Trends in Relative Distribution, Abundance and Population Composition of Humpback Whales, *Megaptera novaeangliae*, in Kawaihae Bay, Hawai‘i 1988-2003

Prepared by

Christine M. Gabriele, Susan H. Rickards, Suzanne E. Yin and Adam S. Frankel

Hawai‘i Marine Mammal Consortium
PO Box 6107, Kamuela, Hawai‘i 96743

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INTRODUCTION

Humpback whales that migrate from feeding grounds in high latitudes along the North Pacific rim are found between November and May in the near-shore waters of the Hawaiian Islands. Their winter presence in tropical waters worldwide is believed to occur primarily for the purposes of mating and rearing newborn calves. Feeding is not believed to occur in humpback whale winter habitats, but rare observations of feeding have been made (Salden 1989, 1990, Baraff et al. 1991, Gendron and Urban 1993) and exploitable prey resources may be available (Benoit-Bird et al. 2001, Benoit-Bird 2003). Identifying essential habitat for this endangered species is important to ensure appropriate conservation and management of these areas. The present study describes changes in the use of the Kawaihae Bay area of West Hawaiʻi over the past 15 years.

The primary period of humpback whale presence in Hawaiian waters is January through April, with peak abundance occurring earlier near the island of Hawaiʻi (also known as the Big Island) than the other islands (Herman and Antinoja 1977, Baker and Herman 1981). Aerial surveys indicate that whales mainly inhabit leeward coasts, in waters shallower than 100 fathoms (183 m) which are typically within 25 nautical miles of shore (Herman and Antinoja 1977, Mobley et al. 1999). Aerial surveys concentrating in West Hawaiʻi waters in 1992 indicated peak presence between mid-January and mid-March, with the highest numbers of whales sighted in the first week of March (Forestell and Brown 1992). This study identified the highest whale densities near Keahole Point and just north of Kawaihae Harbor, and lower densities near the resorts along the shore south of Kawaihae (Forestell and Brown 1992, 1993). The latter two areas were also investigated in the current study (Gabriele et al. 2001).

Twentieth-century commercial whaling decimated worldwide whale populations, including the North Pacific humpback whale. At the time of its listing on the U.S. Endangered Species List in 1973, the North Pacific population of humpback whales was believed to number less than 1,000 individuals, having decreased from an estimated 15,000 whales (Rice 1978, Johnson and Wolman 1984). The first mark-recapture population estimates indicated that 1,000-2,100 whales wintered in the Hawaiian Islands in the early 1980s (Baker and Herman 1987, Darling and Morowitz 1986). The first North Pacific basin-wide mark-recapture population estimate was a large collaborative study that indicated that the Hawaiian Islands hosted 3,760-5,151 whales in 1991-1993 (Calambokidis et al. 1997). Aerial survey estimates of abundance in 1993-2000 indicated a similar increasing trend, with 3,805-5,177 whales present by 2000, consistent with a 7% rate of increase per year (Mobley et al. 2001).

In describing habitat utilization, it is important to consider age-sex composition and site fidelity, along with the numbers of whales. Whales move through the Hawaiian island chain (Baker and Herman 1981, Cerchio et al. 1998), making it difficult to determine residence times of individual whales in the Hawai‘i winter grounds as a whole. Off West Hawai‘i, studies of individually-identified whales revealed that only 15% of whales are sighted on more than one day (Cerchio et al. 1998). Looking only at whales sighted on more than one day, differences in age-sex classes emerge. Approximately 60% of females (with or without a calf) had sighting intervals of one week or less, while most adult males stayed longer, with about 60% of males having residence times of 1 to 5 weeks (Gabriele 1992, Craig et al. 2001). The migratory timing of various age-sex classes also differed, with females without a calf arriving earliest in Hawai‘i and departing earliest in the season, followed by juveniles and males (Gabriele 1992). Females with newborn calves arrived and departed latest (Gabriele 1992, Craig et al. in press). While these results give an indication of the use of Kawaihae Bay, individual whales’ residence times and use of the island chain as a whole are not well understood.

Observations of whales from a shore site on Kuili cinder cone, (located approximately 35 km south of our study area) (Smultea 1994) found that cow/calf pairs were closer to shore and separated from other whale pods. Two additional shore-based studies have used scan sampling methods to document humpback whale presence and behavior in the Kawaihae Bay area. Forestell and Brown (1992, 1993) conducted shore-based observations from the roof of the Mauna Lani resort, to document cetacean use of the area relevant to proposed marine development in the area. Helweg (1989) investigated seasonal and daily changes in whale distribution, numbers and behavior from the “Old Ruins” shore station that was also used for the present study. Helweg’s results are herein compared with the data collected for this study (Gabriele et al. 2001) in 2001-2003.

The Hawaiian Islands Humpback Whale National Marine Sanctuary encompasses approximately 1,400 square miles of marine waters, comprised of five separate areas abutting six of the major islands of the State of Hawai‘i. Off the island of Hawai‘i, Sanctuary waters cover approximately 150 square miles along the northwest coast from Keahole Point to Upolu Point. The waters of Kawaihae Bay are within the Sanctuary. The retrospective analysis of shore-based scan sampling presented here is intended to describe the relative abundance, distribution and population composition of humpback whales in Kawaihae Bay, and identify any trends between 1988 and contemporary data collected using comparable methods in 2001-2003. Sightings of other cetaceans that use the area (Shallenberger 1981, Mobley et al. 2000) such as spinner dolphins (*Stenella longirostris*), spotted dolphins (*Stenella attenuata*), bottlenose dolphins (*Tursiops truncatus*) and false killer whales (*Pseudorca crassidens*) are also reported. Comparison of current findings with archival scan data allows an assessment of potential long-term changes in: age/sex class composition, pod sizes, relative distribution and abundance of whales and vessel traffic in the area. Continuation of scan sampling at the Kawaihae Bay shore station and periodic vessel-based surveys of the entire coastline contribute to a better understanding of humpback whales and their habitat in Sanctuary waters.

METHODS

Study Area

The shore-based observation site is located on the northwest coast of the island of Hawai‘i at 20° 4.925' N; 155° 51.795' W and is approximately 63.6 meters above sea level, overlooking Kawaihae Bay (Fig. 1). The site is known as Old Ruins because of the stone wall remnants of a Hawaiian village on nearby hillsides. The waters of Kawaihae Bay are steeply sloped, leeward waters, typical of volcanic islands like Hawai‘i.

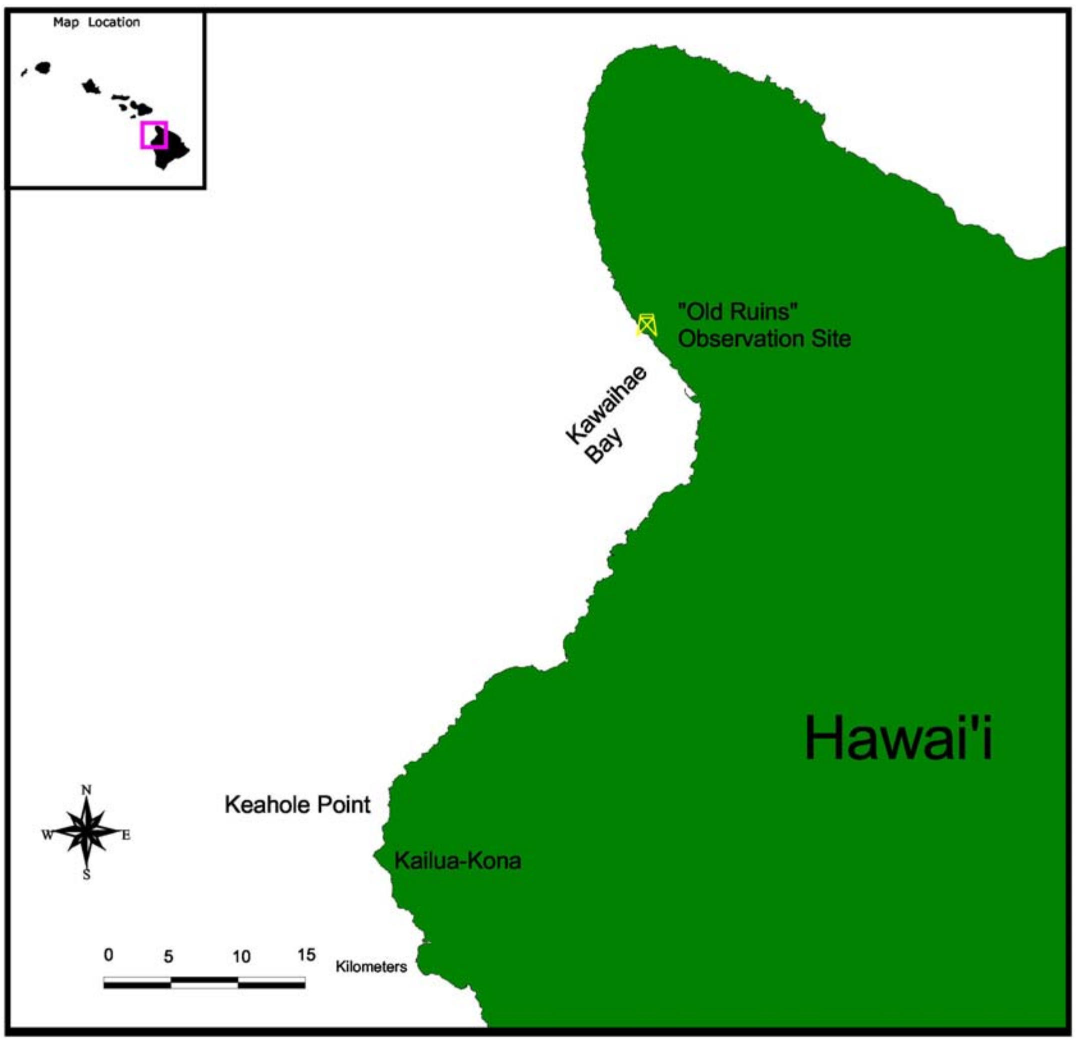

Figure 1. Study area on the northwest coast of the island of Hawai‘i

Scan Samples

A four-person team used scan sample methodology (Altmann 1974) in timed, regimented counts of the number and location of whales, vessels and other marine mammals in the area. The data from each observation are referred to as a "scan sample". Three scan samples, separated by at least one hour, were conducted weekly in one of four alternating time blocks (0700-1000, 1000-1300, 1300-1600 and 1600-1900) to ensure that scans were conducted at various times during daylight hours. The team included an observer who scanned the near-shore area from the coastline out to the horizon (approximately 14 km) using 7x50 binoculars and the naked eye. The theodolite operator determined the position of all marine mammals and vessels relative to the shore station site. Behavioral, scan and theodolite data were recorded using customized computer software (see below). Environmental data that accompanied scan samples included sea state on the Beaufort scale, swell height and a qualitative assessment of visibility. Scans were not conducted in periods where Beaufort sea state was greater than 4. The composition of each pod of whales was noted, including the presence or absence of a calf. A pod was defined as one or more whales within three adult whale-lengths of each other, moving in the same general direction and/or surfacing and diving in synchrony. Calves were identified by their small size, and close, consistent association with an adult, presumed to be its mother. Locations of all vessels were acquired via theodolite in a 'vessel scan' that occurred prior to the timed 'whale scan', and a description of each vessel, and its 'type' was recorded. Vessel types were based on engine power and vessel length (Table 1).

