

## Odontocete Stranding Patterns in the Main Hawaiian Islands (1937–2002): How Do They Compare with Live Animal Surveys?<sup>1</sup>

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**Abstract:** In this study we (1) synthesized 65 yr of odontocete stranding data around the main Hawaiian Islands (1937–2002); (2) analyzed stranding patterns and trends over time; and (3) compared occurrence patterns based on sightings of live animals with stranding data and evaluated the compatibility of these data sets. From 1937 to 2002, 202 odontocete strandings were recorded by the National Marine Fisheries Service, Pacific Islands Regional Office. Strandings increased through time due to increased reporting effort and occurred throughout the year. The four most common of 16 species reported were *Kogia* spp. (18%), spinner dolphins (*Stenella longirostris*) (15%), striped dolphins (*Stenella coeruleoalba*) (11%), and sperm whales (*Physeter macrocephalus*) (10%). The highest proportion of strandings was recorded on O‘ahu (48%), followed by Maui/Lāna‘i (24%), Kaua‘i (12%), Hawai‘i (11%), and Moloka‘i (5%). Comparison with four previously published live animal survey studies suggests that stranding records are a good indicator of species composition and yield reasonable data on the frequency of occurrence of species in the region they cover.

SYSTEMATIC STUDIES OF odontocetes around the main Hawaiian Islands are limited to a few species such as spinner dolphins, *Stenella longirostris* (Norris et al. 1994,

Benoit-Bird 2003, Lammers 2003), and bottlenose dolphins, *Tursiops truncatus* (Baird et al. 2001, 2002). Strandings (Shallenberger 1981, Nitta 1991, Mazzuca et al. 1998, 1999), historical records (Shallenberger 1981, Tomich 1986), opportunistic sightings (Shallenberger 1981), and dedicated surveys (Mobley et al. 2000, 2001, Baird et al. 2003, Barlow 2003, Maldini 2003) have helped to identify 19 species of odontocetes known to occur in that area. Abundance and distribution patterns were documented by Mobley et al. (2000, 2001) for the winter and spring of 1993–1998 and 2000 and, more recently, by Baird et al. (2003) and Barlow (2003). Only one study has documented year-round patterns (Maldini 2003), but it was limited in geographical scope. Until routine scientific monitoring of abundance and distribution patterns of odontocetes is undertaken, strandings documented in the Hawaiian Islands are useful to fill knowledge gaps.

Nitta (1991) reported all cetacean stranding data in Hawaiian waters between 1937 and 1987 but provided no analysis of trends and occurrence patterns; Mazzuca et al. (1998) analyzed strandings of humpback whales (*Megaptera novaeangliae*) between 1972 and 1996, and Mazzuca et al. (1999) analyzed

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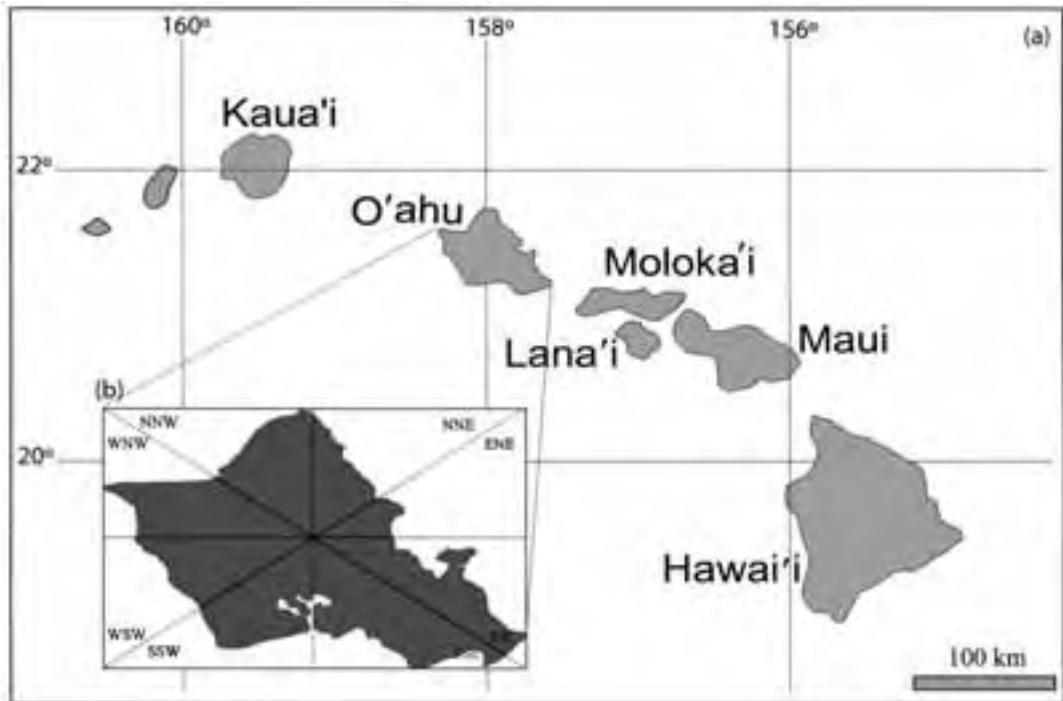


FIGURE 1. (a) Map of the main Hawaiian Islands; (b) diagram of the method used to subdivide each of the main Hawaiian Islands into sectors, according to compass direction, using the island of O'ahu as an example.

cetacean mass strandings between 1957 and 1998. In this study we: (1) synthesized 65 yr of odontocete stranding data around the main Hawaiian Islands (1937–2002); (2) analyzed stranding patterns and trends over time; and (3) compared occurrence patterns based on sightings of live animals with stranding data and evaluated the compatibility of those data sets.

#### MATERIALS AND METHODS

##### *Study Area*

The Hawaiian Island Archipelago consists of a group of volcanic islands, including eight major islands and 124 islets, that stretch in a 1,500-km crescent from Kure Island in the northwest to the island of Hawai'i in the southeast. The archipelago encompasses an area of 16,729 km<sup>2</sup> and is isolated from any other landmass by ca. 4,600 km of deep oceanic water. The five largest islands, from

south to north, are Hawai'i, Maui, Lāna'i, Moloka'i, O'ahu, and Kaua'i, which are known as the main Hawaiian Islands and are the focal region of this study (Figure 1).

