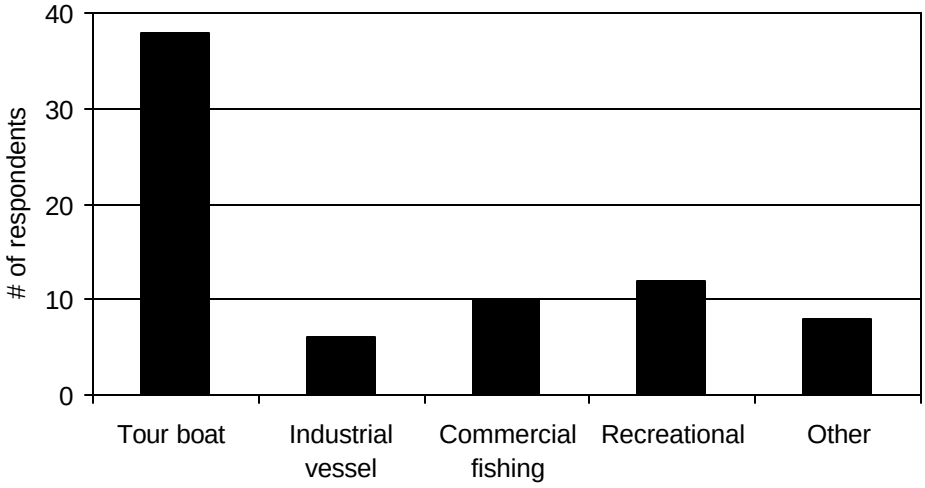

Figure 3 – Questionnaire respondents' occupation(s) or maritime activity.

Questionnaire responses:

The respondent's answers to the questionnaire (see the Appendix) are summarized below.

Questions #4 & #5:

31 out of 58 respondents (53.4%) answered that they were aware of one or more collisions taking place between a vessel and a whale in Hawaiian waters during the period between 1998 and 2002. 27 (46.6%) answered they were not aware of any. The 31 respondents who answered affirmatively were asked to provide an estimate of the number of incidents they had knowledge of for the past five years. Almost two thirds (64.5%) reported that they knew of 1-2 incidents for this period. Nine (29.0%) knew of 3-5 incidents, 1 (0.03%) knew of 6-8 incidents and 1 reported knowing about more than 12 incidents.

Question #6:

Those respondents who answered affirmatively to question 4 were also asked to indicate near which island(s) the incident(s) they were aware of had occurred. Table 1 summarizes their averaged responses. By and large the most incidents were reported occurring in the Maui, Molokai and Lanai region. The number occurring in the historical database is also presented for comparison.

Table 1 – The average number of whale/vessel collisions per island region reported per respondent compared with the number of reports obtained from historical records. S.D. = standard deviation, Max. = maximum number reported, N = the number of respondents claiming knowledge of incidents for an island or region.

	Avg.	S.D.	Max.	N	No. in historical records (1998-2003)
Kauai	1.17	0.39	2	11	1
Oahu	1.50	0.71	2	2	2
Maui, Molokai & Lanai	3.25	2.84	13	20	6
Big Island	1	0	1	1	0
Interisland channels	--	--	--	0	0
Not sure	2	0	2	1	N/A

Question #7:

Respondents who had knowledge of collisions were asked to report the type of vessels that were involved. Vessels were characterized according to their size class and estimated top speed. To provide a relative comparison between vessel types the frequency of reports is presented in Figures 4 and 5. These frequencies were calculated as: total number reported for a class/total number reported x 100.