Scan samples in 2001-2002 were consistently 15 minutes long, but in 2003, due to previous difficulties in adequately counting and acquiring location data for all whale pods in the entire viewing area in 15 minutes, the study area was split into "south" and "north" areas of approximately equal size, each of which were scanned for 15 minutes. This modification facilitated comparison with Helweg's (1989) scan sample results but made direct comparisons with 2001-2002 more difficult. Other than the scan duration, scan sampling methods were consistent in 2001-2003.

Table 1. Definitions of Vessel Type Categories.

Vessel Type	Definition
0	Non-motorized (e.g. kayak, canoe, sailboat under sail)
1	Outboard engine (typically < 9 m length)
2	Inboard engine (typically > 9 m length)
3	All vessels > 23 m length

Theodolite Tracking

The speed, direction of movement and distances between vessels and whales were calculated from a series of positions, called 'fixes', recorded over time using a Sokkia DT500 theodolite with 5-second precision and 30-power magnification. These data can be used to map whale and vessel positions that may address questions about interactions among whales or between whales and vessels. The theodolite was linked to a laptop computer running a time-synchronized data-collection program, "Aardvark" (Mills 1996). Subsequent analysis using Aardvark converts theodolite angles to Cartesian coordinates and latitude/longitude, with correction for curvature of the earth and theodolite height. Theodolite tracking has been used previously in the study of movements and behaviors of a number of cetacean species (Würsig et al. 1991; Smultea 1994; Helweg and Herman 1994; Frankel and Clark 1998; Bejder et al. 1999).

Data Processing

The three scan samples conducted each day within a time block were not independent, as many of the same whales were present from scan to scan. A single scan sample each day, that best represented the number of whales in the area, was chosen for analysis to avoid pseudo-replication. The best scan sample of the three was determined based on the visibility conditions, the proportion of pods fixed, and the number of pod compositions obtained during the scan. Whale counts were categorized into fortnights to enable comparison with Helweg (1989). Fortnights are 14-day periods defined as follows: 1 = 29 January – 11 February, 2 = 12 -25 February, 3 = 26 February – 10 March.

Geographic Information Systems (GIS) maps of whale and vessel distribution were made with latitude/longitude data computed by Aardvark. Data were projected from WGS-1984 datum into UTM 4 North datum to match available Hawai'i base layers and enable mapping in ESRI ArcView 4.1 software. The first fix of each pod or vessel in the best scan sample of the day was mapped.

Statistical Analysis

Most statistical comparisons used non-parametric statistics due to violations of the assumption of normal distributions inherent in parametric statistics. GraphPad Instat software was used to calculate statistical comparisons. All comparisons were considered significant at $p < 0.05$.

RESULTS

Between 1988 and 2003, 167 scan samples were conducted from the "Old Ruins" shore observation site (Table 2).

Table 2. Number of scan samples available in each time block in each year.

Time Block	1988[1]	2001	2002	2003	TOTAL
0700-1000	8	10	16	7	41
1000-1300	11	16	19	7	53
1300-1600	9	15	6	11	41
1600-1900	6	13	8	5	32
Total	34	54	49	30	167

[1] Values from Helweg, 1989

For comparisons between scan data from 1988 through 2003, a subset of each year's data was used. As noted in the methods, only one scan sample per time block per day was selected for these comparisons. Scan samples were chosen based on the highest number of pods per scan which were fixed, as well as on the maximum number of groups with well-confirmed group compositions. Eighty-seven total scan samples were used for these comparative analyses (Table 3).

Table 3. Number of scan samples used for between-year comparisons in each time block in each year.

Time Block	1988	2001	2002	2003	TOTAL
0700-1000	8	4	5	4	21
1000-1300	11	6	7	4	28
1300-1600	9	6	3	4	22
1600-1900	6	5	2	3	16
Total	34	21	17	15	87

Humpback Whales

Numbers and Population Composition: In 1988, the scan area was delineated by a radius of 6.5 km from the shore observation site. Thus, for between-year comparisons, which included 1988, data from 2001 through 2003 were re-analyzed to include only those whale groups sighted within this 6.5 km radius.

The mean number of whales per scan sample sighted within 6.5 km increased consistently from 4.0 (n = 34) in 1988 to 19.9 (± SE 1.5, n = 15) in 2003 (Fig. 2) and varied significantly among years from 2001 to 2003 (Kruskal-Wallis nonparametric ANOVA Statistic KW = 27.485 (corrected for ties), $p < 0.0001$). Statistical comparisons with 1988 were not possible because the number of whales sighted in each scan sample were not available: only summary data in the form of means per time block and fortnight were available. The mean number of whales per scan sample within 6.5 km was significantly greater in 2002 than 2001 (Unpaired t test, two-tailed $p < 0.05$, $t = 2.3$, df = 36) and was also significantly greater in 2003 than 2002 (two-tailed Mann-Whitney U-Test = 22.5, $p < 0.0001$). No obvious trends among years in the mean number of whales sighted by time block (Fig. 3) or fortnight (Fig. 4) were apparent.

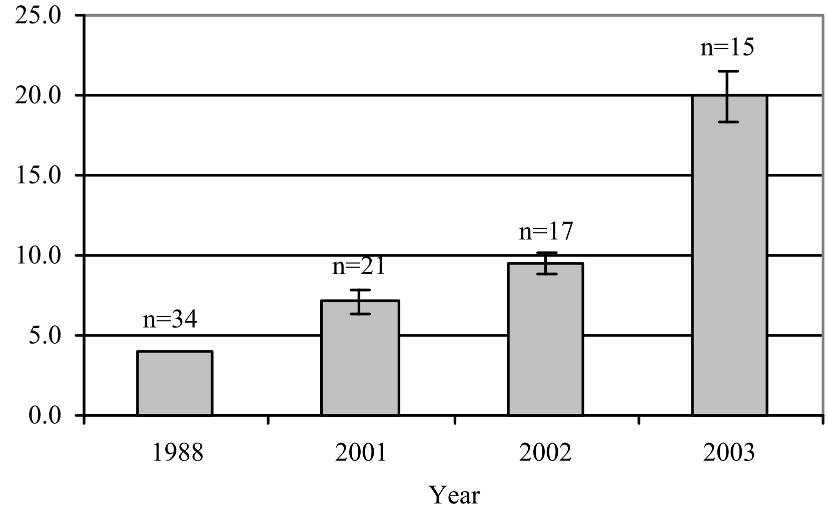

Figure 2. Mean number of whales per scan sample within 6.5km of observation site in 1988-2003. Error bars represent standard error (not available for 1988) and *n* denotes the number of scan samples. Data for 1988 are from Helweg, 1989.

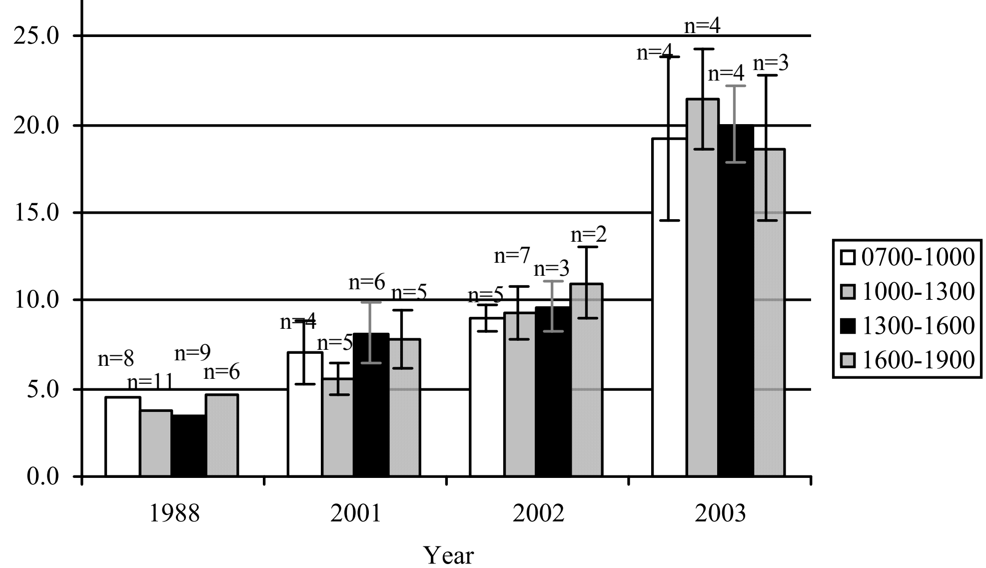

Figure 3. Mean number of whales per scan sample within 6.5km of observation site in 1988-2003, by time block. Error bars represent standard error (not available for 1988) and *n* denotes the number of scan samples. Data for 1988 are from Helweg, 1989.

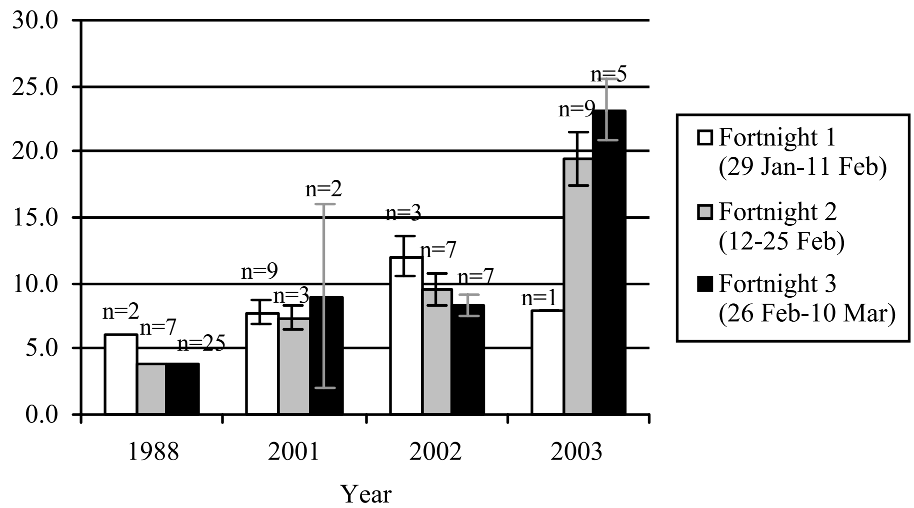

Figure 4. Mean number of whales per scan sample within 6.5km of observation site in 1988-2003, by fortnight. Error bars represent standard error (not available for 1988) and *n* denotes the number of scan samples. Data for 1988 are from Helweg, 1989.