##### *Compilation of Stranding Data*

Stranding data from 1937 to 2002 on the main Hawaiian Islands were obtained from the National Marine Fisheries Service, Pacific Islands Regional Office (NMFS/PIR) and previously published work (Shallenberger 1981, Nitta 1991, Mazzuca et al. 1999). The date, species (when identifiable), location of stranding, and number of animals present were obtained from the stranding records included in the NMFS/PIR database (summarized in Appendix 1). Exact latitude and longitude coordinates were not available in the NMFS/PIR database; therefore, the closest town to the stranding site was used to indicate location (Appendix 1).

### *Stranding Patterns*

Differences in stranding frequency by species, island, sector (each representing a different compass direction [see definition following]), and season were investigated for all the main Hawaiian Islands. The database did not contain any strandings for the islands of Ni'ihau and Kaho'olawe (the federal stranding network is inactive on those islands because beach access on Ni'ihau is limited to native Hawaiians, and Kaho'olawe is uninhabited), and strandings for Maui and Lāna'i were combined because only three strandings were reported on Lāna'i.

To determine if the distribution of strandings was skewed toward a particular compass direction, each island was divided into eight wedge-shaped sectors (Figure 1). The length of the coastline delimited by each sector was calculated (in kilometers) using a measuring tool included in the ArcView (1997) software package. Number of strandings per kilometer of coastline was calculated for each compass direction and for each island. Although accounting for population size on each island was considered, the time frame of the database was too wide and population size on some Hawaiian Islands has varied considerably within the period of time in question, making potential search effort too complex to take into account with this method. Comparisons among islands and sectors were accomplished using a two-way analysis of variance (ANOVA). A Tukey's multiple comparison was used to explain significant differences between islands or sectors. A Kruskal-Wallis test was used to detect significant differences in number of strandings per month.

### *Comparison with Live Animal Surveys*

The species composition in the stranding record for all main Hawaiian Islands was compared with four recent studies employing either boat or aerial surveys to determine abundance and distribution patterns of cetaceans in the same region: (1) Mobley et al. (2000), (2) Baird et al. (2003), (3) Barlow (2003), and (4) Maldini (2003). These studies

covered overlapping areas of the main Hawaiian Islands but generally differed by the extent of coverage.

Mobley et al. (2000) conducted aerial surveys within ca. 42 km of the main Hawaiian Islands covering an area of 71,954 km<sup>2</sup> between February and April 1993, 1995, and 1998. Baird et al. (2003) conducted boat-based surveys covering 8,461 km of trackline around the main Hawaiian Islands in May and June 2003. Although they used different survey platforms, Mobley's and Baird's studies covered both inshore and offshore areas at a similar range of depths. Barlow (2003) conducted systematic ship-based surveys of 20,000 km of transect lines around the entire U.S. Economic Exclusion Zone (EEZ) surrounding Hawai'i in summer/fall 2002. That study surveyed the deepest waters but lacked coverage close to shore. Maldini (2003) conducted year-round aerial surveys of waters 0 to 500 m deep around the island of O'ahu between 1998 and 2000.

Frequency of occurrence of each odontocete species in the stranding data was compared with its occurrence in each of the four live animal studies using *z*-statistics. These studies are referred to as Baird, Barlow, Mobley, and Maldini, respectively, in the Results.

## RESULTS

### *Total Strandings and Trends over Time*

Between 1937 and 2002, 202 odontocete strandings were recorded in the main Hawaiian Islands by the NMFS/PIR. Although records in the NMFS/PIR database dated back to 1937, the first odontocete stranding was documented in 1950. One hundred and eighty-two strandings were identifiable to species, seven to genus (six *Kogia* spp. and one *Stenella* spp.), two were doubtful identifications (one short-finned pilot whale, *Globicephala macrorhynchus*, and one *Kogia* spp.) because of the state of decomposition of the carcass, and 11 were unidentified (Appendix 1). The temporal trend in the data showed an increase in the number of strandings with time (Figure 2).

