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HABITAT UTILIZATION PATTERNS OF HUMPBACK WHALES (MEGAPTERA NOVAEANGLIAE) OFF THE ISLAND OF HAWAII

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ABSTRACT

The distribution of humpback whale groups was assessed from shore by tracking whales in a relatively undisturbed area off the island of Hawaii during the 1988 and 1989 calving seasons. The temporal and spatial distribution of whales differed with group size and composition. Groups containing a calf occurred in water significantly more shallow and nearer to shore than did groups without calves during afternoon hours throughout the study period. During the late breeding season (11 March to 7 April), this same distribution pattern occurred throughout the day. No significant relationship was found between the distribution of groups with a calf and the number of adults within the calf group. In addition the distribution of calf groups when alone in the study area did not differ significantly from when adult groups were present. However, distances between groups with a calf and all other groups were significantly greater than inter-distances between non-calf groups. Single adult whales were also sighted more frequently in shallower nearshore water during the afternoon than the morning; yet they still occurred in deeper water and farther from shore than calf groups during the afternoon. However, the use of shallow areas by single adults was different from groups of two or more adults only during late February/early March (near the peak period of whale abundance).

The overall number of whales observed per hour in the study area peaked during mid-February in both 1988 and 1989. This peak occurred approximately one month earlier than that reported off the island of Maui in 1987 and 1988, and one to two weeks later than the reported peak for a coastal area 35-45 km north-northeast of the study site in 1989. However, the relative abundance of whales based on group size and composition varied across the study period. Adult pairs and trios decreased in relative abundance through the breeding season while that of single adults remained fairly constant at 40-50% of all sightings. In contrast, groups with a calf increased in relative abundance across the breeding season, as did the proportion of cow/calf pairs accompanied by at least one adult. In addition, the study site was utilized by a higher overall proportion of cows with calves than has been previously reported for the island of Hawaii.

Temporal and spatial habitat preferences of humpback cows with calves may be related to changes in reproductive conditions and relative abundance of humpback social groups. Cows with calves may prefer shallow nearshore water to: (1) avoid harassment and risk of injury to the calf from aggressively courting males; (2) minimize predation; or (3) reduce exposure to more turbulent sea conditions in offshore areas. Adults may prefer offshore deep water to facilitate surface-active breeding behavior and propagation of song.

However, a preference for shallow, nearshore habitat increases the vulnerability and exposure of cows and their calves to expanding coastal development and associated human aquatic activities which could potentially disturb and displace them. These results provide baseline data on the distribution and abundance of humpback whales that can be used to identify and evaluate potential changes in habitat use by whales resulting from increased human-related development and recreational activities planned for the region.

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INTRODUCTION

Little information exists on the habitat-use patterns of humpback whales based on sex, age, or reproductive class while on their winter breeding and calving grounds. Knowledge of preferred habitat is essential to make sound management decisions for protection of endangered humpbacks, particularly with respect to human-related aquatic activities which may disturb and displace whales in coastal waters. Before effects of human-related development on humpbacks may be assessed, it should be determined whether and when certain habitats are preferentially occupied by humpbacks and by which classes of the population. This study (1) systematically quantifies baseline data on the temporal and spatial distribution and occurrence of humpbacks based on group size and composition off the island of Hawaii prior to nearshore development, and (2) attempts to test the hypotheses that (a) humpback cows with calves prefer nearshore shallow water, and (b) groups without a calf prefer offshore deep water.

While on the breeding and calving grounds, humpback whales appear to prefer water depths well under 180 m (Dawbin 1966; Forsyth et al. 1991). Preliminary observations on the wintering grounds in Hawaii, the Caribbean, and Mexico suggest that segregation may exist within this parameter. Humpback cows with calves tend to predominate in nearshore shallow water (Herman and Antinoja 1977; Herman et al. 1980; Whitehead and Moore 1982; Glockner and Venus 1983; Glockner-Ferrari and Ferrari 1985; Brown et al. 1989; Mattila and Clapham 1989; Ladron de Guevara et al. 1991). In contrast to cow/calf pairs, socializing groups of adult humpbacks tend to occur in offshore deep waters of these regions (Herman et al. 1980; Mattila and Clapham 1989; Forestell et al. 1991; Ladron de Guevara et al. 1991). Yet recent aerial surveys by Forsyth et al. (1991) near the island of Maui in Hawaii showed that mean depth location of humpback groups with calves did not differ from groups without calves. However, the latter study did not consider the influence of historical increases in human-related aquatic habitat use on humpback distribution. There is thus a need to systematically quantify observed trends in habitat preferences of humpback social groups, particularly before the introduction of human activities.