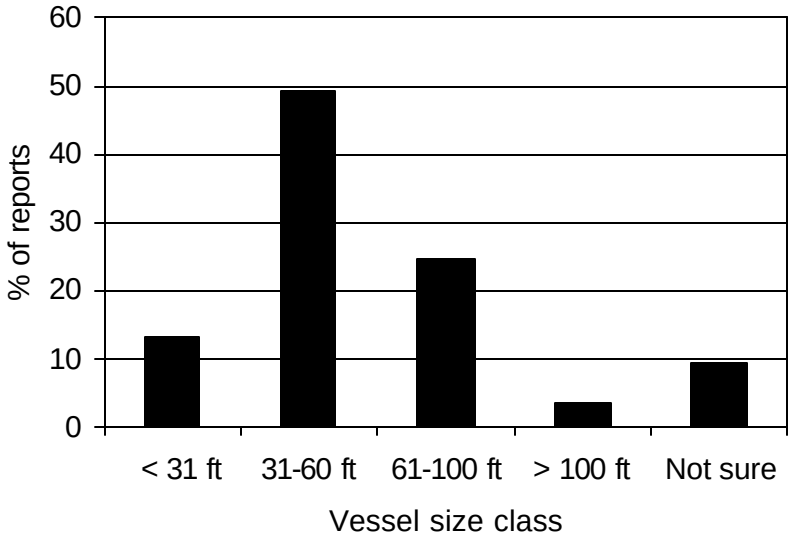

Figure 4 – The frequency of vessel size classes involved in collisions with whales as reported by questionnaire respondents.

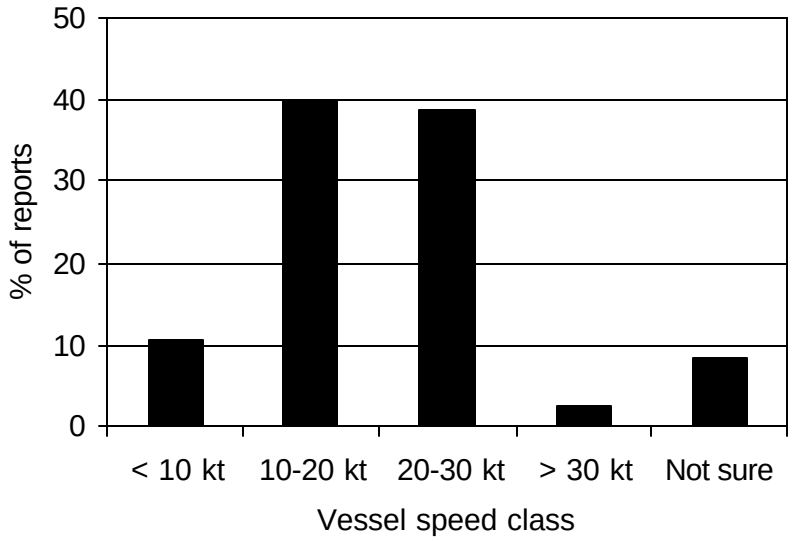

Figure 5 – The frequency of vessel speed classes (based on estimated top speed) involved in collisions with whales as reported by questionnaire respondents.

Questions #8, #9 & #10:

11 of the 58 respondents (19.0%) answered that they had come across a whale with recent vessel collision injuries. All indicated that they reported the sighting to one or more government entities or individuals. Incidents were reported most frequently to a Federal agency, specifically the National Marine Fisheries Service (Fig. 6). Other boaters and researchers were also commonly contacted.

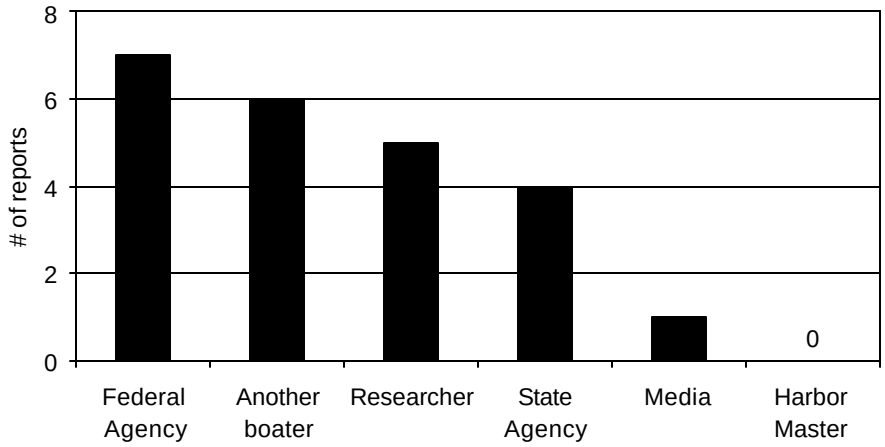

Figure 6 – Reports of injured whales made to government and private entities by questionnaire respondents.