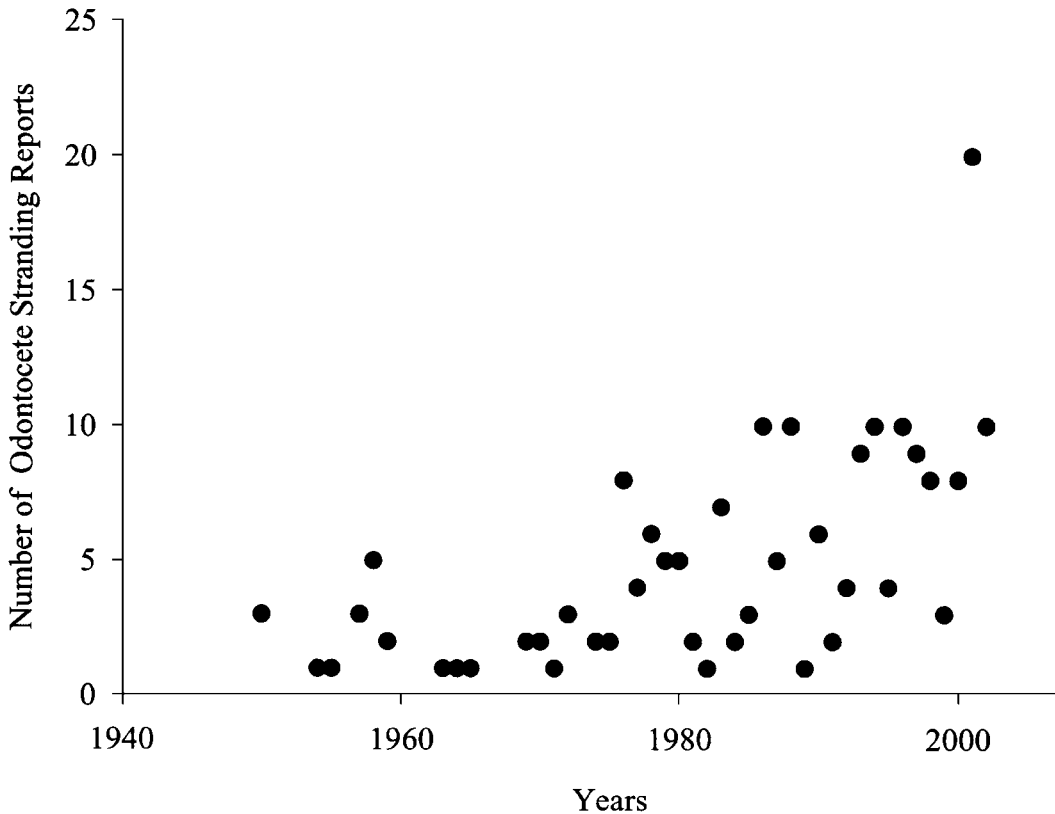


FIGURE 2. Number of odontocete strandings recorded on the main Hawaiian Islands by the National Marine Fisheries Service, Pacific Islands Regional Office between 1937 and 2002. The number of strandings increased substantially throughout the years.

### Stranding Patterns

The highest proportion of strandings was recorded on O'ahu (48%), followed by Maui/Lāna'i (24%), Kaua'i (12%), Hawai'i (11%), and Moloka'i (5%). Average number of strandings per 100 km of coastline was significantly different between islands (ANOVA:  $F = 0.226$ ,  $df = 4$ ,  $P = 0.008$ ; Figure 3) but not between sectors throughout the Islands (ANOVA:  $F = 1.299$ ,  $df = 7$ ,  $P = 0.287$ ; Figure 4). A Tukey's multiple comparison supported the conclusion that differences between islands were explained by the differences between O'ahu and Hawai'i. Strandings occurred throughout the year and the difference in number of strandings per month was not significant (Kruskal-Wallis:  $H = 17.873$ ,  $P = 0.085$ ).

### Species Composition and Comparison with Live Animal Surveys

Sixteen species were included in the stranding record, although pygmy sperm whales (*Kogia breviceps*) and dwarf sperm whales (*Kogia sima*) were pooled as *Kogia* spp. for analysis. All 16 species were observed by Barlow, 12 by Mobley, 14 by Baird, and Maldini recorded only 7 (Table 1). In addition, Barlow found two species that were not reported in strandings: Fraser dolphins (*Lagenodelphis hosei*) and Longman's beaked whales (*Indopacetus pacificus*).

The four most common species throughout the main Hawaiian Islands, as percentage of total strandings, were *Kogia* spp. (primarily pygmy sperm whales; 18%), spinner dolphins (15%), striped dolphins (*Stenella coeruleoalba*;

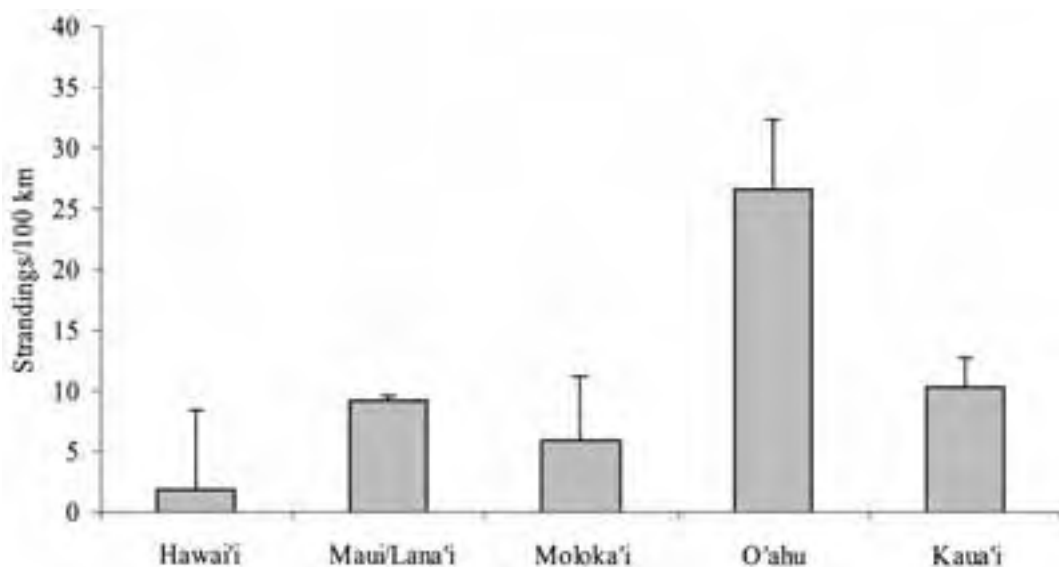


FIGURE 3. Number of strandings on the main Hawaiian Islands by island between 1937 and 2002. Bars show standard error.