The impacts of human-whale interactions are difficult to define but have evoked concern among researchers, managers, the tourism industry, and the public in general. Chronic human-related disturbance could potentially stress animals, resulting in disruption of pregnancy, nursing, or breeding, and thereby threaten reproductive success (Laws 1973; Norris and Reeves 1978; Herrenkohl 1979; Herman et al. 1980; Oldfield 1988). Recreational water activities such as boating, jet skiing, and parasailing have been increasing in nearshore areas of Hawaii, and there is evidence that such activity may displace humpback whales from preferred habitat. Herman et al. (1980) and Forestell (1989) described a conspicuous absence of whales near boat harbors off Maui. A progressive decrease in the percentage of cows and calves sighted in the nearshore waters off the west coast of Maui near Lahaina was reported from 1977 to 1988 by Glockner-Ferrari and Ferrari (1985, 1987, 1990) and by Salden (1988) based on non-systematic, vessel-based surveys; an increase in recreational activity in coastal waters, including the implementation of three jet-ski operations in the study area from 1981 to 1983, was cited as a possible factor contributing to this apparent distributional shift by cow/calf pods. Recent 1990 aerial surveys by Forsyth et al. (1991) near Maui indicating that humpback groups with a calf occur in deeper mean water than that reported in the 1970s support the displacement trends reported by Glockner-Ferrari and Ferrari (1985, 1987, 1990). In contrast, Forestell et al. (1991) reported no significant change in the mean distance from shore of humpbacks, including groups with a calf, near the islands of Maui and Lanai based on aerial and vessel surveys between 1976 to 1991. More information from systematic control studies on whale and vessel distribution prior to disturbance is necessary to quantitatively assess habitat parameters preferred by humpback social groups and to correlate increased vessel activity with changes in distribution. Moreover, these parameters should be examined for potential diurnal, within-season, or behavioral influences.

Many studies have arbitrarily delineated and defined "preferred" habitat (i.e. inshore versus offshore categories, geographical regions) (Herman and Antinoja 1977; Herman et al. 1980; Whitehead and Moore 1982; Glockner-Ferrari and Ferrari 1985, 1987, 1990; Mattila and Clapham 1989; Forestell 1989). While such information is generally useful and descriptive, it may be biased by selection of habitat parameters interpreted as important by observers but not necessarily biologically important to whales. Quantitative assessment of habitat selection by humpback social groups based on continuous environmental parameters, such as water depth and proximity to shore, is desirable.

Nearshore shallow habitat may be important as a refuge for humpback cows with calves from sexually active adults. Gray (*Eschrichtius robustus*) and southern right whale (*Eubalaena australis*) cows with calves are believed to segregate themselves in shallow nearshore water to avoid harassment from surface-active groups of breeding adults which prefer deep water (Taber and Thomas 1982; Jones and Swartz 1984; Swartz 1986). There is indication that humpback cows with calves may behave similarly. Brown et al. (1989) reported that humpback groups with a calf avoided areas preferred by adults in Maalaea Bay, Maui, throughout the period from January to April 1989. Additionally, behavioral studies show that humpback cows with calves avoid contact with other whales and move away from active social groups and their sounds (Herman et al. 1980; Tyack 1982; Tyack and Whitehead 1983; Mobley et al. 1988). Yet there remains the need to quantitatively define the temporal and spatial parameters of potential habitat preferences of cows with calves relative to adults before appropriate management decisions can be made.

The island of Hawaii is relatively undisturbed by human activities compared to the Maui region, yet many areas are slated for development, including the construction or expansion of hotel resorts and boat harbors. Humpback cows with calves and courting adults are known to occur off Hawaii, although in smaller numbers than the Four Island (comprised of Maui, Molokai, Lanai, and Kahoolawe) and Penguin Bank regions of the Hawaiian Islands (Herman and Antinoja 1977; Herman et al. 1980; Mobley and Herman 1985; Helweg 1989). Detailed descriptions of seasonal abundance and distribution near the island of Hawaii are limited and out-of-date, and such studies have generally not extended across the entire period in which humpbacks are present. Information on the abundance of whales and vessels off Hawaii is necessary to establish baseline data which can be used to describe distribution and to identify and evaluate changes in habitat-use patterns of whales possibly resulting from changes in vessel abundance and other human-related activities planned for the study area.