For scan values from 2001 through 2003 (including those whales sighted beyond the 6.5 km radius) the number of whales per scan sample increased from 9.0 (± SE 0.8, n = 21) in 2001, to 14.5 (± SE 0.8, n = 17) in 2002, and finally to 30.5 (± SE 2.3, n = 15) in 2003 (Fig. 5). These values varied significantly among years (Kruskal-Wallis (corrected for ties), $p < 0.0001$). Again, the mean number of whales per scan sample was significantly greater in 2002 than 2001 (Unpaired t test, two-tailed $p < 0.0001$, $t = 4.8$, $df = 36$) and significantly greater in 2003 than 2002 (two-tailed Mann-Whitney U-Test = 17.0, $p < 0.0001$).

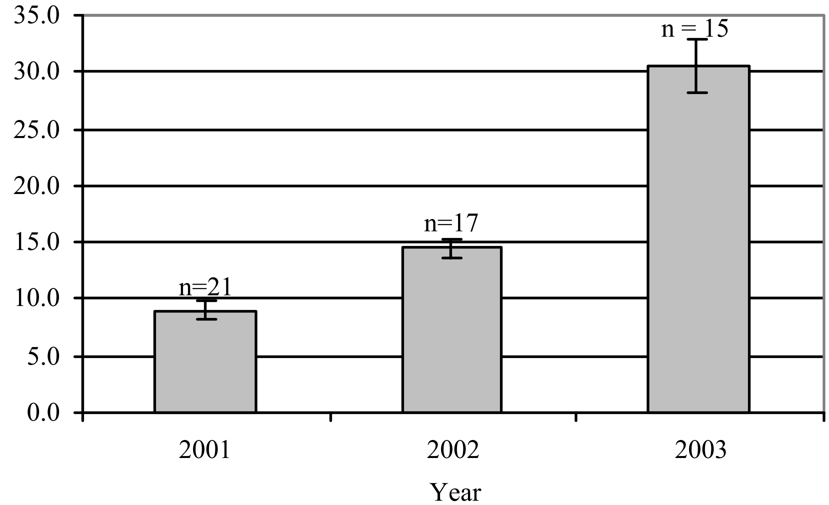

Figure 5. Mean number of whales per scan sample in 2001-2003. Error bars represent standard error and *n* denotes the number of scan samples.

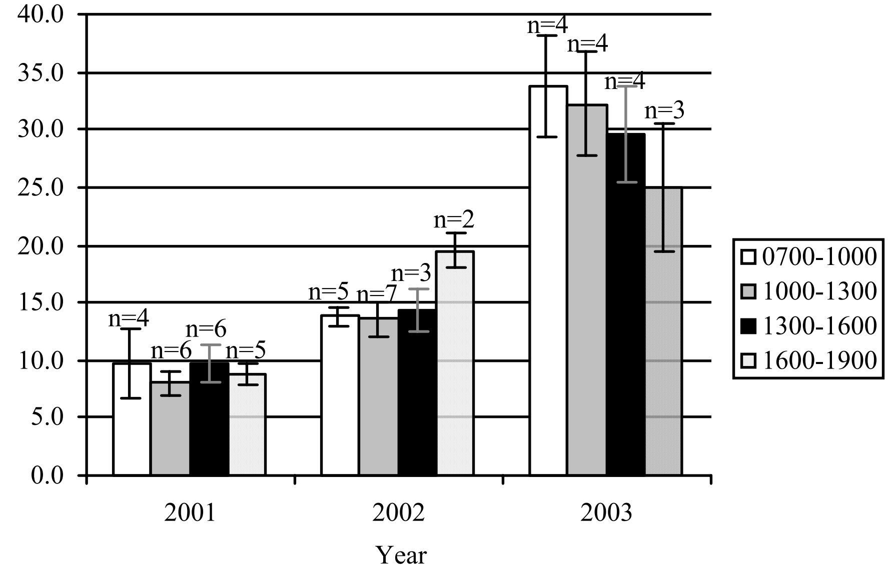

Figure 6. Mean number of whales per scan sample in 2001-2003, by time period. Error bars represent standard error and *n* denotes the number of scan samples.

The number of large pods (those including at least 3 adults) per scan sample (Fig. 7) also increased significantly from 0.3 (± SE 0.1, n = 21) in 2001, to 0.8 (± SE 0.2, n = 17) in 2002, and to 1.5 (± SE 0.4, n = 15) in 2003 (Kruskal-Wallis nonparametric ANOVA

Statistic KW = 13.9 (corrected for ties), $p < 0.001$). However, the percentage of large pods per scan sample (Fig. 8) was highest in 2002, at 9.5%, and did not vary significantly among years (Kruskal-Wallis nonparametric ANOVA Statistic KW = 5.6, $p > 0.05$).

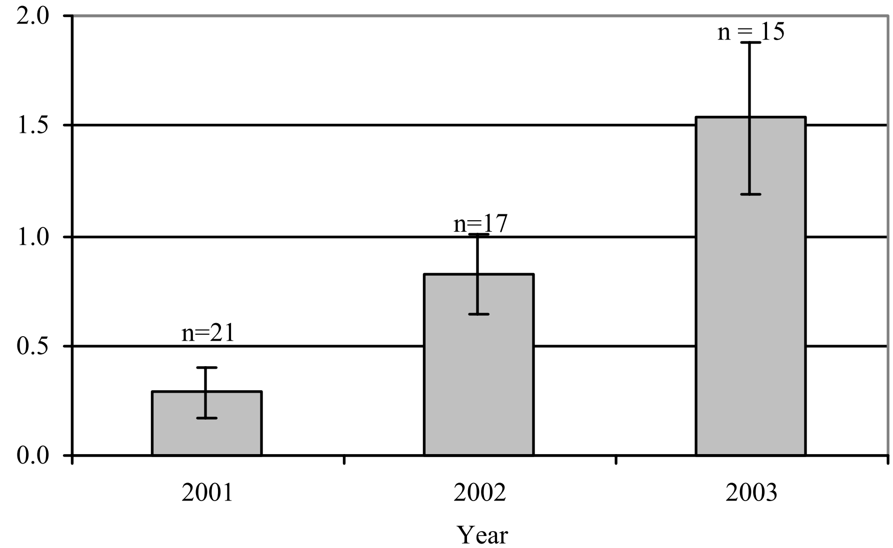

Figure 7. Mean number of large pods (≥ 3 adults) per scan sample in 2001-2003. Error bars represent standard error and *n* denotes the number of scan samples.

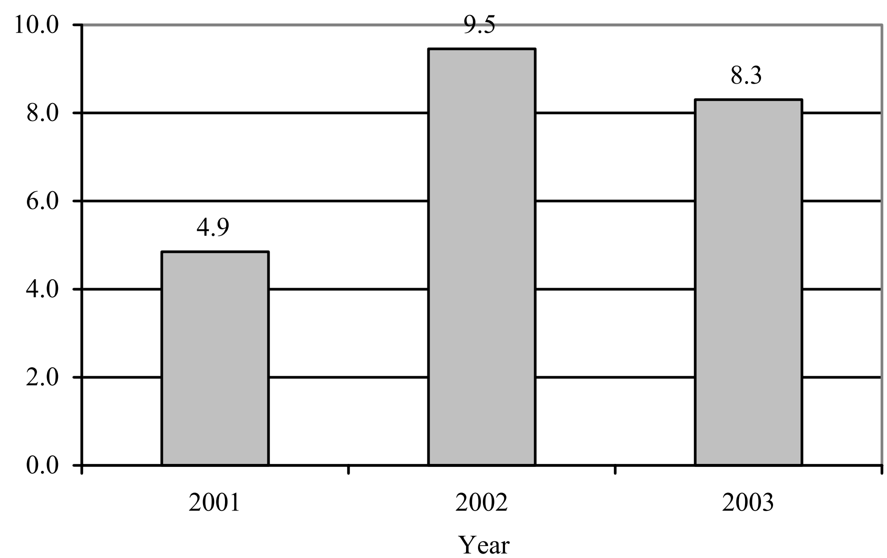

Figure 8. Percentage of large pods (≥ 3 adults) per scan sample in 2001-2003.

While the number of calves sighted per scan sample (within 6.5 km) increased from 1988 (0.3, $n = 34$) through 2003 (1.3 ± SE 0.4, $n = 15$) (Fig. 9), the percentage of calves sighted per scan sample peaked in 2001, at 10.1%, and decreased thereafter (Fig. 10). Despite these trends, neither the variation in the number of calves nor the percentage of calves per scan sample were found to vary significantly among years (2001 to 2003) (Kruskal-Wallis KW = 3.945 (corrected for ties), $p > 0.05$ and KW = 0.5527 (corrected for ties), $p > 0.05$, respectively). Moreover, no obvious trends among years in the mean number or percentage of calves sighted by time block (Figs. 11 and 12) or fortnight (Figs. 13 and 14) were apparent.

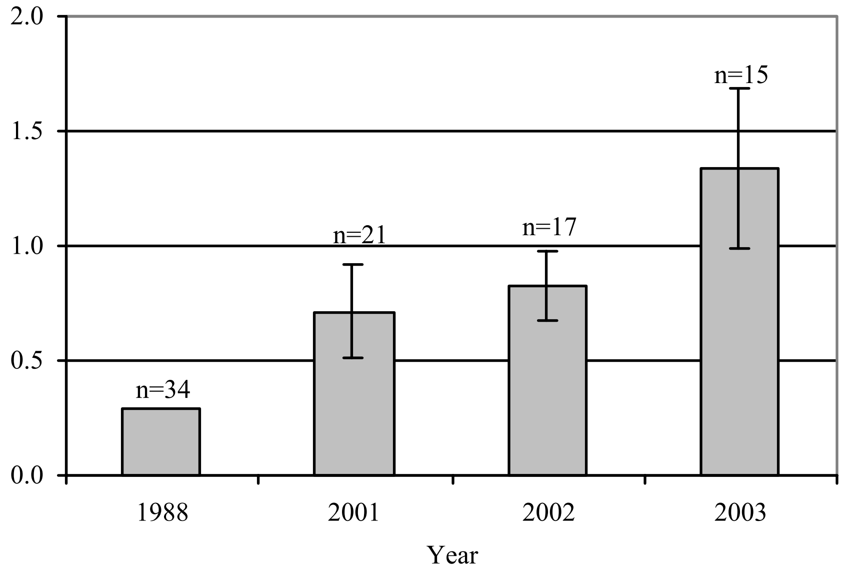

Figure 9. Mean number of calves per scan sample within 6.5km of observation site in 1988-2003. Error bars represent standard error (not available for 1988) and *n* denotes the number of scan samples. Data for 1988 are from Helweg, 1989.