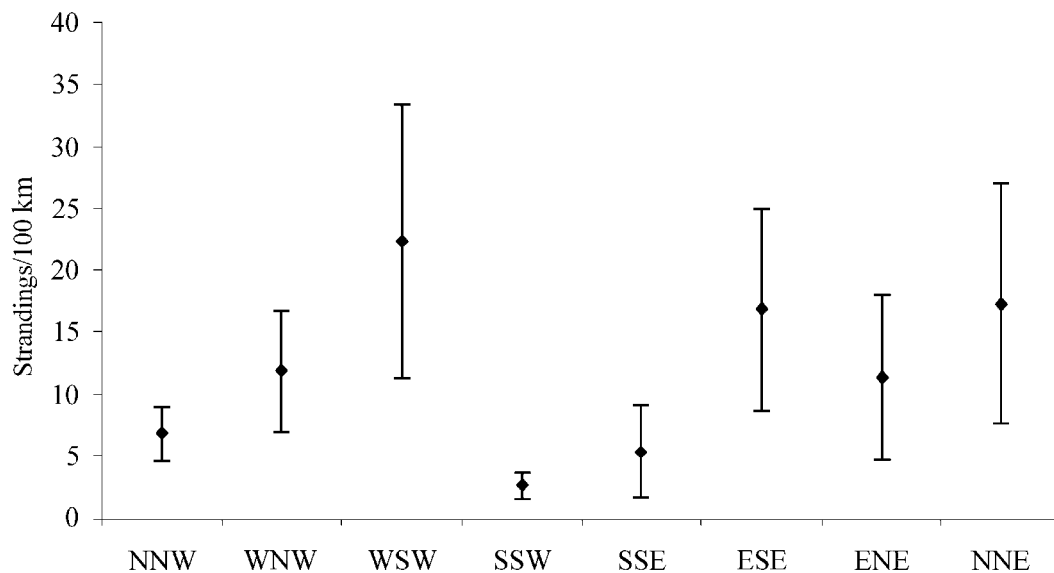


FIGURE 4. Number of strandings on the main Hawaiian Islands by sector between 1937 and 2002. Bars show standard error.

11%), and sperm whales (*Physeter macrocephalus*; 10%). Spinner dolphins were among the four most common species in three out of four live animal survey studies.

Following are some of the more notable results for the comparisons between the occurrence of each species in the stranding database and its occurrence in each of the

TABLE 1

Comparative Summary of Species Occurring around the Main Hawaiian Islands as Proportion of Total Occurrences Based on Stranding Reports (1937–2002) and Systematic Surveys of Live Animals Using Aerial (Mobley et al. 2000, Maldini 2003) and Boat-Based Platforms (Baird et al. 2003, Barlow 2003) (Results of  $z$ -Statistic Comparing Strandings with Each of the Live Studies are reported Only When Significant)

Species	Strandings (1937–2002)	Mobley et al. (2000)	Maldini (2003)	Barlow (2003)	Baird et al. (2003)
<i>Kogia</i> spp.	0.18	—	—	0.05 $z = 2.869$ $P = 0.004$	0.07 $z = 2.715$ $P = 0.007$
Spinner dolphin ( <i>Stenella longirostris</i> )	0.15	0.19	0.18	0.04 $z = 2.600$ $P = 0.009$	0.14
Striped dolphin ( <i>Stenella coeruleoalba</i> )	0.11	0.01 $z = 4.539$ $P < 0.001$	—	0.11	0.01 $z = 3.318$ $P < 0.001$
Sperm whale ( <i>Physeter macrocephalus</i> )	0.10	0.08	—	0.18	0.01 $z = 3.089$ $P = 0.002$
Melon-headed whale ( <i>Peponcephala electra</i> )	0.08	0.01 $z = 3.552$ $P < 0.001$	—	0.01 $z = 2.173$ $P = 0.030$	0.02 $z = 2.103$ $P = 0.035$
Short-finned pilot whale ( <i>Globicephala macrorhynchus</i> )	0.07	0.27 $z = 5.271$ $P < 0.001$	0.41 $z = 6.366$ $P < 0.001$	0.14	0.12
Bottlenose dolphin ( <i>Tursiops truncatus</i> )	0.06	0.18 $z = 3.607$ $P < 0.001$	0.18 $z = 2.695$ $P = 0.007$	0.09	0.30 $z = 5.669$ $P < 0.001$
Spotted dolphin ( <i>Stenella attenuata</i> )	0.05	0.09	0.07	0.08	0.18 $z = 3.602$ $P < 0.001$
Rough-toothed dolphin ( <i>Steno bredanensis</i> )	0.04	0.03	0.01	0.14 $z = 2.829$ $P = 0.005$	0.09
Pygmy killer whale ( <i>Feresa attenuata</i> )	0.03	—	—	0.01	0.01
False killer whale ( <i>Pseudorca crassidens</i> )	0.03	0.08 $z = 2.025$ $P = 0.043$	0.10 $z = 1.975$ $P = 0.048$	0.01	0.01
Cuvier's beaked whale ( <i>Ziphius cavirostris</i> )	0.03	0.03	—	0.02	—
Risso's dolphin ( <i>Grampus griseus</i> )	0.03	0.01	—	0.05	—
Blainville's beaked whale ( <i>Mesoplodon densirostris</i> )	0.01	0.03	0.04	0.01	0.04
Killer whale ( <i>Orcinus orca</i> )	0.01	—	—	0.02	0.01
Fraser dolphin ( <i>Lagenodelphis borei</i> )	0.01	—	—	0.01	—
Longman's beaked whale ( <i>Indopacetus pacificus</i> )	0.01	—	—	0.01	—

four live animal studies. The arrows in parentheses indicate whether frequency of occurrence was higher ( $\uparrow$ ) or lower ( $\downarrow$ ) in the stranding database than in the live animal

study being compared. Details of these statistical differences are summarized in Table 1.

Differences between the stranding data and Barlow were significant for four species:

*Kogia* spp., (↑); spinner dolphins, (↑); melon-headed whales (*Peponocephala electra*), (↑); and rough-toothed dolphins (*Steno bredanensis*), (↓). Differences between the stranding data and Mobley were significant for five species: striped dolphins, (↑); melon-headed whales, (↑); short-finned pilot whales, (↓); bottlenose dolphins, (↓); and false killer whales (*Pseudorca crassidens*), (↓). Differences between the stranding data and Maldini were significant for three species: short-finned pilot whales, (↓); bottlenose dolphins, (↓); and false killer whales, (↓). Differences between the stranding data and Baird were significant for six species: *Kogia* spp., (↑); striped dolphins, (↑); sperm whales, (↑); melon-headed whales, (↑); bottlenose dolphins, (↓); and spotted dolphins, (↓). Fraser dolphins and Longman's beaked whales were not compared because they were not present in the stranding database.

#### DISCUSSION

Despite increased effort and a more organized stranding network, the overall number of strandings recorded for a 65-yr period in the main Hawaiian Islands is low when compared with other geographic areas. These low odontocete densities are supported by recent wide-area line transect surveys (Barlow 2003). As a comparison, a 200-km stretch of coast between the Loire and Gironde estuaries on the central French Atlantic coast yielded 259 odontocete strandings between 1972 and 1986 (Duguy and Wisdorff 1988). On O'ahu, which has a similar length of coastline (ca. 225 km), only 30 strandings were reported during the same period.