Objectives

The goals of this study were to describe the distribution of humpback whale social groups, to associate whale distribution with abundance, and to establish a baseline on the occurrence of whales and vessels in the study area off the western coast of the island of Hawaii. In order to meet these goals, the study objectives were to determine:

(1) the preferred distributions of groups containing a calf and groups without a calf based on water depth and distance from shore by period (fortnight) of the breeding season and time of day, and then to assess whether this distribution was related to group size;

(2) the distribution of groups containing a calf based on water depth and distance from shore while alone in the study area versus when non-calf groups were present;

(3) whether distances between groups containing a calf and all other groups differed from distances between non-calf groups, and whether this difference was related to (i) group size and composition or (ii) period of the breeding season;

(4) relative abundance of individual whales, groups, and social groups across the breeding season;

(5) the occurrence of vessels in the study area and the distribution of humpback social groups based on water depth and distance from shore while vessels were absent versus present in the study area.

METHODS

Study Area and Observation Dates

Land-based observations were made from the Kuili cinder cone off the western Kona coast of the island of Hawaii (the Big Island), Hawaii (Fig. 1). The observation station was located 104.2 m above sea level (ASL) and approximately 300 m from shore. The study area consisted of the coastal waters within a 5 km radius of the land station and encompassed a depth range of 0 to 128 m (Fig. 2). Observations were made from 9 February to 29 March 1988, and from 20 January to 5 April 1989, dates coinciding with known seasonal occurrence of the majority of humpbacks in Hawaii during the breeding/calving season. Data collection began in the third fortnight of 1988 and in the second of 1989.

Subjects

Observations were made on a subpopulation of eastern North Pacific humpback whales which wintered off the island of Hawaii. A humpback pod was defined as a single whale or two or more whales (Mobley and Herman 1985) within 10 body lengths (approximately 150 m) of one another, and characterized by synchronized surfacing patterns. Pod composition was categorized as one of the following social groups (as described by Tyack 1981; Tyack 1982; Darling 1983; Glockner and Venus 1983; Tyack and Whitehead 1983; Baker and Herman 1984; Silber 1986): cow/calf pair; cow/calf pair accompanied (escorted) by one adult; cow/calf pair accompanied by two or more adults; single adult (singleton); two adults (dyad); or a pod of three or more adults. All non-calf whales were designated as adults since subadults other than calves could not be reliably distinguished from adults. Any pod containing a calf was defined as a calf pod; any pod that did not contain a calf was defined as an adult pod.

Apparatus

A surveyor's theodolite (Lietz/Sokkisha Model DT20E, 20-second precision, 30-power magnification) was used to track pod locations and determine pod compositions as described by Tyack (1981) and Würsig et al. (1991). Theodolite-measured vertical angles were converted to measures of distance from the land station through application of a computer program which utilized trigonometric calculations corrected for curvature of the earth (Würsig 1978; Rusconi and Hawkinson 1991). Using the theodolite information, the initial positions of all pods were plotted on bathymetric charts. The distance-from-shore variable used in analyses was determined by using calipers to measure the distance from a plotted pod position to the closest point of land; the water-depth variable was assessed by interpolating between charted depths nearest the pod location. Inter-pod distances (the distance between plotted whale groups) were also determined using calipers. Since the fluctuation in tidal height off the Hawaiian coast is less than 30 cm, the minimal resultant distance error was ignored (Bauer 1986). Location and time were noted once for each pod when the cross-hairs within the scope of the theodolite were first positioned with the waterline of the surfacing whale.

Data collection

Land-based observations were conducted six days per week by two or three people: a theodolite operator and a recorder, with both functioning as observers; or a theodolite operator, a recorder, and a primary observer, with all three functioning as observers while searching for whales. The theodolite observer was generally equipped with 7 x 35 binoculars, the recorder with 8 x 40 binoculars, and the observer with 10 x 50 binoculars.