Question #11:

45 (78.9%) respondents expressed at least some level of concern over the issue of whale/ship collisions in Hawaii. One third (33.3%) indicated they were "very" concerned about the issue, close to half (45.6%) said they were "somewhat" concerned and approximately one fifth (21.1%) replied they had no concerns at all. The level of concern over the issue varied somewhat with respect to the island or region from which respondents hailed, with mariners from the Maui, Molokai, Lanai region generally expressing the most concern. The level of concern did not vary much with respect to the type or mariner. Tour boat operators expressed on average slightly more concern than the rest, but the other groups each averaged the "somewhat" concerned level.

Questions #12 & #13:

51 respondents expressed an opinion about the percentage of whale/ship collisions they believe get reported. Almost half (24 respondents; 47.1%) estimated that less than one quarter of incidents get reported to the media or local authorities, 8 (15.7%) answered 26-50%, 5 (9.8%) answered 51-75% and 14 (27.5%) believed reporting was close to 100%.

56 respondents offered an opinion regarding whether/how improvements could be made to the reporting process of whale/ship collisions. 22 selected more than one improvement. The most common suggestion was to allow anonymous reports to be made (Fig. 7). Also popular were suggestions for a public awareness campaign and the establishment of a toll-free hotline for reporting. 12 respondents (21.4%) felt no improvements were needed.

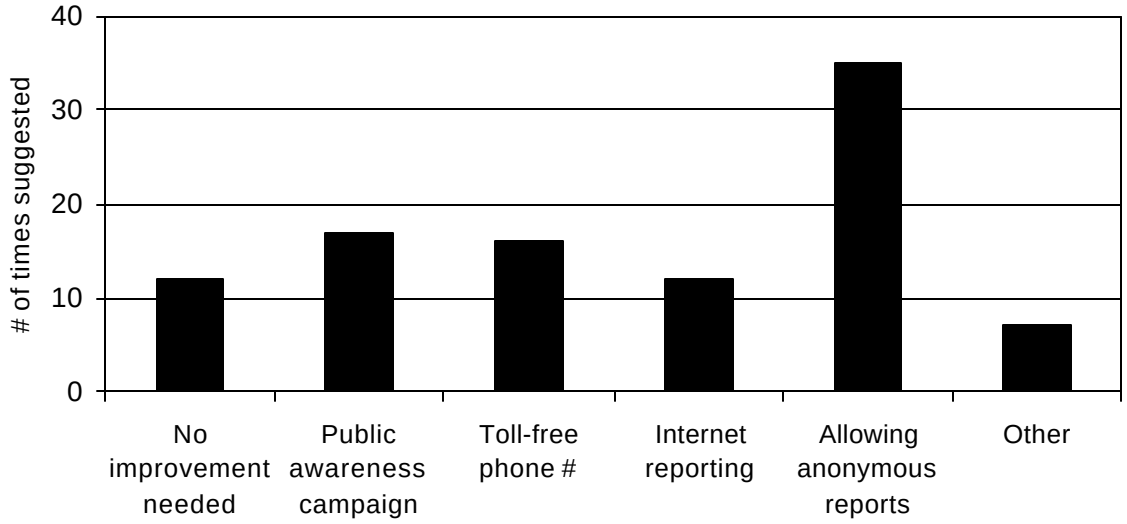

Figure 7 – Suggestions made by questionnaire respondents for improving the reporting process of whale/vessel collisions.