The location of stranding events may be substantially affected by bottom topography, tides, currents, and weather patterns such as the northeast trade winds, which prevail most of the year (Klinowska 1985, Mignucci-Giannoni et al. 1999). Furthermore, sharks, which are abundant in Hawaiian waters, are known to scavenge on marine mammal carcasses and may consume many of them before they reach land (Long and Jones 1996, Heithaus 2001).

It is not surprising that almost half (48%)

of the total number of stranding reports were on the island of O'ahu, which has the largest human population and the most crowded beaches. This indicates that a considerable proportion of strandings may be either missed or not reported on other main Hawaiian Islands, where large portions of the coastline are remote. The frequency of stranding reports, standardized by the length of the coastline for each island, suggests that considerable effort is needed to expand the stranding network on the island of Hawai'i, where number of strandings per kilometer of coastline was lowest. In fact, Hawai'i has long stretches of coastline that are not easily accessible and it also has a low population density relative to the other islands.

The number of strandings per kilometer, for each compass direction, was not significantly different for all islands combined (Figure 3). However, there was a low number of strandings reported on some islands; therefore, interisland differences in stranding patterns by compass direction could not be further explored.

Inspection of results by sector for all islands indicates that strandings are generally less common in south-facing sectors, which are less exposed to onshore wind conditions than other sectors (Figure 4). Strandings occurred in all months with no significant trend. In contrast, results of year-round aerial surveys conducted around O'ahu (Maldini 2003) indicated an increased frequency of odontocete sightings in the winter.

The species composition in the stranding database reflects the composition of species found in live animal surveys and advocates for the usefulness of stranding data as a source of information when other data are not available. Only the wide-area surveys conducted by Barlow (2003), which included the deepest waters within the U.S. EEZ surrounding the Hawaiian Islands, resulted in a number of species comparable with, and actually larger than, that in the stranding database.

The frequency of occurrence of some species that are not easily detected in systematic surveys due to factors such as size, surfacing behavior, or pelagic life history may be better represented by stranding data. This may be

the case for *Kogia* spp., which had the highest frequency of stranding but were either not detected or detected with low frequency during surveys, and for melon-headed whales, which are not cryptic but could be misidentified in the field. Balcomb (1987) described melon-headed whales as preferring the open ocean and as not being particularly abundant in Hawaiian waters although present year-round.

Some differences in frequency of occurrence of different species between strandings and live animal surveys can be explained by the types of habitat surveyed in each of the four studies. For example, the frequency of occurrence of spinner dolphins in Barlow (2003) was lower than in all other studies, but that of rough-toothed dolphins was higher. Spinner dolphins are generally found in shallow waters close to shore, an area that Barlow (2003) did not survey. Conversely, Barlow's surveys covered waters to the north of the main Hawaiian Islands, where most rough-toothed dolphin sightings occurred. In addition, Barlow's surveys confirmed that striped dolphins are among the most abundant species in pelagic waters around the main Hawaiian Islands and recorded a frequency of occurrence of sightings similar to that predicted by strandings. All other live animal surveys occurred closer to shore and were not as extensive so that the occurrence of striped and rough-toothed dolphins was misrepresented.

Short-finned pilot whales and bottlenose dolphins appear to be more common than predicted by strandings. This discrepancy is difficult to interpret. Short-finned pilot whales were particularly abundant around O'ahu (Maldini 2003).

There appear to be two ecotypes of bottlenose dolphins (inshore and offshore) in Hawai'i (Baird et al. 2003). Inshore bottlenose dolphins appear to prefer areas close to the shelf break and are generally localized (Baird et al. 2002). Little is known about the offshore ecotype. Stranding patterns for these two ecotypes may differ, but available stranding data did not distinguish between the two.

In conclusion, stranding patterns around the main Hawaiian Islands suggest overall low

odontocete densities, which are supported by Barlow (2003). Stranding patterns do not suggest seasonality; an increase in strandings over time is likely due to an increase in reporting effort over time. Comparison with live animal survey data suggests that stranding records are a good indicator of species composition and yield reasonable data on the frequency of occurrence of species in the region they cover. However, comparisons with live animal surveys are indispensable to identify and interpret anomalous stranding patterns.

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#### Literature Cited

- ArcView. 1997. Version 3.2 (<http://www.esri.com/software/arcview/>).
- Baird, R. W., A. M. Gorgone, A. D. Ligon, and S. K. Hooker. 2001. Mark-recapture estimate of bottlenose dolphins (*Tursiops truncatus*) around Maui and Lana'i, Hawai'i during the winter of 2000/2001. NMFS/SWFSC Tech. Rep. 40JGNF0-00262.
- Baird, R. W., A. M. Gorgone, and D. L. Webster. 2002. An examination of movements of bottlenose dolphins between islands in the Hawaiian Island chain.