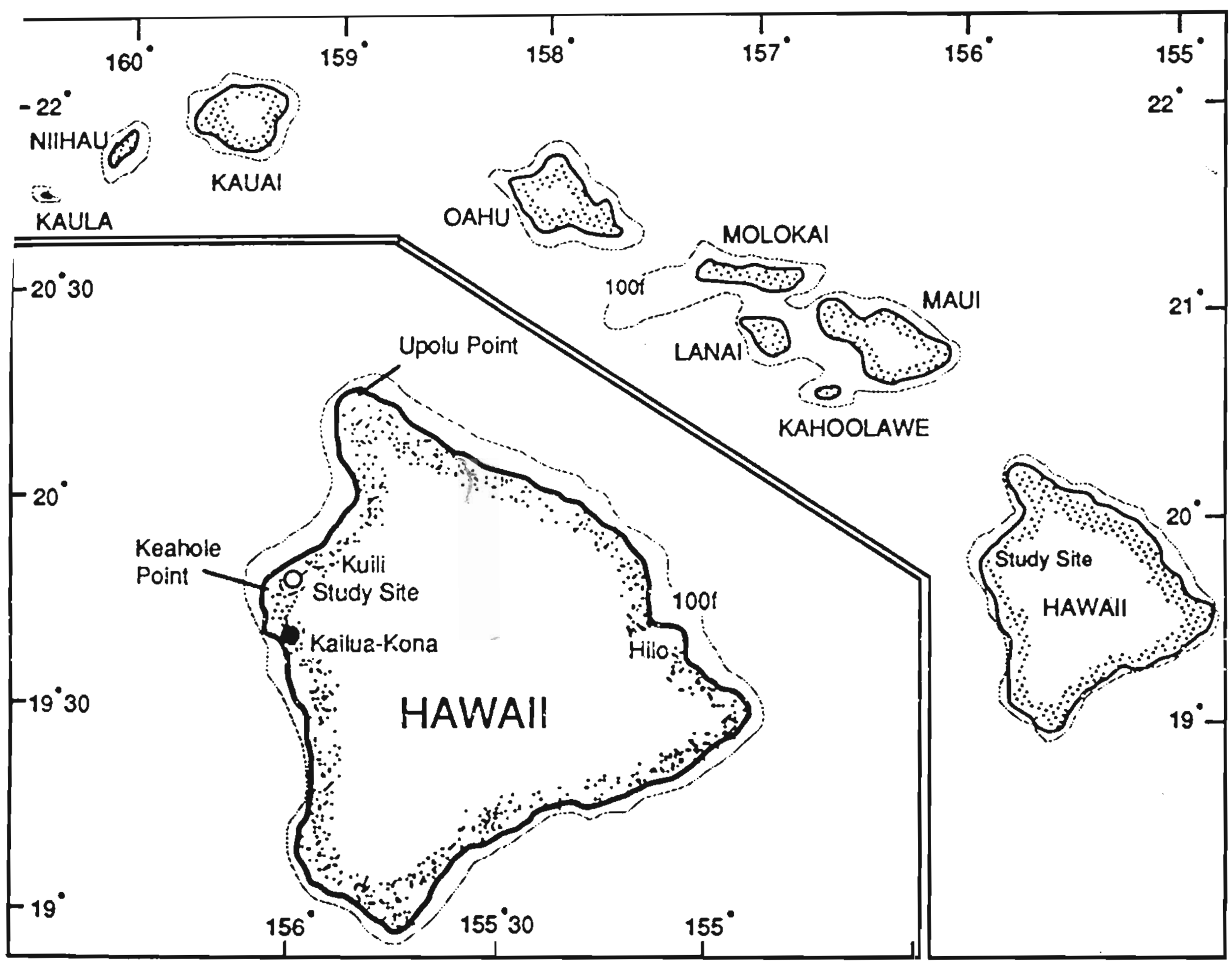

FIG. 1. Map of the Hawaiian Islands and the study site on Hawaii.