DISCUSSION

Historical Database

Reported whale/vessel collisions:

The increased frequency of collisions reported between 1975 and 2003 suggests that these incidents are on the rise in Hawaiian waters. In the past ten years the number of reports made nearly tripled from the previous decade (0.5/year between 1984-93 vs. 1.5/year between 1994-2003), with close to half of all reports (9 out of 22) occurring during the past five years. These numbers, which are almost certainly not inclusive of all incidents that have taken place, indicate that attention to this issue is timely and that some measure of concern is valid from both a conservation and safety standpoint.

There are likely a number factors contributing to the increasing rate of incidents. Probably the most significant is that the number of humpback whales wintering in Hawaiian waters has been steadily increasing over the past three decades. As mentioned earlier, the North Pacific stock of humpback whales, which had been heavily depleted by whaling until the latter half of the 20th century, is recovering. Mobely et al. (2001) have estimated that Hawaii's population is increasing at a rate of 7% each year. If we assume that this rate has remained more or less consistent over the twenty-eight year period considered in this study, then there are likely over six times the number of whales in Hawaiian waters these days as there were in the mid 1970s. Consequently, the increased probability of encounter alone predicts a rise in the number of yearly whale/vessel collision incidents between then and today.

Another likely factor is the parallel increase in the number of vessels transiting through and/or occupying areas preferred by whales, such as the west Maui region where the whale population is among the densest in Hawaii (Herman et al., 1980; Mobley et al., 1999). The rising popularity of whale watching and the increased focus on Maui as a primary tourist destination in Hawaii have resulted in a rising number of commercial vessels engaged in eco-tourism, diving and fishing activities in Maui and the surrounding region. Here again, the resulting higher probability of encounter surely accounts for at least some of the increase in collision frequency.

Finally, confounding factors must also be considered as a potential, if only partial, explanation for the noted increase in reports. Improvements in reporting by the media and mariners and/or better record keeping in recent years may have influenced the results of our search for information. For example, several of the reports obtained for the last ten years came from Government records, for which we could not find a long-term database spanning the earlier periods of the study. Also, it is not clear whether and how much some of the drastic advances in communication of the 1990's may have impacted the reporting and data gathering process. Certainly the widespread ability to post and send information electronically, which has become a trademark of our society over the past ten years, could present a potential biasing factor in any effort to gather information spanning the time both before and during this period.

Collision characteristics:

As noted earlier, vessel collisions with whales can result in two types of injuries, propeller wounds and blunt trauma. Both types are evident in our compiled whale/vessel collision

database. The data compiled by Laist et al. (2001) indicated that calves and juveniles were highly vulnerable to boat collisions. For humpback whales in Hawaiian waters, we found that 8 of the 14 incidents (57%) in which the age class of the whale was specified involved either a calf or a juvenile.

The whale/vessel collision reports appearing in our database can be grouped into three general categories. The first category encompasses collisions that occur with little or no forewarning between a whale and a traveling vessel. Over half of the incidents reported (12 of 22) fall under this category. Both motorized and sailing vessels were implicated in these incidents, but cases involving motor vessel were ten times more frequent than those involving vessels under sail. In the eight cases where some indication of vessel speed is provided (either given or inferred by the type of vessel involved) it ranged from 7 knots (8 mph) to 26 knots (30 mph). Of these, five were traveling at 8 knots or less, the others at speeds probably exceeding 15 knots (the exact "full-throttle" speed of the diving vessel involved on 1/1/1987 is not known).

Typical in this category of incidents are accounts of a whale surfacing directly in front of the vessel without sufficient warning for either the whale or the vessel to take evasive action. Considering that such cases were reported for both slow and fast moving craft, it suggests that, in at least some situations, the whales were either not aware of the vessel's presence or could not resolve it's proximity and/or vector of travel based on the available acoustic cues (see Bauer & Herman, 1986, for effects of vessel approaches on humpback whale behavior in Hawaiian waters). We can only speculate on this, however, because very little is currently known about the hearing acuity or the ability to localize sound of humpback whales, or any of the other large baleen whales (Erbe, 2002)

Additionally, the social context of the situation may also play an important role in collisions. Nursing mothers may be reluctant to take fast evasive action for fear of abandoning a neonate or young calf and the calves themselves may be naïve to the dangers of the approaching vessel. Males, on the other hand, preoccupied with competition for females, may not be willing to give up their position relative to a female or yield in a confrontation with another male. In other words, because behavioral processes related to reproduction are the primary pre-occupation of most humpback whales while in Hawaii, some individuals may simply be less reactive to distraction from nearby human activities than they would be otherwise.