- NMFS/SWFSC Tech. Rep. 40JGNF1-10270.
- Baird, R. W., D. J. McSweeney, D. L. Webster, A. M. Gorgone, and A. D. Ligon. 2003. Studies of odontocete population structure in Hawaiian waters: Results of a survey through the main Hawaiian Islands in May and June 2003. NOAA Tech. Rep. AB133F-02-CN-0106.
- Balcomb, K. C., III. 1987. The whales of Hawaii, including all species of marine mammals in Hawaiian and adjacent waters. Marine Mammal Fund, San Francisco, California.
- Barlow, J. 2003. Cetacean abundance in Hawaiian waters during summer/fall of 2002. SWFSC Admin. Rep. LJ-03-13.
- Benoit-Bird, K. J. 2003. Dynamics of the Hawaiian mesopelagic boundary community and their effects on predator foraging. Ph.D. diss., University of Hawai'i at Mānoa, Honolulu, Hawai'i.
- Duguay, R., and D. Wisdorff. 1988. Cetacean stranding and meteorological factors on the central French Atlantic coast. *Oceanol. Acta* 11 (3): 227–233.
- Heithaus, M. R. 2001. Predator-prey and competitive interactions between sharks (order Selachii) and dolphins (suborder Odontoceti): A review. *J. Zool. (Lond.)* 253 (1): 53–68.
- Klinowska, M. 1985. Interpretation of the UK cetacean stranding records. *Rep. Int. Whaling Comm.* 35:459–467.
- Lammers, M. O. 2003. The behavior and broadband acoustic signaling of Hawaiian spinner dolphins (*Stenella longirostris*). Ph.D. diss., University of Hawai'i at Mānoa, Honolulu, Hawai'i.
- Long, D. J., and R. E. Jones. 1996. White shark predation and scavenging on cetaceans in the eastern North Pacific Ocean. Pages 293–307 in A. P. Klimley and D. G. Ainley, eds. *Great white sharks: The biology of *Carcharodon carcharias**. Academic Press, San Diego.
- Maldini, D. 2003. Abundance and distribution patterns of odontocetes around O'ahu and Penguin Banks, Hawai'i. Ph.D. diss., University of Hawai'i at Mānoa, Honolulu, Hawai'i.
- Mazzuca, L., S. Atkinson, and E. Nitta. 1998. Deaths and entanglements of humpback whales, *Megaptera novaeangliae*, in the main Hawaiian Islands, 1972–1996. *Pac. Sci.* 52:1–13.
- Mazzuca, L., S. Atkinson, B. Keating, and E. Nitta. 1999. Cetacean mass strandings in the Hawaiian Archipelago, 1957–1998. *Aquat. Mamm.* 25 (2): 105–114.
- Mignucci-Giannoni, A. A., B. Pinto-Rodriguez, M. Velasco-Escardero, R. A. Montoya-Ospina, N. M. Jimenez-Marrero, M. A. Rodriguez-Lopez, E. H. Williams Jr., and D. Odell. 1999. Cetacean strandings in Puerto Rico and the Virgin Islands. *J. Cet. Res. Manage.* 12:191–198.
- Mobley Jr., J. R., S. S. Spitz, K. A. Forney, R. Grotefendt, and P. H. Forestell. 2000. Distribution and abundance of odontocete species in Hawaiian waters: Preliminary results of 1993–98 aerial surveys. SWFSC Admin. Rep. LJ-00-14C.
- Mobley, J., S. Spitz, and R. Grotefendt. 2001. Abundance of humpback whales in Hawaiian waters: Results of 1993–2000 aerial surveys. Admin. Rep. Hawaiian Islands Humpback Whale National Marine Sanctuary, Office of National Marine Sanctuaries/National Oceanic and Atmospheric Administration, U.S. Department of Commerce/Department of Land and Natural Resources, State of Hawai'i, Honolulu, Hawai'i.
- Nitta, E. T. 1991. The marine mammal stranding network for Hawai'i, an overview. Pages 55–62 in John E. Reynolds III and Daniel K. Odell, eds. *Marine mammal strandings in the United States: Proceedings of the 2nd Marine Mammal Stranding Workshop, 3–5 December 1987, Miami, Florida*. NOAA Tech. Rep. NMFS 98.
- Norris, K., B. Wursig, R. S. Wells, and M. Wursig. 1994. *The Hawaiian spinner dolphin*. University of California Press, Los Angeles.
- Shallenberger, E. W. 1981. The status of Hawaiian cetaceans. *Tech. Rep. Mar. Mamm. Comm.* PB82109398.
- Tomich, P. Q. 1986. *Mammals in Hawai'i: A synopsis and notational bibliography*. 2nd ed. Bishop Mus. Spec. Publ. 76.

## Appendix 1

List of Odontocete Strandings Recorded between 1937 and 2002 in the Main Hawaiian Islands (Although Strandings Have Been Reported since 1937, No Odontocetes Were Found until 1950)

Year	Species	No. of Individuals	Location	Island
1950	Cuvier's beaked whale	1	—	O'ahu
1950	Killer whale	1	South Point	Hawai'i
1950	Cuvier's beaked whale	1	South Point	Hawai'i
1954	Sperm whale	1	Kahuku	O'ahu
1955	Melon-headed whale	1	Wailupe Circle	O'ahu
1957	Short-finned pilot whale	1	Punalu'u	O'ahu
1957	Short-finned pilot whale	2	Waikiki	O'ahu
1957	<i>Kogia</i> spp.	1	Wailupe Circle	O'ahu
1958	Short-finned pilot whale	1	Kalihi Beach	Kaua'i
1958	Short-finned pilot whale	24	Keomuku Beach	Lana'i
1958	Short-finned pilot whale	1	Waikiki	O'ahu
1958	Short-finned pilot whale	12	Kalihi Beach	Kaua'i
1958	Striped dolphin	1	Ala Wai	O'ahu
1959	Short-finned pilot whale	28	'Anini Beach	Kaua'i
1959	Short-finned pilot whale	1	Waimanalo	O'ahu
1963	Pygmy sperm whale	1	Bellows Beach	O'ahu
1964	Melon-headed whale	1	Kahuku	O'ahu
1965	Melon-headed whale	1	Lahaina	Maui
1969	Rough-toothed dolphin	1	Wai'anae	O'ahu
1969	Spinner dolphin	1	Sandy Beach	O'ahu
1970	Cuvier's beaked whale	1	Makaha	O'ahu
1970	Spinner dolphin	1	Kahului Harbor	Maui
1971	Melon-headed whale	1	Ke'ehi Lagoon	O'ahu
1972	Spinner dolphin	1	Makapu'u	O'ahu
1972	Melon-headed whale	1	Kahuku	O'ahu
1972	Pygmy sperm whale	1	Lā'ie	O'ahu
1974	Pygmy sperm whale	1	Kalaupapa	Moloka'i
1974	False killer whale	1	Kailua Beach	O'ahu
1975	Spotted dolphin	1	Hale'iwa	O'ahu
1975	Pygmy killer whale	1	Hāwī	Hawai'i
1976	Spinner dolphin	1	Sea Life Park	O'ahu
1976	Pygmy sperm whale	2	Kihei	Maui
1976	Melon-headed whale	1	Punalu'u	O'ahu
1976	Sperm whale	1	Kahuku	O'ahu
1976	Rough-toothed dolphin	18	Kihei	Maui
1976	Rough-toothed dolphin	1	Kā'anapali	Maui
1976	Rough-toothed dolphin	4	Kihei	Maui
1976	Unidentified odontocete	1	Kā'anapali	Maui
1977	Spinner dolphin	1	Mokulē'ia	O'ahu
1977	Striped dolphin	1	Punalu'u	O'ahu
1977	<i>Kogia</i> spp.	1	Waimea	Kaua'i
1977	Risso's dolphin	1	Wailuku	Maui
1978	Spinner dolphin	1	Kailua	O'ahu
1978	Spinner dolphin	1	Port Allen	Kaua'i
1978	Risso's dolphin	1	Kāhala	O'ahu
1978	Striped dolphin	1	Hale'iwa	O'ahu
1978	Risso's dolphin	1	Pāpōhaku	Moloka'i
1978	Striped dolphin	1	Reef Runway	O'ahu
1979	Pygmy sperm whale	1	Kihei	Maui
1979	False killer whale	1	Mōkapu	O'ahu
1979	Short-finned pilot whale	1	Hanauma Bay	O'ahu
1979	Striped dolphin	1	Kahuku	O'ahu
1979	Sperm whale	1	Barbers Point	O'ahu
1980	False killer whale	1	Mōkapu	O'ahu