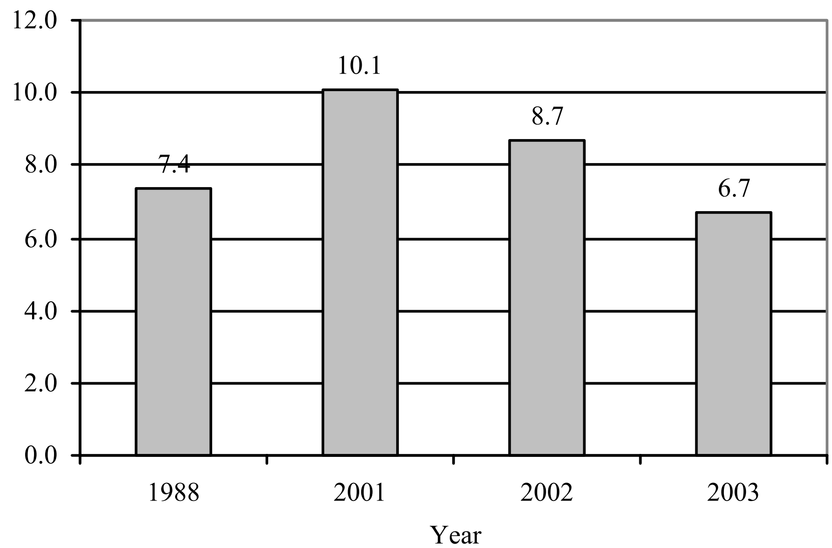

Figure 10. Percentage of calves per scan sample within 6.5km of observation site in 1988-2003.

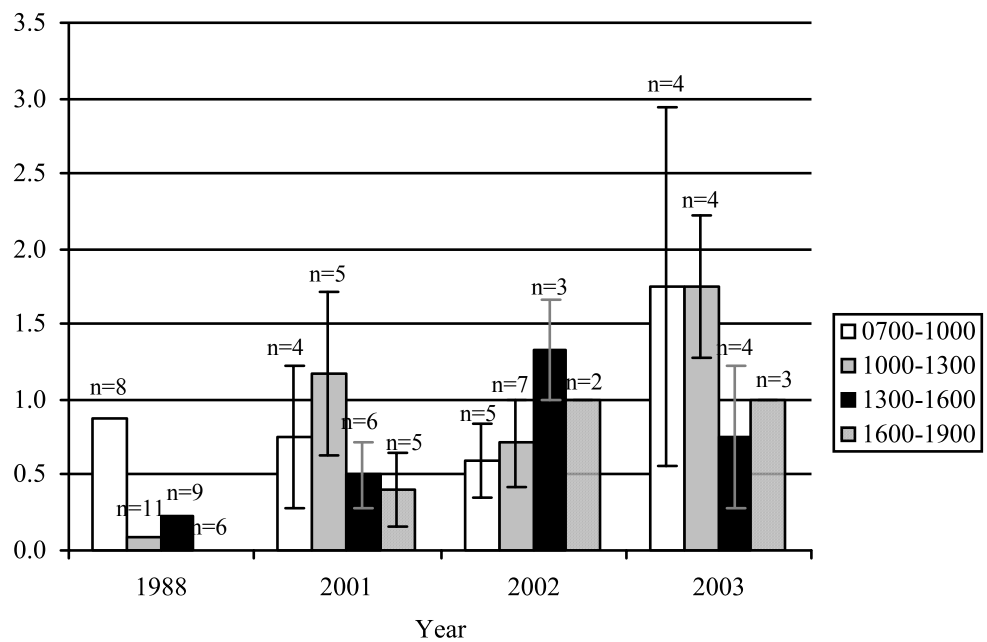

Figure 11. Mean number of calves per scan sample within 6.5km of observation site in 1988-2003, by time block. Error bars represent standard error (not available for 1988) and *n* denotes the number of scan samples. Data for 1988 are from Helweg, 1989.

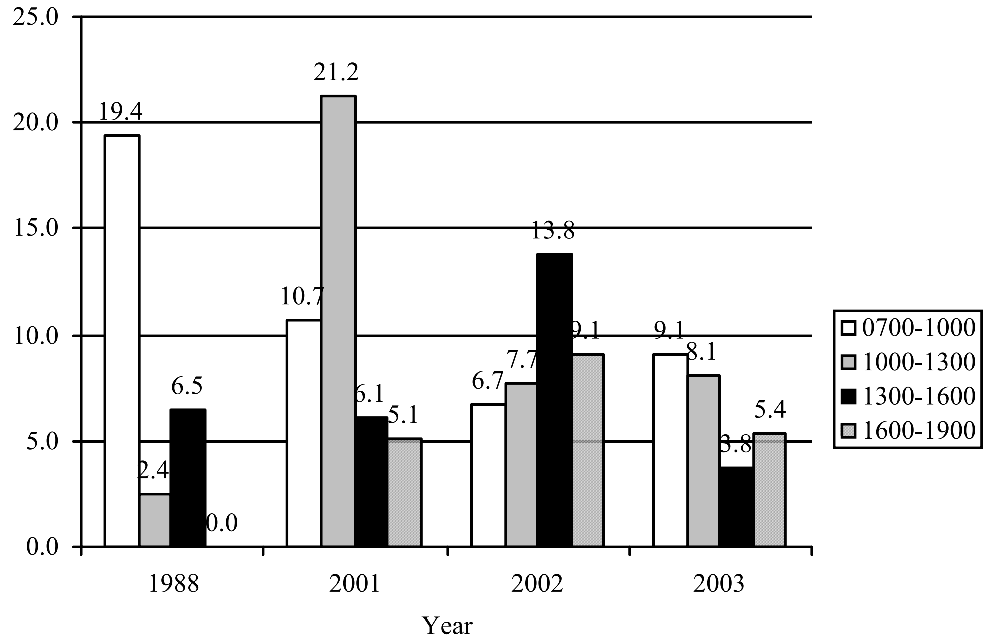

Figure 12. Percentage of calves per scan sample within 6.5km of observation site in 1988-2003, by time block. The number of scan samples for each year is displayed in Figure 11. Data for 1988 are from Helweg, 1989.

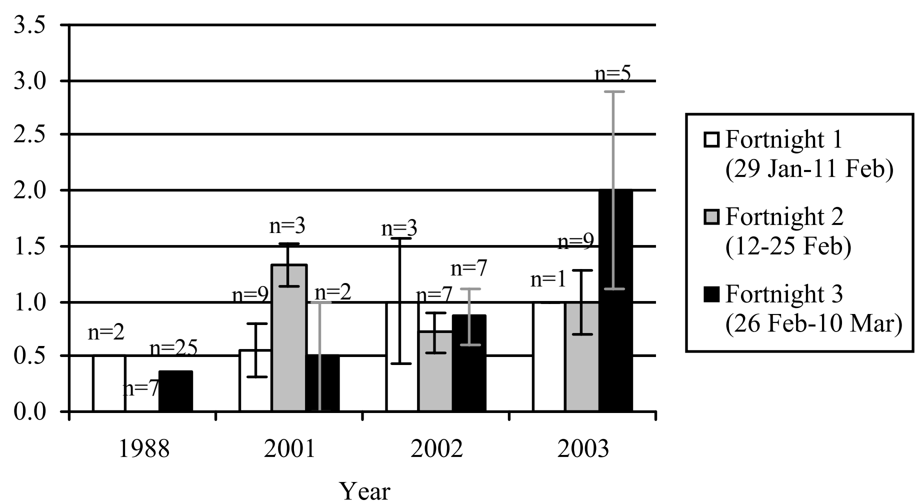

Figure 13. Mean number of calves per scan sample within 6.5km of observation site in 1988-2003, by time block. Error bars represent standard error (not available for 1988) and *n* denotes the number of scan samples. Data for 1988 are from Helweg, 1989.

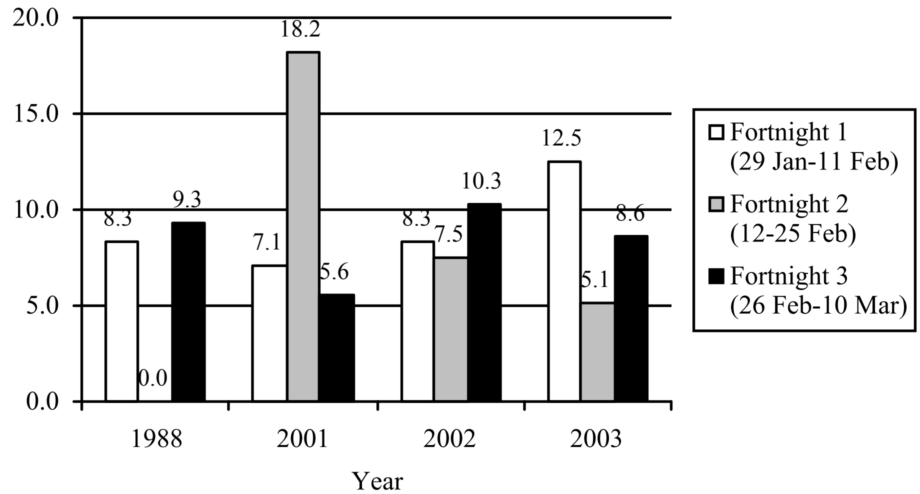

Figure 14. Percentage of calves per scan sample within 6.5km of observation site in 1988-2003, by fortnight. Data for 1988 are from Helweg, 1989.

Distribution: The first fix of each humpback whale pod that occurred during the "best" scan sample of the day was plotted. No data on whale distribution were available for 1988. Humpback whales were found throughout the study area in all years (Figs. 15-17). Most whales were within the 100-fathom (183 m) isobath. Pods containing a calf seemed to be distributed closer to shore. No detectable differences in whale distribution were found between years. Whales appeared to be clustered near shore, near the observation site, in all years. In 2003, the year with the largest number of sightings, whale distribution was slightly wider than in other years, especially in the southern end of our observation arena.