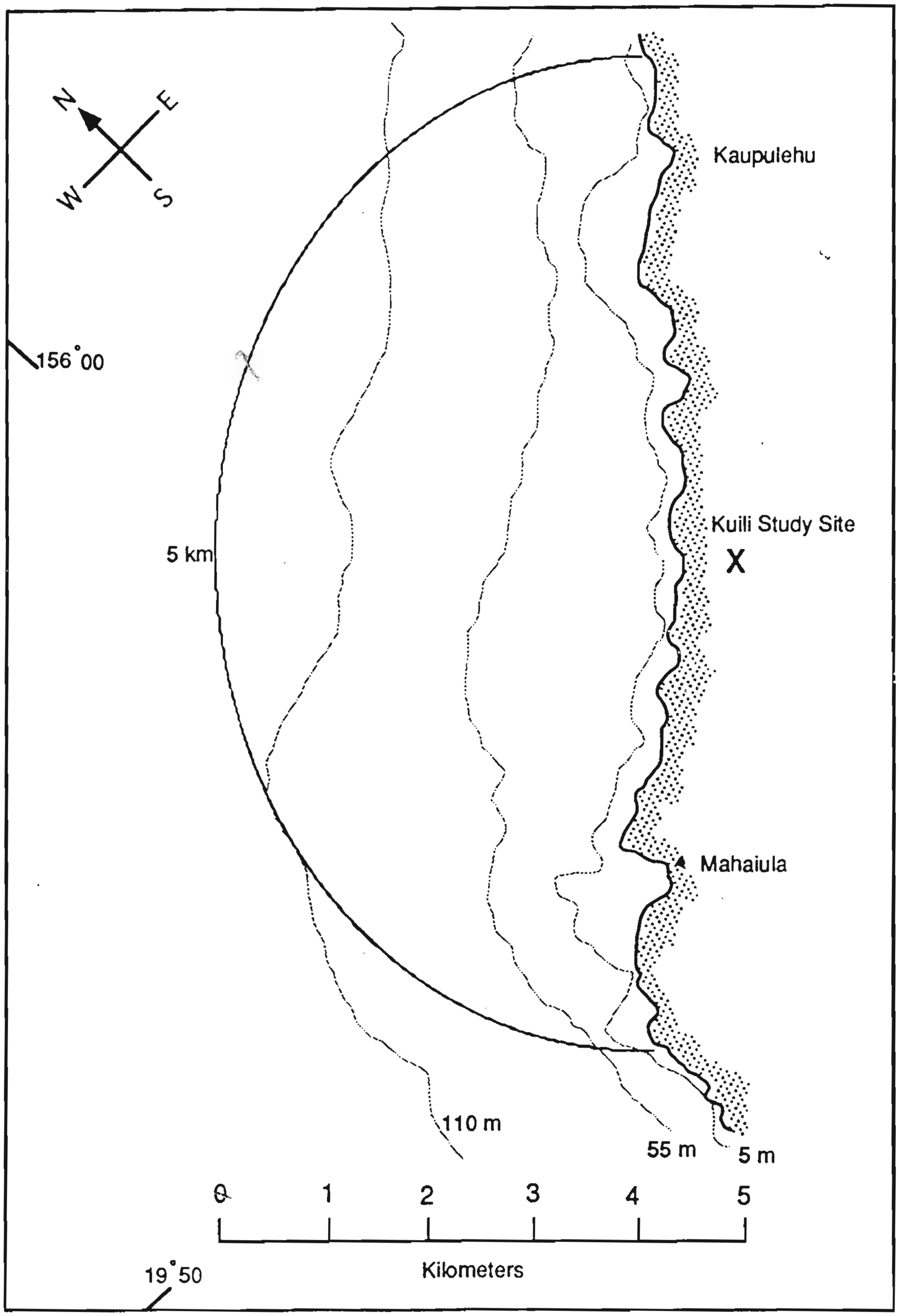

FIG. 2. Map of the Kuili cinder cone study area indicating water depth contours.

A scan sampling technique (Altmann 1974; Lehner 1979; Martin and Bateson 1986) was used to document whale distribution. In this method, the population of interest is censused or "scanned" at preselected intervals of short duration to obtain a representative sample of time. For each scan in this study, the observation field was divided into two equal sections covering approximately 90 degrees each as described by Bauer (1986) and Helweg (1989). A scan was defined as a consecutive search of the left and right sections (or vice versa) totaling 30 minutes. Each section was consecutively searched for whales for 15 minutes at two-hour intervals, beginning alternately on the left and right sections to control for selection bias. Four consecutive scans were generally conducted each day, weather permitting. Scan times alternated every other day on the following schedule to detect possible temporal shifts in distribution: day 1: 7:00, 9:00, 11:00, and 13:00; day 2: 11:00, 13:00, 15:00, and 17:00.