The second category of incidents includes those in which whales were struck as a result of an effort to intentionally maneuver around them, such as during whale-watch or research activities. Five such cases were reported. In one incident, a juvenile whale breached onto a stationary vessel, causing injury to a passenger. Accounts of the incident indicate that the whale had been very active on the surface prior to its collision with the vessel and that it simply misjudged or was not aware of the vessel's location/presence. In the other four incidents, the whale "bumped" the vessel as it was idling in neutral gear nearby. It appears that on at least one occasion the bump was deliberate on the part of the whale, considering that it pursued the vessel following the collision.

These incidents lend support to the suggestion that whales may, in some cases, become quite distracted and either remain unaware of a nearby vessel, or perhaps view it as a threat to their mating/courtship activities. Additionally, juvenile whales may investigate stationary boats out of curiosity, and adult females may use larger vessels to evade advances by males. With the exception of the juvenile whale breaching onto the vessel, these incidents probably pose a relatively low risk of injury for the whale, assuming the propellers are not engaged. However,

the effect on the whale's behavior could be substantial and as a result create a significant disruption as well as a potential risk to the vessel and it's passengers.

The third and final category of incidents encompasses those that are mostly circumstantial. These are cases where the collision itself was not reported, but evidence of recent trauma from a collision is described. Five such cases appear in our database. The relatively low number, however, probably does not accurately reflect the number of whales with such injuries. Injured, but living whales are likely less newsworthy than actual collisions. Additionally, in order to be visible to boaters, the injury needs to be on the dorsal side, where the whale's body usually protrudes while at the surface. This may often not be the case, particularly with respect to blunt trauma injuries.

One of the incidents reported in the press came on the heels of a report earlier in the week of a collision on Maui. Based on the accounts given, it is unclear whether it was the same whale in both reports. We deem it unlikely because the whale that was hit earlier in the week was described as a lone male, whereas the whale with the injuries was reported to be a mother with a calf. Interestingly, two more reports of injured whales were made during that same week. One of these, the whale reported by Osmond and Kaufman (1999) detailing a lice-infested adult female with a spinal deformity, was judged by one of us who witnessed the whale first hand (A. Pack) as almost certainly a victim of a vessel collision. The other was the very young calf found dead on the beach near Nanakuli, Oahu. The nature and severity of this whale's injuries clearly indicated an encounter with a boat propeller, although whether this was the actual cause of death or a post-mortem injury is unknown.

A Coast Guard vessel made one of the other two circumstantial reports. However, few details were given besides the location of the animal. Finally, the fifth incident was reported at a scientific meeting as evidence of recovery by a calf following a propeller related injury (Deakos et al, 1999). This observation provides intriguing evidence that in at least some cases collisions with calves are not necessarily fatal despite rather severe injury.

The extent of injuries suffered from collisions by whales is a difficult variable to quantify. Laist et al (2001) indicated that trauma suffered from collisions among stranded whales is often not apparent unless a thorough necropsy is performed and the integrity of the bones is examined by flensing through the blubber. Lacerations resulting from propeller cuts are the more obvious form of injury observable, but perhaps not necessarily the most common type. Blunt trauma such as fractures and internal bleeding are more difficult to establish and probably go unnoticed more often. Therefore, although several of the reports described suggested that no injuries were sustained, these assessments were likely biased by the ability to only view the presence or absence of surface injuries.