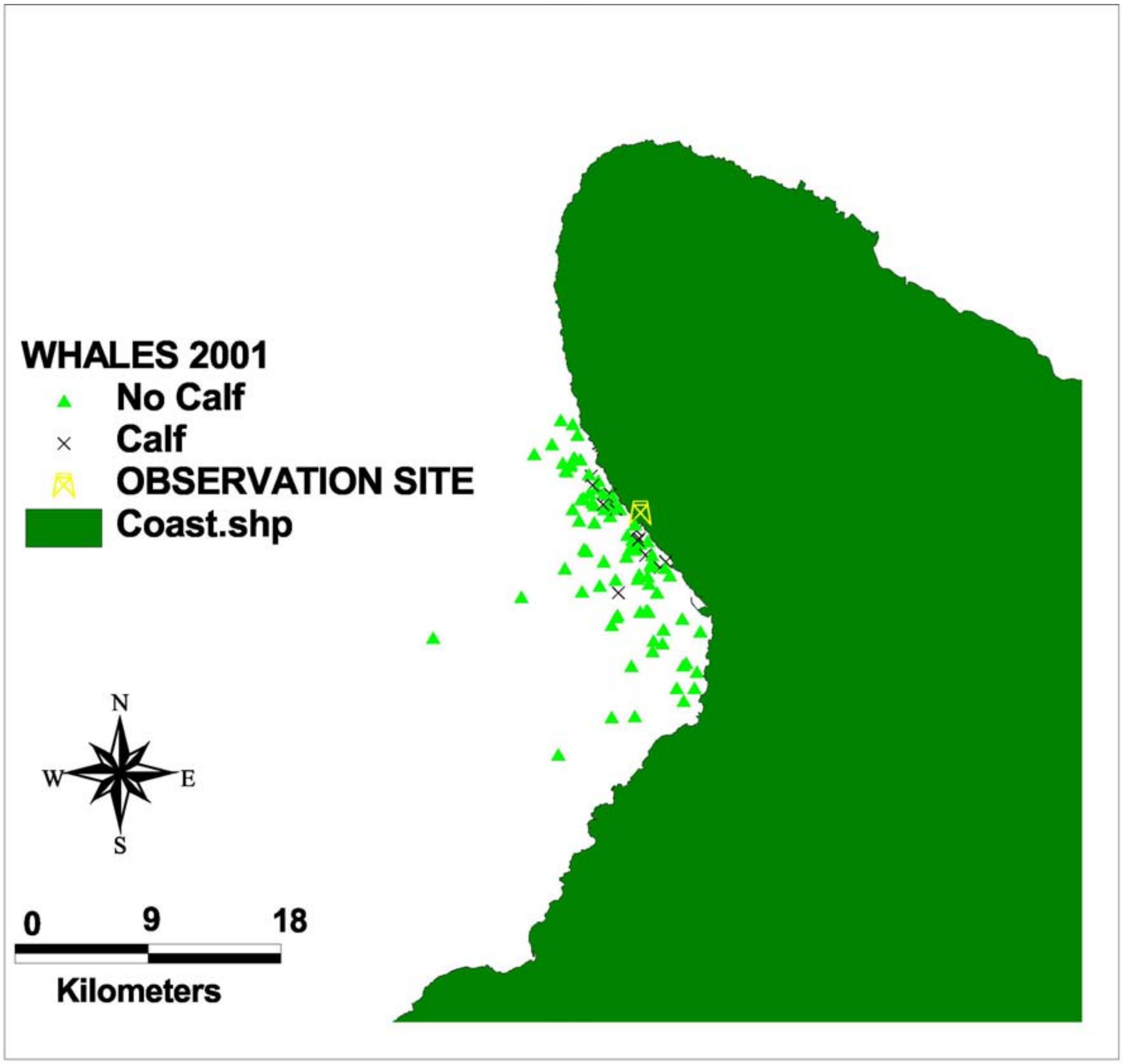

Figure 15. Distribution of humpback whales sighted from shore in 2001. Pods containing a calf are denoted with X.

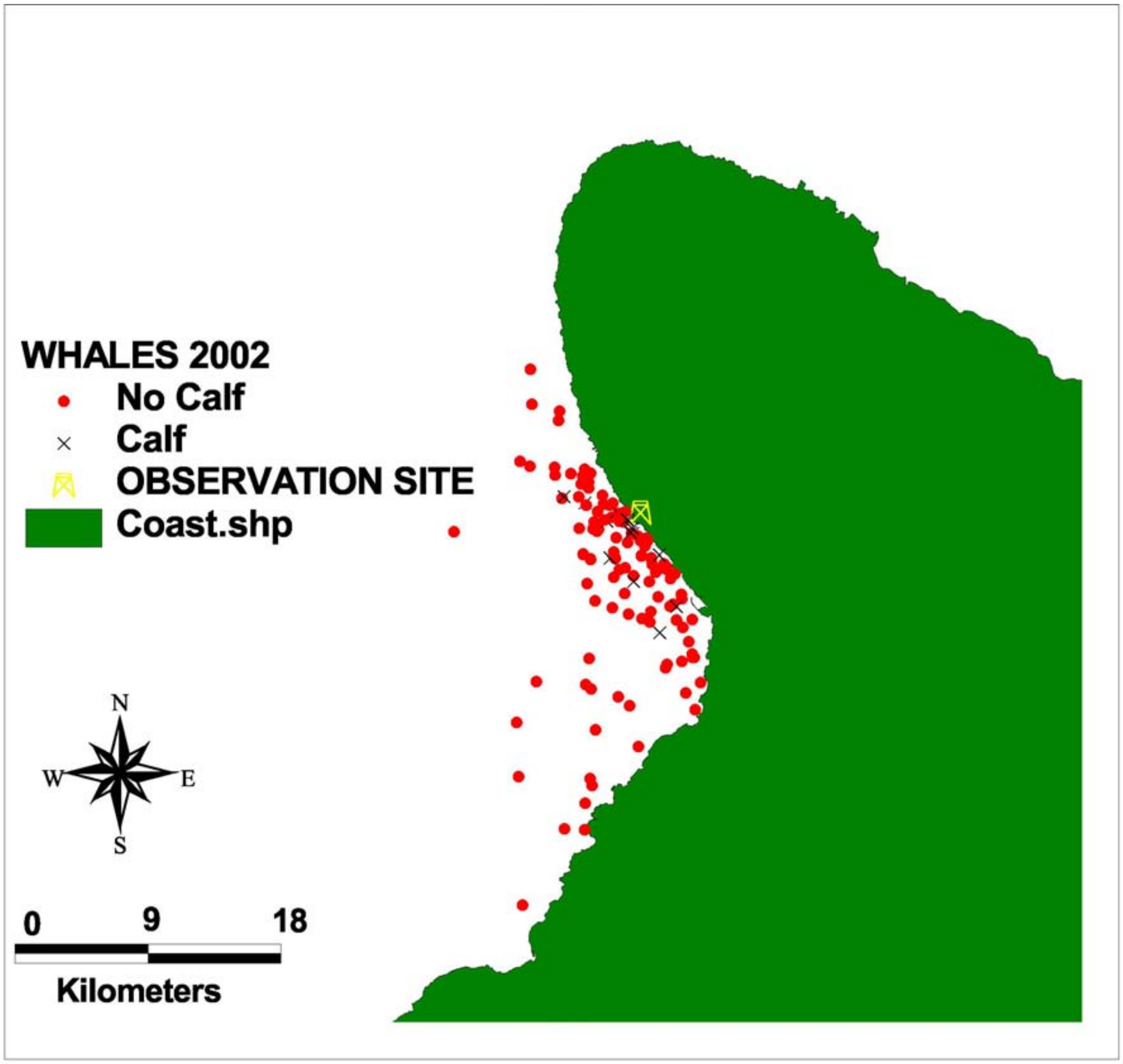

Figure 16. Distribution of humpback whales sighted from shore in 2002. Pods containing a calf are denoted with X.

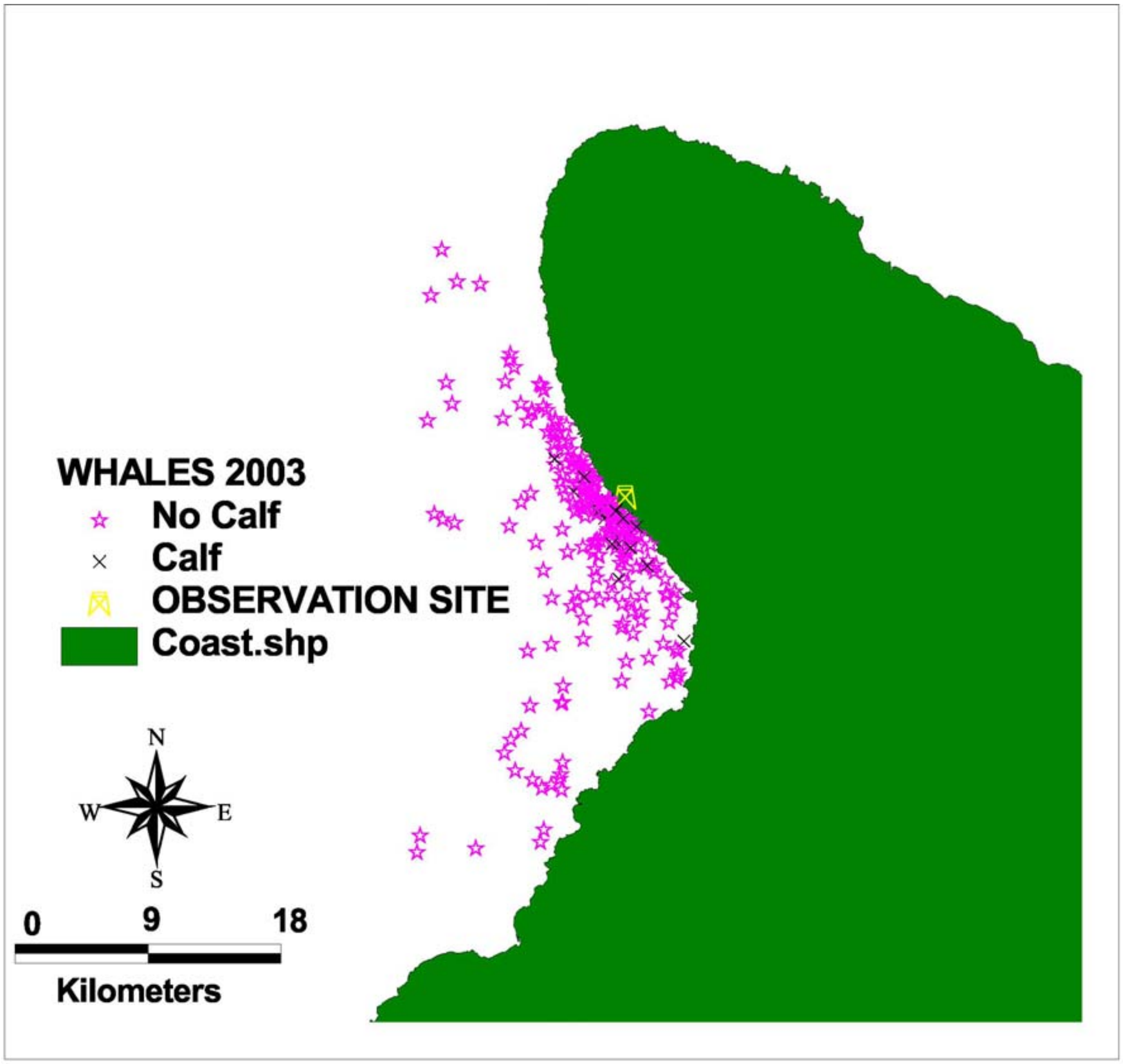

Figure 17. Distribution of humpback whales sighted from shore in 2003. Pods containing a calf are denoted with X.