Notes were made in real time with respect to whales and vessels in the study area. The following information was collected while observing whales: time of initial sighting of pods, including location, number of animals in the pod, and presence or absence of calves. A pod was tracked until its composition was determined in terms of number of animals and presence or absence of a calf. Effort was concentrated on closely monitoring pods during scans to avoid recounting individuals. The position and physical description of vessels in the study area (including whether the vessel was stationary or moving) were recorded prior to each scanned section.

Each pod was treated as an independent sample. This assumption was based on studies suggesting that humpbacks tend to be transient, predominantly traveling in apparent local migratory movement (Herman and Antinoja 1977; Baker and Herman 1981; Darling et al. 1983). Humpbacks do not tend to stay in one area for extended periods, as indicated by low, within-season resight rates (Darling et al. 1983; Glockner and Venus 1983; Mobley and Herman 1985). In addition, most humpbacks travel at a mean speed of approximately 4 km/h while on the wintering grounds (Glockner and Venus 1983; Tyack and Whitehead 1983; Bauer 1986) (Appendix A), which was assumed to be sufficient time for most whales to move out of the study area (pers. observ.). Between scan periods, focal pods were opportunistically followed for up to one hour for separate studies on humpback behavior (unpubl. data; Greenberg 1989). Those pods which were known resights between scans were not included in the analyses.

Observations were conducted only during good to excellent visibility conditions and during a Beaufort number of 3 (windspeed < 21 km/hour, occasional whitecaps) or less to ensure consistent observation conditions (Appendix B). Beaufort number and sighting conditions were monitored at the beginning and end of each scanned section. Reilly et al. (1983) reported no significant interference from weather in the number of migrating gray whales, including calves, sighted within 4.8 km from an observation station 23 m ASL during weather/visibility conditions labeled good to "fair" (fair = fog, full overcast, frequent whitecaps).

Equal sightability of all pod sizes and compositions within the 5-km-arc study area was assumed based on results of vessel-based verification of observations from land. In addition, land-based studies of gray and humpback whales (Reilly et al. 1983; Herzing and Mate 1984; Bauer 1986; Helweg 1989) indicate that it was reasonable to make this assumption based on my relatively high observation height of 105.8 m ASL. For example, Herzing and Mate (1984) arbitrarily limited effective observations of migrating gray whales to 4.8 km from a perch height of 50 m ASL. Bauer (1986) and Helweg (1989) tracked humpbacks confidently up to 6.5 km from perches ranging in height from 42 to 119 m ASL.

Data analysis

Distribution

General linear model, fixed-effects, multivariate analysis of variance (MANOVA) for unbalanced data (Zar 1984; Ott 1988) was used to analyze distribution data. The following independent variables were separately tested against the dependent variables of water depth and distance from shore of whale locations: time of day, fortnight (two-week periods beginning 1 January)(Table 1), year, Beaufort number, and the presence or absence of one or more vessels in the study area. Each of the following social groups was tested: pods containing a calf, and lone adult, two adult, and three or more adult pods. A MANOVA was initially run to check for differences in the mean water depth and distance from shore of lone cow/calf pairs, cow/calf pairs accompanied (escorted) by one adult, or cow/calf pairs accompanied by two or more adults. If no significant differences were found among these groups, the data were pooled into calf pods (any pod containing a calf) to reduce sampling variance and to increase test power in further analyses.

The general models for these tests were:

(i) Water depth = Independent variable + Group type + Interaction + e and
(ii) Distance from shore = Independent variable + Group type + Interaction + e,

where e = error. The exact model used for each test may be found in Smultea (1991).

Histograms of mean water depth and distance from shore for each group type and associated variances were determined to evaluate normalcy of data distribution. To determine which variables contributed to significant ($p < 0.05$) MANOVA differences, least square means were used to do Bonferroni t-tests where significance values are adjusted for multiple comparisons.

To analyze within-season changes in distribution, the breeding season was divided into fortnights in order to maintain consistency across years, to facilitate comparisons with studies by Mobley and Herman (1985) and Helweg (1989), and to increase sample size and test power. Diurnal data were analyzed according to morning (7:00, 9:00, and 11:00 scans) and afternoon (13:00, 15:00, and 17:00 scans) periods; these categories were selected to increase sample size and test power.