It should be noted that, other than the two apparently fatal cases involving the whale described by Osmond and Kaufman (1998) and the dead stranded calf with propeller injuries on Oahu, no other fatal incidents were reported. This does not exclude the possibility that additional individuals may not have also perished some time following the collision as a result of their injuries. However, our examination of the available government stranding information did not find evidence of this. In fairness, however, the stranding records available generally lacked sufficient detail to infer the cause of death of the whale.

Additionally, no cases of whale carcasses pinned to the bow of ships were reported in Hawaii during the period examined. This is in contrast to the findings of Laist et al. (2001) for whom such cases comprised a significant component of the database. In Hawaii, it appears, most vessels involved in collisions are small to medium sized boats ranging in length from 19 to

approximately 80 feet. The lack of incidents reported involving large ships is somewhat curious, but perhaps indicates that presently established shipping lanes are not a major problem in this regard. However, a more thorough assessment of this assumption is clearly warranted, as alternate explanations such as under-reporting are equally likely.

Questionnaire Database

The questionnaire responses provide valuable insight into the experiences and opinions of local mariners on the issue of whale/vessel collisions in Hawaii. While not exhaustive in its representation of Hawaii's maritime community, the survey does provide added information that could not be derived from an examination of the historical database alone.

Reported whale/vessel collisions:

Most of the mariners that responded to the questionnaire were aware of at least some whale/vessel collision incidents occurring over the last few years. Due to the anonymous nature of the questionnaire, it was not possible to establish the extent to which cited cases overlapped between respondents or with reports compiled from historical records. Therefore, the absolute number of known collisions cannot be derived, but relative comparisons between islands or regions are possible.

As was the case with the historical records, the Maui, Molokai and Lanai region had the highest proportion of known whale/vessel collisions. Combined, the two sets of data provide compelling evidence that this region is more prone to such incidents than any other in the Hawaiian archipelago. This does not come as a great surprise considering that the so-called 'four-island region' (which includes the uninhabited island of Kahoolawe) has been known for some time to have among the densest concentrations of wintering whales in the islands, with only Penguin Banks, off the western coast of Molokai, reaching similar or greater abundances (Baker and Herman, 1981; Mobley et al., 1999). For the most part, the average number of incidents reported by respondents was somewhat lower for Maui than the number appearing in the historical database for the same period. Two individuals, however, indicated knowledge of 8 and 13 incidents, which is higher than the 6 appearing historically.

Oahu had the second most reported incidents, although this was based on only the reports of two respondents. However, the trend matched the historical information in terms of the relative number of collisions by island reported for the same period (Table 1). Kauai and the Big Island had the fewest reports of incidents in both data sets. Several respondents indicated knowledge of one incident on Kauai, which in all likelihood was the highly publicized case involving the juvenile whale breaching into the whale-watch boat. Two individuals knew of at least one other incident. On the Big Island, one respondent reported a single case although none appeared historically for the same period.

When questioned about the types of vessels involved in the collisions, the majority of respondents implicated medium sized boats ranging from 31 to 60 feet in length with top speeds between 10 and 30 knots. Large (61-100 ft) boats were also frequently involved, whereas small (< 31 ft) and very large (> 100 ft) vessels comprised only 16% of all reports combined. Noteworthy is the response from one individual who implicated very large vessels being

involved twice on Oahu (the respondent's primary experience was with this category of vessel). Only one such incident involving a navy submarine appears in the historical database.

Based on both sets of information, medium to large boats with top speeds of 10-20 knots or faster appear to be the primary class of vessels involved in collisions in Hawaiian waters. This profile fits the description of most private and commercial pleasure and fishing craft associated with daily coastal traffic in Hawaii. Two explanations are likely for why these are the most commonly involved vessels. First, several of the incidents reported involved whale-watching vessels, which by their very nature seek out and transit through areas with high whale densities. Second, the coastal waters used by most recreational and commercial boaters likely overlap considerably with the preferred habitats of whales. The highest concentrations of whales are consistently found near island slopes and banks less than 100 fathoms (600 feet) deep (Herman et al. 1980; Mobley et al., 1999; Lammers et al. 2001). Local fishermen, diving charters and many smaller transiting vessels seeking protection from rough offshore conditions all heavily use these nearshore waters. In fact, all vessels, regardless of their destination, at some point transit across the 100-fathom coastal shelf when entering or leaving any of Hawaii's harbors. Thus, while perhaps unbeknownst to most boaters, their travel paths may quite frequently intersect those of whales in the area.