Other Cetaceans

Numbers of sightings: Cetacean species, other than humpback whales, sighted during shore-based observations from 2001 through 2003, included spinner dolphins, spotted dolphins, and false killer whales (Table 4). Because sightings of other cetaceans are infrequent, all sightings are listed, regardless of whether they occurred during scans (Table 4).

Table 4. Cetaceans, other than humpback whales, sighted in 2001-2003, during and outside of scan samples. Values in parentheses are groups sighted only during those scan samples chosen for inter-annual comparisons (see Table 3).

	Number of Groups Sighted		
Year	*Stenella longirostris*	*Pseudorca crassidens*	*Stenella attenuata*
2001	4 (2)	2[1] (1)	0
2002	15 (6)	1 (1)	0
2003	7 (4)	0	1 (0)

[1] One group was described as a probable *Pseudorca crassidens*.

Distribution: Sighting locations of all other cetaceans sighted during the study (both during and outside of scan samples) are shown in Fig. 18. All other cetaceans sighted were odontocetes; no other mysticete cetaceans were sighted. Spinner dolphins appeared to be primarily coastal, while other species (spotted dolphins and false killer whales) were found farther offshore.

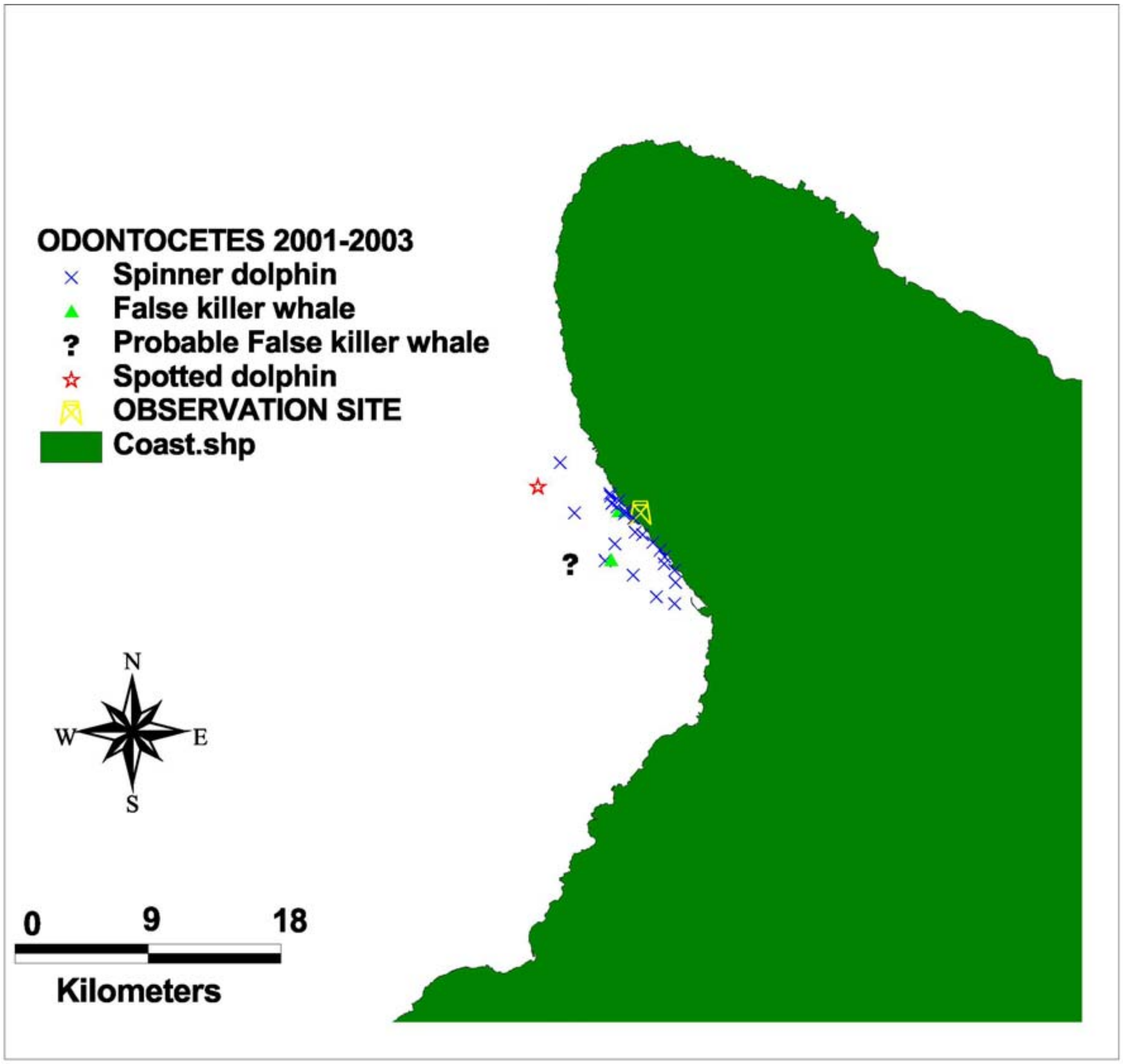

Figure 18. Distribution of odontocetes sighted from shore in 2001-2003. Colors denote species (spinner dolphin, spotted dolphin, false killer whale).

Vessels

Numbers: The mean number of vessels per scan sample (Fig. 19) did not vary significantly among years from 2001 through 2003 (ANOVA, $p > 0.05$), with values of 5.0 (± SE 0.5, $n = 21$) in 2001, 6.3 (± SE 0.8, $n = 17$) in 2002 and 5.0 (± SE 0.7, $n = 15$) in 2003. The mean number of each vessel type also did not vary significantly among these years (Kruskal-Wallis tests, $p > 0.05$) (Fig. 20). No vessel data were available from 1988.

Combining years, the mean number of vessels per scan sample did vary significantly among time blocks (ANOVA, $F = 6.214$, $p < 0.05$), with the 1000 to 1300 time block tending to have the most vessels, with a mean of 7.1 (± SE 0.5, $n = 17$) vessels per scan sample (Fig. 21).

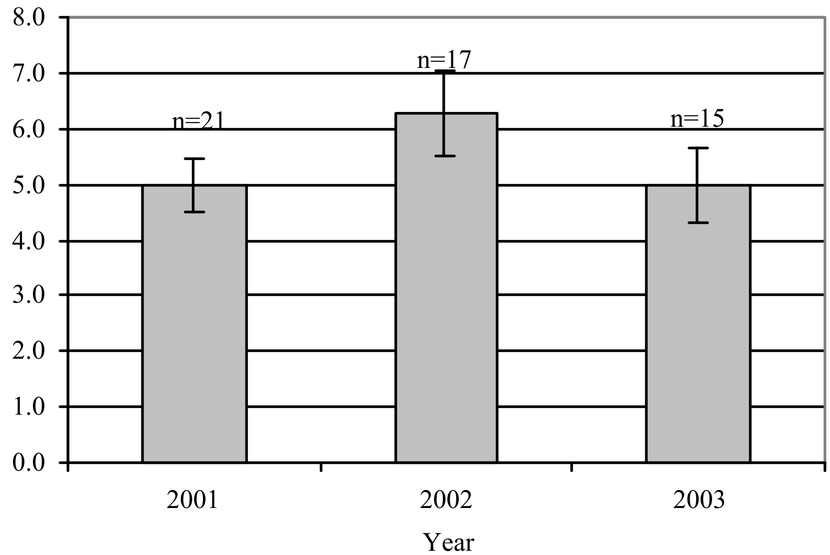

Figure 19. Mean number of vessels per scan sample in 2001-2003. Error bars represent standard error and *n* denotes the number of scan samples.

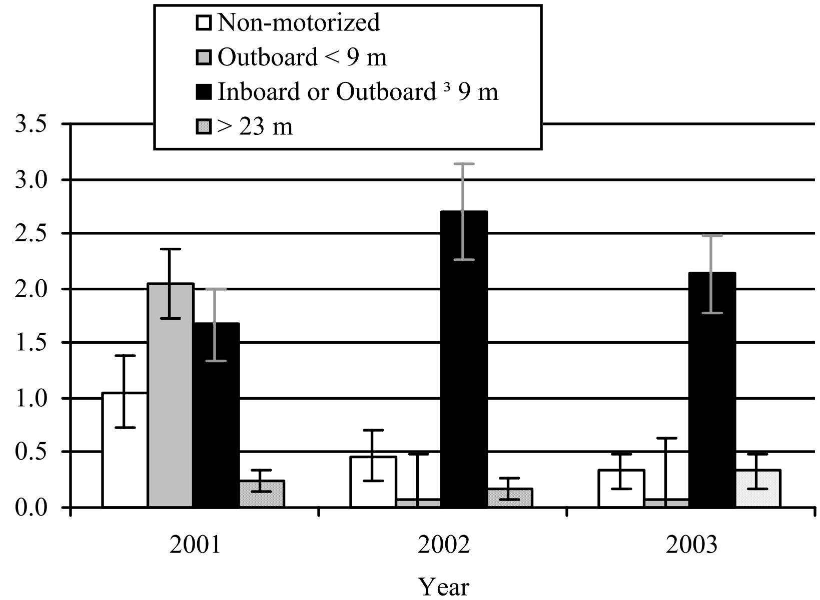

Figure 20. Mean number of vessels per scan sample by type in 2001-2003. Error bars represent standard error. The number of scan samples for each year is displayed in Figure 19.

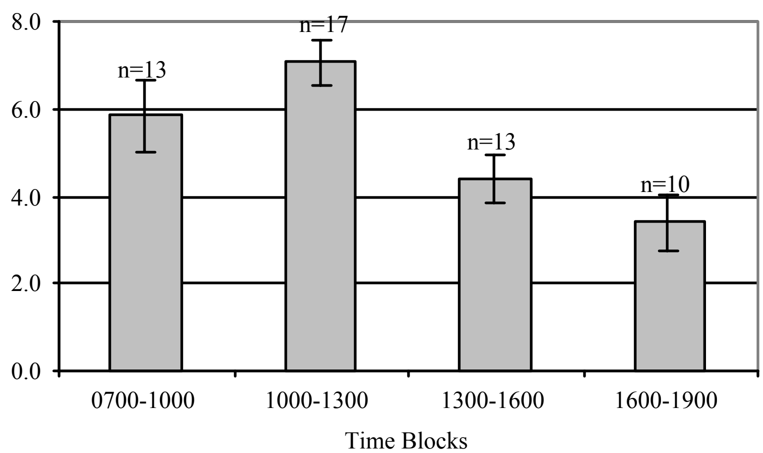

Figure 21. Mean number of vessels per scan sample for years combined (2001-2003), by time block. Error bars represent standard error and *n* denotes the number of scan samples.