## Appendix 1 (continued)

Year	Species	No. of Individuals	Location	Island
1980	Spinner dolphin	1	Ka'a'awa	O'ahu
1980	Pygmy sperm whale	1	Kihei	Maui
1980	Striped dolphin	1	Kihei	Maui
1980	Striped dolphin	1	Kailua Beach	O'ahu
1981	Pygmy killer whale	4	Mā'alaea	Maui
1981	Cuvier's beaked whale	1	Hilo	Hawai'i
1982	Unidentified odontocete	1	Kihei	Maui
1983	Pygmy killer whale	1	South Point	Hawai'i
1983	Bottlenose dolphin	1	Kepuhi Beach	Moloka'i
1983	Unidentified odontocete	1	Waiakalua-Pi'la'a	Kaua'i
1983	Melon-headed whale	1	Mākaha	O'ahu
1983	Striped dolphin	1	Punalu'u	O'ahu
1983	Sperm whale	1	Hā'ena	Kaua'i
1983	Risso's dolphin	1	Kihei	Maui
1984	Short-finned pilot whale	1	Kahana Bay	O'ahu
1984	Striped dolphin	1	Pauwahu Harbor	Moloka'i
1985	Bottlenose dolphin	1	Mokulē'ia	O'ahu
1985	Melon-headed whale	1	Mokulē'ia	O'ahu
1985	Sperm whale	1	Kāne'ohe	O'ahu
1986	Spinner dolphin	1	Kāne'ohe	O'ahu
1986	Striped dolphin	1	Lanikai	O'ahu
1986	False killer whale	1	Mōkapu	O'ahu
1986	Unidentified odontocete	1	Olowalu	Maui
1986	Spotted dolphin	1	Ka'ō'io Point	O'ahu
1986	Short-finned pilot whale	1	Kahului	Maui
1986	Bottlenose dolphin	1	Bellows Beach	O'ahu
1986	Melon-headed whale	1	Kū'au Bay	Maui
1986	Striped dolphin	1	Kailua	O'ahu
1986	Pygmy sperm whale	1	Kalaupapa	Moloka'i
1987	Spinner dolphin	1	Hale'iwa	O'ahu
1987	Bottlenose dolphin	1	Wailua	Moloka'i
1987	Dwarf sperm whale	1	Hauola Gulch	Lāna'i
1987	Spotted dolphin	1	Mākaha	O'ahu
1987	Rough-toothed dolphin	1	Waipi'o Bay	Hawai'i
1988	Melon-headed whale	1	Mokulē'ia	O'ahu
1988	Spinner dolphin	1	Kā'anapali	Maui
1988	Sperm whale	1	Ahukini	Kaua'i
1988	Pygmy killer whale	1	Kihei	Maui
1988	Pygmy sperm whale	1	Punalu'u	O'ahu
1988	Pygmy killer whale	1	Mā'alaea	Maui
1988	Pygmy killer whale	1	Kihei	Maui
1988	Bottlenose dolphin	1	Pauwahu	Moloka'i
1988	Spinner dolphin	1	Nukumoi Point	Kaua'i
1988	Risso's dolphin	1	Pā'ia	Maui
1989	Short-finned pilot whale	1	Wailau	Moloka'i
1990	<i>Stenella</i> spp.	1	Honolulu	O'ahu
1990	False killer whale	1	Hā'ena	Kaua'i
1990	Bottlenose dolphin	1	Kualoa	O'ahu
1990	Striped dolphin	1	Mākaha	O'ahu
1990	Spinner dolphin	1	Mokulē'ia	O'ahu
1990	Sperm whale	1	Po'ipū	Kaua'i
1991	Bottlenose dolphin	1	Kihei	Maui
1991	Spinner dolphin	1	Open ocean	Hawai'i
1992	Sperm whale	1	Wailua Beach	Kaua'i
1992	Sperm whale	1	Anahola Bay	Kaua'i
1992	<i>Kogia</i> spp.	1	Makapu'u	O'ahu
1992	Bottlenose dolphin	1	Pounders Beach	O'ahu