Reporting of incidents:

It is difficult to empirically gauge what percentage of whale/vessel collision incidents get reported to the media or the authorities. However, based on the discrepancies noted between the historical database and several of the respondents' questionnaires it is clear that not all incidents are reported and/or that record keeping is not comprehensive. Based on the responses given regarding the reporting issue (question # 12), it appears that most mariners believe that many if not most incidents go unreported. Certainly within the historical record itself, there are indications that some incidents for which respondents claimed knowledge were never brought to the attention of the media or the authorities. If we consider that almost half of respondents believe that only a quarter or less of all incidents actually get reported, it could well be that the problem is considerably greater than the records suggest.

The apparent good news is that the shortcomings in the reporting process can probably be addressed and to some degree resolved. The fact that all those who indicated they had come across an injured whale also claimed they made a report is an encouraging sign that most mariners are willing to make the effort to pass on information. Furthermore, almost 80% expressed at least some concern over the whale/vessel collision issue. In other words, there appears to be the interest and willingness among most mariners in Hawaii to work with the appropriate authorities on ways to improve the situation.

When asked how the reporting of collisions could be improved, over 60% of respondents included 'allowing anonymous reports to be made' as part of their answer. This indicates that, while there may be a willingness to assist management agencies to mitigate the problem, there are also concerns over the potential consequences of doing so. Clearly, the majority of collisions are accidental. However, fears of lengthy investigations and potential fines probably make many mariners reluctant to disclose their knowledge of these incidents. A statement written across one respondent's unanswered questionnaire perhaps illustrated this point best. He/she exclaimed in large letters: "You won't get me to snitch!"

Also popular among many respondents were suggestions of a public awareness campaign and the establishment of a toll-free phone number for making reports. It would appear, therefore, that for many mariners education on the issue combined with a well-publicized anonymous telephone reporting system would be the preferred management approach.

Conclusions:

The results indicate that whale/vessel collisions in Hawaiian waters are occurring with increased frequency and will likely continue to increase unless steps are taken to actively mitigate the problem. Providing specific recommendations to this end is beyond the scope of this report. However, making some general suggestions based on what the available data reveal is warranted.

The findings presented indicate that, while a potential for whale/vessel collisions exists island-wide, certain areas are more problematic than others. These areas, not surprisingly, coincide with locations that have high whale densities and high vessel traffic. Therefore, it appears important that an understanding of whale distribution and habitat use patterns become an integral part of any future management effort. Some of this work has already taken place. Evidence indicates that humpback whales have a strong affinity for waters shallower than 100 fathoms and that the highest densities of whales are found in the four-island region and penguin banks (Herman et al., 1980; Mobley et al., 1999). Additionally, Craig and Herman (2000) found that calves formed a greater proportion of the whale population off Maui than off the Big Island, and that individual females were on average found more often in Maui waters in years they were with a calf, and in waters off the Big Island in years they were without a calf. The extent to which juvenile whales (another vulnerable class of humpbacks) show habitat preferences has yet to be determined. Educating Hawaii's maritime community about these scientifically established trends, together with providing recommendations on how to minimize the likelihood of a collision in sensitive areas (e.g., reducing speed, posting a lookout, knowing what to look for), would be a significant step in the right direction. Encouraging and supporting research efforts to characterize the occurrence and distribution patterns of whales in a variety of locations would be another.