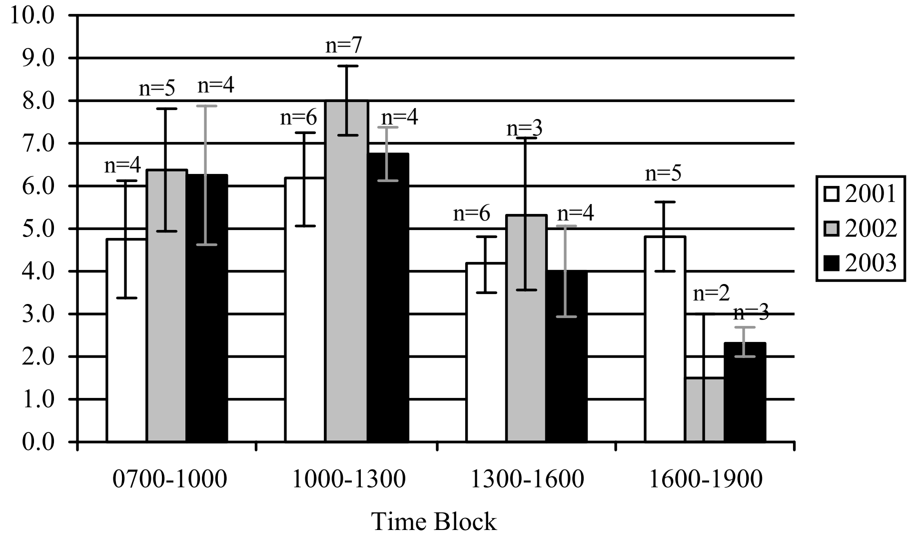

Figure 22. Mean number of vessels per scan sample each year, by time block. Error bars represent standard error and *n* denotes the number of scan samples.

Distribution: The first fix of each vessel that occurred during a “best” scan sample was plotted. Vessels were found throughout the study area in all years (Figs. 23, 24, 25). Non-motorized vessels, including kayaks, wind-surfers and sailboats showed a tendency to be distributed closer to shore.

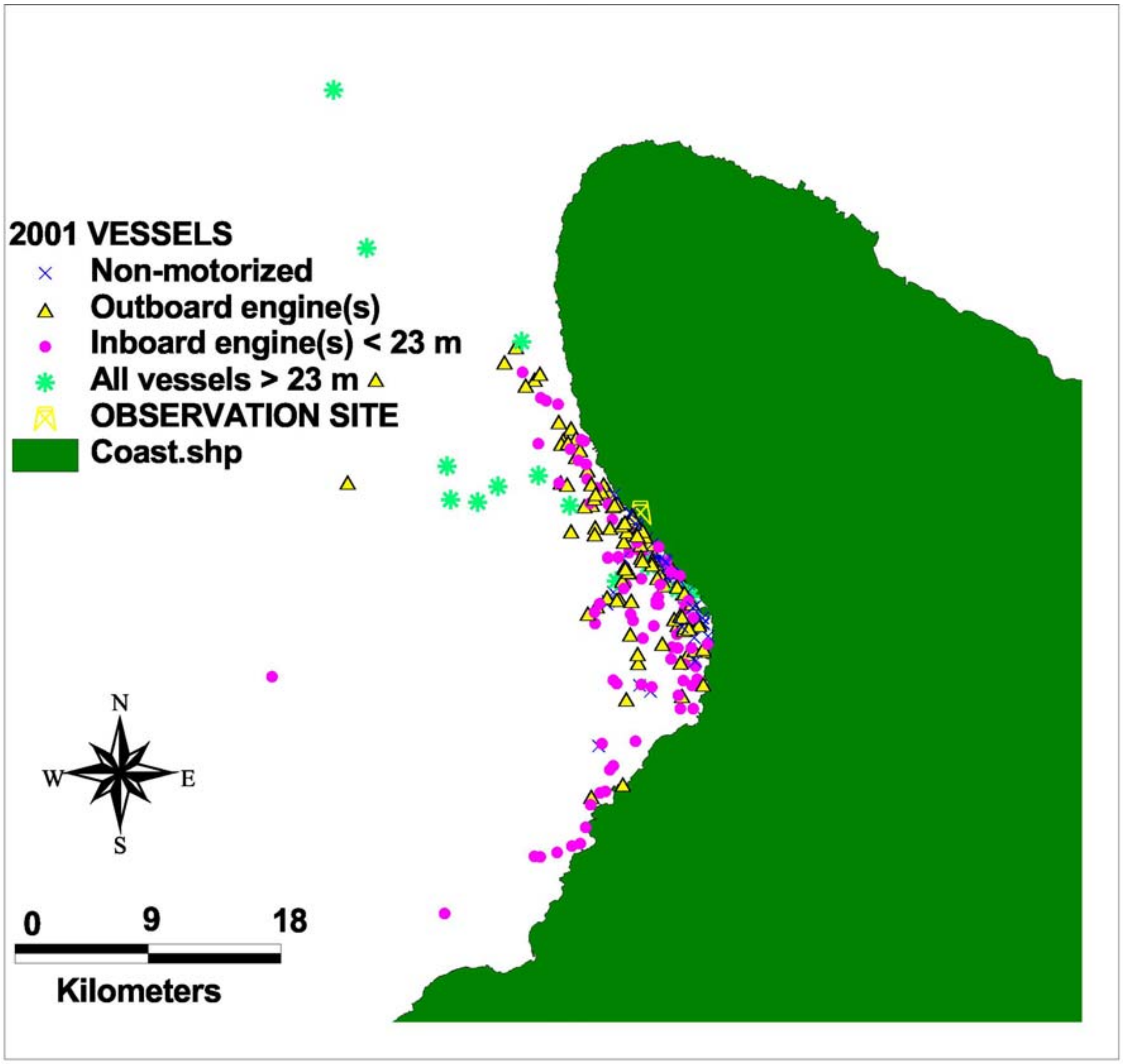

Figure 23. Distribution of vessels sighted from shore during scan samples in 2001. Colors and shapes denote vessel types defined in Table 1.

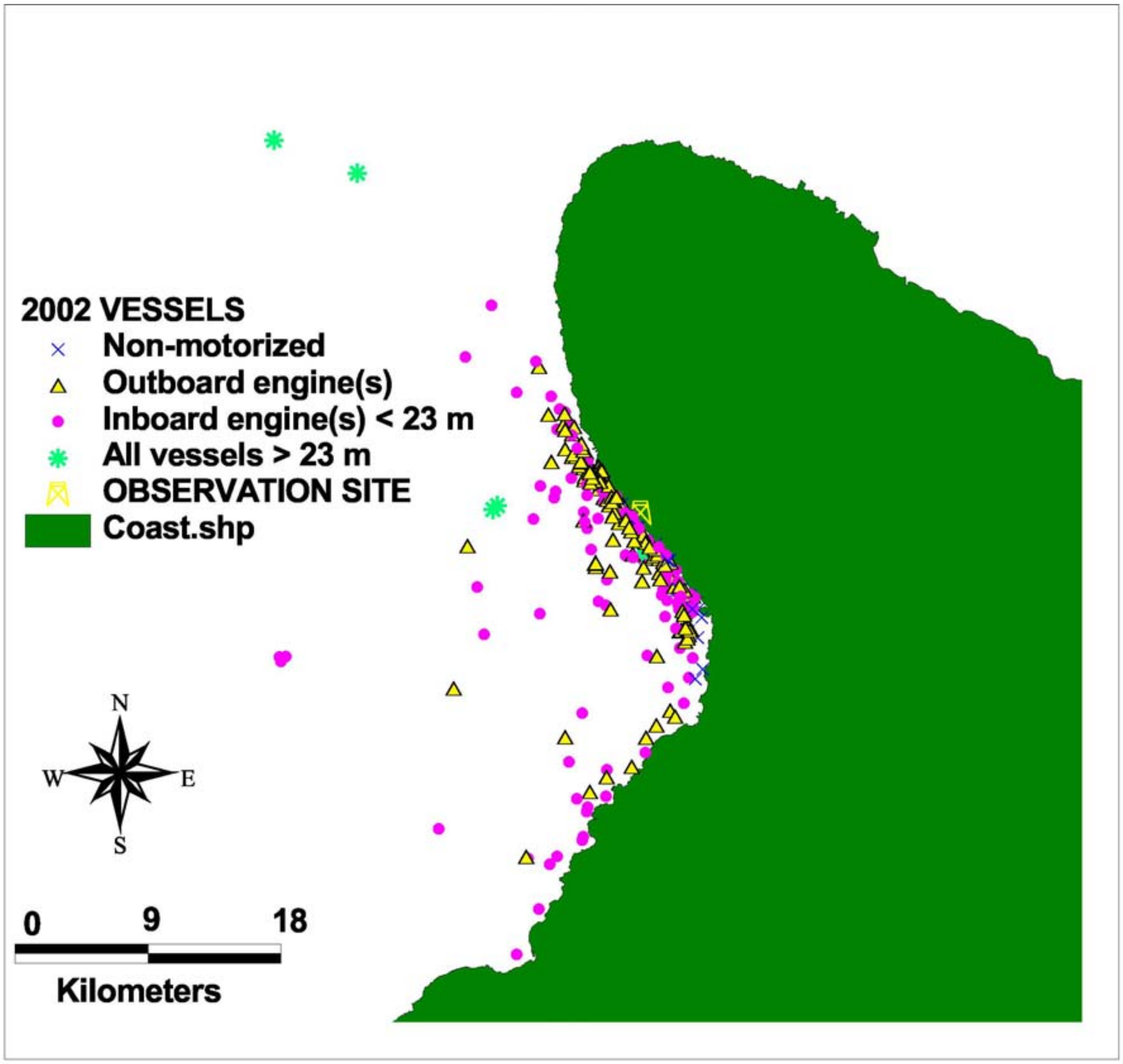

Figure 24. Distribution of vessels sighted from shore during scan samples in 2002. Colors and shapes denote vessel types defined in Table 1.