## Appendix 1 (continued)

Year	Species	No. of Individuals	Location	Island
1993	Striped dolphin	1	Kāneʻohe	Oʻahu
1993	Spinner dolphin	1	Waiʻanae	Oʻahu
1993	Pygmy sperm whale	1	Kekaha	Kauaʻi
1993	Striped dolphin	1	Kihei	Maui
1993	Sperm whale	1	Cape Kumukahi	Hawaiʻi
1993	Spinner dolphin	1	Kōkeʻe Beach	Kauaʻi
1993	Spinner dolphin	1	Anahola	Kauaʻi
1993	Pygmy sperm whale	1	Waiehu	Maui
1993	Melon-headed whale	1	Ko Olina Resort	Oʻahu
1994	Spotted dolphin	1	KMCAS	Oʻahu
1994	Striped dolphin	1	Māʻalaea	Maui
1994	Unidentified odontocete	1	Kaʻena Point	Oʻahu
1994	Spinner dolphin	1	Hanauma Bay	Oʻahu
1994	Spinner dolphin	1	Nānākuli Beach	Oʻahu
1994	Pygmy sperm whale	1	Kailua Beach	Oʻahu
1994	Spinner dolphin	1	Kāneʻohe	Oʻahu
1994	Spinner dolphin	1	Mokulēʻia	Oʻahu
1994	Spotted dolphin	1	Hauʻula	Oʻahu
1994	Sperm whale	1	Kapaʻa	Kauaʻi
1995	<i>Kogia</i> spp.	1	Waipiʻo Valley	Hawaiʻi
1995	Melon-headed whale	1	Brennecke Beach	Kauaʻi
1995	Striped dolphin	1	Pāpōhaku Beach	Molokaʻi
1995	Short-finned pilot whale	1	Barking Sands	Kauaʻi
1996	Striped dolphin	1	Olowalu	Maui
1996	<i>Kogia</i> spp.	1	Halepalaoa	Lānaʻi
1996	Pygmy sperm whale	1	Waikoloʻa	Hawaiʻi
1996	Short-finned pilot whale?	1	Hilo	Hawaiʻi
1996	Sperm whale	1	Laupāhoehoe	Hawaiʻi
1996	Melon-headed whale	1	Mākaha	Oʻahu
1996	Spotted dolphin	1	Kailua Beach	Oʻahu
1996	<i>Kogia</i> spp.	1	Waiheʻe	Maui
1996	Unidentified odontocete	1	Kailua-Kona	Hawaiʻi
1996	Cuvier's beaked whale	1	Nānākuli	Oʻahu
1997	Unidentified odontocete	1	Nānākuli	Oʻahu
1997	Sperm whale	1	Kahuku	Oʻahu
1997	Spinner dolphin	1	Kailua	Oʻahu
1997	Striped dolphin	1	Waimānalo	Oʻahu
1997	Sperm whale	1	Waiheʻe	Maui
1997	False killer whale	1	Kailua-Kona	Hawaiʻi
1997	Sperm whale	1	Kahuku	Oʻahu
1997	Spinner dolphin	1	Nānākuli	Oʻahu
1997	Striped dolphin	1	Haleʻiwa	Oʻahu
1998	Bottlenose dolphin	1	Kamaʻole Beach	Maui
1998	Spinner dolphin	1	Spreckelsville	Maui
1998	Bottlenose dolphin	1	Punaluʻu Beach	Oʻahu
1998	Sperm whale	1	Anahola	Kauaʻi
1998	Cuvier's beaked whale	1	Wailua	Kauaʻi
1998	Bottlenose dolphin	1	Wāialua	Oʻahu
1998	Pygmy sperm whale	1	Lahaina	Maui
1998	Melon-headed whale	1	Keahou Bay	Hawaiʻi
1999	Short-finned pilot whale	1	Kāneʻohe	Oʻahu
1999	Sperm whale	1	Kāneʻohe	Oʻahu
1999	<i>Kogia</i> spp.?	1	Kaʻupa Bay	Maui
2000	Unidentified odontocete	1	Poʻipū Harbor	Kauaʻi
2000	Dwarf sperm whale	1	Kailua Beach	Oʻahu
2000	Bottlenose dolphin	1	Lāʻie	Oʻahu
2000	Rough-toothed dolphin	1	Puakō	Hawaiʻi

## Appendix 1 (continued)

Year	Species	No. of Individuals	Location	Island
2000	Spinner dolphin	1	Anahola	Kaua'i
2000	Pygmy sperm whale	1	Hanalei Bay	Kaua'i
2000	Spinner dolphin	1	Ka'ena Point	O'ahu
2000	Dwarf sperm whale	1	Kailua	O'ahu
2001	Pygmy sperm whale	1	Sugar Beach	Maui
2001	Melon-headed whale	1	Mokule'ia	O'ahu
2001	Sperm whale	1	Kailua-Kona	Hawai'i
2001	Spinner dolphin	1	Mokule'ia	O'ahu
2001	Pygmy sperm whale	1	Kihei	Maui
2001	Rough-toothed dolphin	1	Kihei	Maui
2001	Unidentified odontocete	1	Alan Davis Beach	O'ahu
2001	Dwarf sperm whale	1	Kihei	Maui
2001	Potted dolphin	1	Lā'ie	Hawai'i
2001	Striped dolphin	1	Kahuku	Hawai'i
2001	Pygmy sperm whale	1	Sugar Beach	Maui
2001	Melon-headed whale	1	Mokule'ia	O'ahu
2001	Sperm whale	1	Kailua-Kona	Hawai'i
2001	Spinner dolphin	1	Mokule'ia	O'ahu
2001	Pygmy sperm whale	1	Kihei	Maui
2001	Rough-toothed dolphin	1	Kihei	Maui
2001	Unidentified odontocete	1	Alan Davis Beach	O'ahu
2001	Dwarf sperm whale	1	Kihei	Maui
2001	Spotted dolphin	1	Lā'ie	Hawai'i
2001	Striped dolphin	1	Kahuku	Hawai'i
2002	Spotted dolphin	1	Pōka'i Beach	O'ahu
2002	Pygmy sperm whale	1	North Shore	Kaua'i
2002	Pygmy sperm whale	1	Kihei	Maui
2002	Spinner dolphin	1	Magic Island	O'ahu
2002	Dwarf sperm whale	1	Not reported	Moloka'i
2002	Pygmy sperm whale	1	Mākena	Maui
2002	Blainville's beaked whale	1	Kama'ole	Maui
2002	Pygmy sperm whale	1	One'uli Beach	Maui
2002	Unidentified odontocete	1	Keahau	Hawai'i
2002	Spotted dolphin	1	Pōka'i Beach	O'ahu