Finally, our efforts to gather the available evidence on whale/vessel collisions in Hawaii revealed two areas that require considerable improvement. First, our investigation into the historical record of ship collisions with whales revealed that information on this subject is presently quite scattered and undoubtedly not comprehensive. Consequently, no data management system or central repository of records exists that could be used to gauge the effectiveness of any future mitigation efforts. This is a problem that could be solved by establishing a centralized database with a publicized means to accept reports. To be most effective in gathering information, such a system should be able to receive anonymous reports and not be tied to a government enforcement agency. Furthermore, efforts should be made to gather standardized information that includes photo-identification of the whale (i.e., photo of the ventral side of its tail flukes), the sex of the whale, the length of the whale (in order to determine age/class), a detailed description and photographs of the injuries, the location where the vessel collision occurred or where the injured whale was observed, type and speed of the vessel involved, the number of whales in the pod, and as many other details as possible on the circumstances surrounding the incident.

The second area requiring improvement is the post-mortem handling of stranded whales and dead whales found at sea. As noted above, many blunt trauma injuries can go undetected unless the carcass is flensed to the bone. While this may not always be feasible, as a minimum, detailed information on the carcass and photographic records should be obtained and filed in a database. Such information is critical in order to obtain an accurate assessment of the extent to which vessel collisions are impacting humpback whales in Hawaiian waters.

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APPENDIX

Whale/Vessel Collision Questionnaire

About yourself…

1. Your experience in Hawaiian waters is primarily as a:

A. Tour boat captain/crew
B. Industrial vessel captain/crew
C. Commercial fishing vessel captain/crew
D. Recreational/fishing vessel operator
E. Harbor/shipyard worker
F. Other: _____

2. How many years of experience do you have in waters around the different Hawaiian islands (check all that apply):

	Years			
	1-3	4-8	9-15	> 15
Kauai				
Oahu				
Maui, Molokai & Lanai				
Big Island				
Interisland routes				

3. With what size vessels have you had the most experience in Hawaiian waters? Rank as: 0 = No experience, 1 = Some experience, 2 = The most experience

< 30 ft _____
31-60 ft _____
61-100 ft _____
> 100 ft _____

About your experience…

4. Are you aware of any collisions between a vessel and a humpback whale in Hawaiian waters in the past five years?

Yes_____
No_____

If yes, please proceed to question # 5. If no, skip to # 8.

5. How many whale/ship collisions are you aware have occurred in the last five years (please circle)?

1-2 3-5 6-8 9-12 >12 (# _____)

6. Of these incidents, approximately how many occurred in the following areas?

Kauai	
Oahu	
Maui, Molokai & Lanai	
Big Island	
Interisland channels	
Not sure where	

7. In the table below, please indicate the type of vessels that were involved in these collisions. Specify how many if one type of vessel was associated with more than one collision.

	Vessel's top speed				
Vessel size	< 10 knots	10-20 knots	20-30 knots	> 30 knots	Not sure
< 30 ft					
31-60 ft					
61-100 ft					
> 100 ft					
Not sure					

8. Have you ever come across a whale with recent ship collision injuries?

Yes_____
No_____

If yes, please proceed to question # 9. If no, skip to # 11.

9. Was this whale reported to anybody by you or someone else?

Yes_____
No_____

10. If yes, to whom was it reported (circle all that apply)?

A. Another boater
B. Harbor master
C. State agency (which one? _____)
D. Federal agency (which one? _____)
E. Media (TV, radio, newspaper)
F. Researcher
G. Other _____

In your opinion…

11. How concerned are you about the issue of whale/ship collisions in Hawaii?

Not at all Somewhat Very

12. What percentage of whale/ship collisions in Hawaii do you think get reported to the media and/or the authorities?

10-25% 26-50% 51-75% 76-100%

13. How could the reporting of whale/ship collisions in Hawaii be improved?

A. No improvement needed
B. Through a public awareness campaign
C. Reporting via a toll-free phone number
D. Reporting via the internet
E. Allowing anonymous reports to be made
F. Other suggestions:_____

14. (Optional) Please add any comments on the back of this page that you feel would be helpful in understanding the whale/ship collision issue in Hawaii.