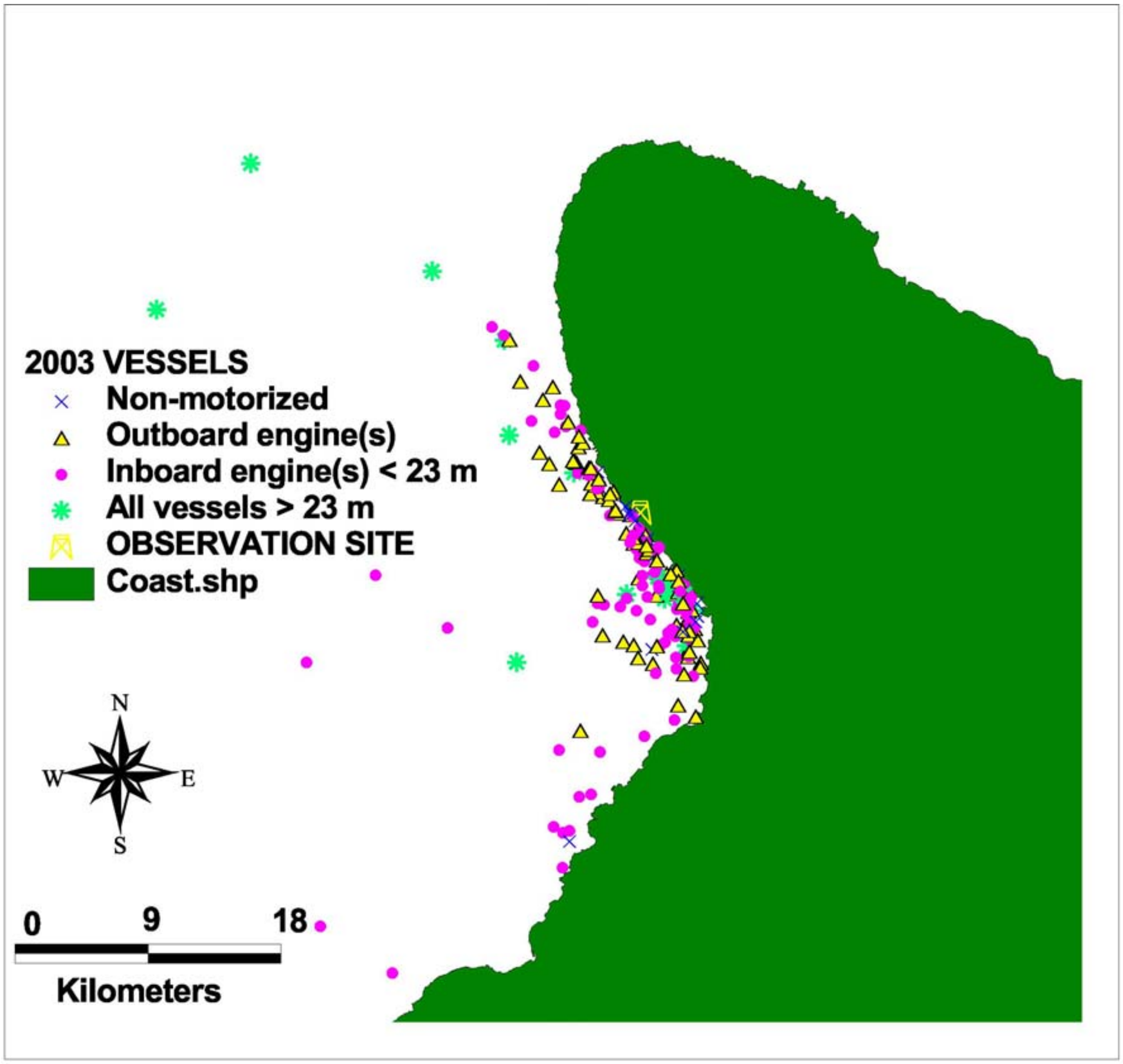

Figure 25. Distribution of vessels sighted from shore during scan samples in 2003. Colors and shapes denote vessel types defined in Table 1.

DISCUSSION

The number of whales sighted during scan samples, within 6.5 km of the shore station, increased from a mean of 7.1 whales in 2001 to 19.9 whales in 2003, with intervening years showing steady, incremental increase (Fig. 2). Although statistical comparisons to verify this trend were not possible with 1988 data, it seems apparent that the increasing trend extends back to 1988, when a mean of 4.0 whales per scan was observed. Although humpback whale population growth documented in the North Pacific (Calambokidis et al. 1997, Mobley et al. 1999) is the most likely explanation for the increasing trend in Kawaihae Bay, several alternative explanations merit consideration.

First, rates of sighting whales are affected by environmental conditions (Barlow et al. 2001). Observation conditions in each year, as indicated by the mean Beaufort states during scans (2001 = 2.5, 2002 = 2.4, 2003 = 2.7), were not sufficiently different to explain differences in the number of whales sighted between years. Second, increases in the number of whales off West Hawai‘i could be attributed to whales moving from other waters in the main Hawaiian Island chain. Despite knowledge that whales travel throughout the main islands (Baker and Herman 1981, Cerchio et al. 1998), the current incomplete understanding of humpback whale habitat use makes it difficult to know if or when whales would congregate offshore of one island versus another during an entire season or subset of a season. Third, the observed increase in whale numbers in a given year could have been due to a short-term influx of new animals into the area. However, the increase in whale numbers was evident in most fortnights (Fig. 4), and was, therefore, not attributable to a single large pulse of whales into the study area in later years. Analysis by fortnight also indicates inter-year differences in the timing of peak whale numbers, although the fortnight segments have small sample sizes in most cases. Similarly, larger numbers of whales were observed in later years regardless of the time of day that the scan was performed (Fig. 3). And, finally, including whales in the entire study area in 2001-2003 (not just those within 6.5 km of the shore station) shows the same increasing trend (Fig. 5), illustrating that changes in the inshore-offshore distribution of whales was unlikely the sole reason for the observed increase.

Observations of pod sizes and population composition in Kawaihae Bay, particularly by large pods and cow/calf pairs, provide an indication of the vital life history stages that make this habitat important. Large pods are frequently “competitive groups” (Tyack and Whitehead 1983, Baker and Herman 1984, Medrano et al. 1994) that are believed to be associated with male-male competition for receptive females. The observed significant increase in the number of large pods in the study area in 2001-2003 (Fig. 7) appears to be a direct result of larger numbers of whales, while the proportion of large pods remained relatively stable between 4.9 and 9.5% (Fig. 10). Previous studies, indicating that Kawaihae Bay had a smaller proportion of large pods than had been reported for other areas of the Hawaiian Islands (Herman and Antinoja 1977 , Forestell and Brown 1992), may have been observing this same phenomenon. If data on the number and proportion of large pods observed near Maui become available, we could determine whether large pods have remained less frequent off West Hawai‘i.

The percentage of pods with a calf per scan sample, within 6.5 km of the study area, ranged from 6.7 to 10.1%, peaking in 2001, and showed no statistically detectable trend over time. Although the number of calves per scan increased from 0.3 in 1988 to 1.3 in 2003, this trend was not statistically significant either. The calf proportions were consistent with the 3.6-12.7% range of variation reported in February through April by Mobley et al. (1999) and from calf proportions detected in feeding areas, which are highly variable and ranged from 3.4 to 18.5% in 1985-2003 (mean = 10.75%, SE 4.51; Doherty and Gabriele 2002). In a growing population, one might expect a decrease in the proportion of calves as the population reaches its carrying capacity, if reproduction is density dependent. The timing of the peak presence of calves appears to be quite variable among years (Figs. 13 and 14). This variability may be explained in part by small sample sizes in fortnight subsets, but is believed to reflect actual variability in the timing of the use of Kawaihae Bay by cow/calf pairs. Data from 2001-2003 did not corroborate the predominance of calf pods in 0700-1000 scans found in 1988 (Helweg and Herman 1994, Fig 12).

Other than humpback whales, spinner dolphins were the most frequently sighted cetacean in the study area. Other species sighted, including false killer whales and spotted dolphins, appeared to use the area less frequently. Other species, previously reported for this area but not detected during this study, include bottlenose dolphins (A. Frankel, unpublished data) and melon-headed whales (*Peponocephala electra*) (Forestell and Brown 1992). Because they lack the conspicuous tall blow of humpback whales, it might be difficult for us to sight small cetaceans reliably, particularly species that do not typically assemble into large groups. Most of these odontocete species are found more often in deep-water habitat, further reducing the probability of sighting them. Spinner dolphins regularly come into shallow near-shore waters to rest (Norris and Dohl 1980), increasing their probability of detection. Spotted dolphins have often been observed with spinner dolphins along the West Hawaiʻi coastline (pers. obs.). Little is known about seasonal patterns of odontocete use of the waters off West Hawaiʻi, so it is unclear if the likelihood of sightings would be higher outside the winter months during which this humpback whale study occurred. Sightings of spinner dolphins were not frequent enough in 2001-2003 to assess trends in the relative numbers or distribution of this species.

Vessel traffic in Kawaihae Bay was stable over the 2001-2003 period. The characteristics of vessel traffic were also stable over this three-year period. No information on vessel traffic is available for 1988, but since the authors have been observing whales in the area throughout that time period, anecdotally we have not observed any dramatic changes in the number or types of vessels using the area. However, two or three sailing catamaran tour vessels, whose home-port is Kawaihae Harbor, that were common in vessel scans for 2001-2003, were not present in the 1980s and early 1990s. The number of catamarans operating in the southern end of the study area, near the resorts, has appeared to increase slowly as well. Business records from the resorts and tour companies could easily verify these anecdotal observations. The distribution of vessels is such that they overlap strongly with humpback whale use of the area (Figs. 15-17 and 23-25).

Most of the humpback whales documented in this study were in Sanctuary waters off West Hawaiʻi. Historical records (Herman and Antinoja 1997, Forestell and Brown 1992) and the contemporary data presented here indicate that Kawaihae Bay continues to represent important humpback whale habitat. Increases in the number of whales in Kawaihae Bay are encouraging signs for the recovery of the endangered North Pacific population of humpback whales. However, increasing human use of the area, combined with increases in whale numbers, herald more whale-human interaction, which can in some cases be detrimental to the whales. The slow growth of vessel traffic and appreciable increases in whale numbers highlight the uniqueness of this area among important whale habitats in the Hawaiian Islands. Although Kawaihae is the commercial port for West Hawai‘i it has relatively low levels of vessel traffic, slowly increasing in primarily tourism and recreation sectors. New proposed commercial uses of nearshore waters, including a proposed aquaculture facility, would contribute an unprecedented steady stream of traffic, as well increasing the risk of entanglement and marine pollution. The trend for increasing shoreline and marine development in West Hawai‘i will require calm and consistent management to preserve the humpback whale habitat in this important area within Sanctuary waters.

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