The presence or absence of adult groups without a calf on the distribution of calf pods was analyzed with a MANOVA by comparing mean water depth and distance from shore of a calf pod(s) when alone in the study area versus when one or more adult groups were in the study area on a fortnight basis.

Inter-pod Distance

One- and two-factor analyses of variance were used to determine the effects of pod type and fortnight on inter-pod distances. The mean water depth and distance from shore of pods containing a calf were respectively compared by fortnight to the following groups: other calf, one adult, two adult, and three or more adult pods. If pod type and fortnight were found to be independent of inter-pod distances, the data were pooled and retested as mean inter-pod distance between calf pods and all other pods versus mean inter-pod distance between adult pods.

TABLE 1. Definitions of fortnight observation periods by inclusive dates

Fortnight of the year	Inclusive dates
2	15 January - 28 January
3	29 January - 11 February
4	12 February - 25 February
5	26 February - 10 March
6	11 March - 24 March
7	25 March - 7 April

Abundance

Seasonal abundance data were analyzed according to fortnight periods defined previously. To compensate for differential effort across the breeding season and years, the number of pods (or whales) observed per hour was used as an index of comparison to assess abundance according to fortnight periods.

Vessel-based Verification of Observations from Land

Validation of land-based observations was opportunistically assessed by simultaneous estimates of pod size and composition collected from shore with estimates made by observers in a 5.2 meter Boston Whaler vessel in close proximity to the pods. Land-based observers counted 65 of 66 whales (98%) in 35 pods identified by vessel-based observers, including the presence of all 13 calves, within a distance of 2 to 5 km from the land station.

RESULTS

A total of 536 pods were observed from the Kuili cinder cone on the western Kona coast of the island of Hawaii during the winters of 1988 and 1989. Table 2 summarizes the study effort and the number of whales seen. Baseline distribution data including individualized whale sightings and associated information are listed in Appendix C. A Beaufort number 0, 1, or 2 (no whitecaps) occurred during 76% (205) of the scans; the remaining 24% (65) of the scans were made during a Beaufort number 3.

The original hypothesis that cows with calves prefer nearshore shallow water was conditionally both supported and refuted by the study results. Pods containing a calf were distributed predominantly in shallow nearshore water only during certain periods of the breeding season and the day; at other times, they were distributed in relatively deep offshore water. The second hypothesis that groups without a calf prefer offshore deep water was generally supported by the results. In addition, the distribution of non-calf groups in deep offshore water was significantly different from that of groups with a calf during certain periods of the breeding season and the day. Results of statistical tests are presented below in the order that they addressed the original objectives. Detailed MANOVA statistics may be found in Smultea (1991).

Distribution Across Fortnights of the Breeding Season

The mean water depth and distance from shore of whales was influenced by the interaction of fortnight and group type ($F = 2.70$ and 1.90, respectively, df = 12, 460, $p = 0.0016$ and 0.032). Mean separation tests indicated that pods containing a calf ($n = 91$) were found in significantly shallower water and closer to shore during fortnights six and seven relative to fortnights four and five (12 February to 10 March) (Bonferroni t-test, df = 516, $p = 0.038$ and 0.011) (Tables 3 and 4, Figs. 3 and 4). The number of adults accompanying a cow/calf pair was not found to influence distribution patterns (water depth: $F = 0.31$, $p = 0.73$, df = 2, 88; distance from shore: $F = 0.00$, df = 2, 88, $p = 0.9957$). These data were thus pooled into calf pods (any pod containing a calf) for further analyses.

Mean separation tests indicated that the water depth and distance from shore of pods containing a calf differed significantly from groups without a calf only during fortnights six and seven (11 March to 7 April) (Bonferroni t-test, df = 516, $p = 0.0036$ and 0.010) (Tables 3 and 4, Figs. 3 and 4). At this time, calf pods were in shallower water and closer to shore than groups of one and two adults. During the remainder of the breeding season, calf pods occurred predominantly in offshore deep water with adult groups.

Within-season analysis excluded fortnight two due to small samples during this period to avoid empty MANOVA cells. Five calf pods were resighted on the same day; thus information from second sightings of the same five calf pods was not included in the data analyses due to violation of test assumptions for independence of observations.

The only significant shift in distribution among adult groups occurred with the water depth of single adults: their mean depth distribution was significantly less during fortnight five than fortnight two (Bonferroni t-test, df = 516, $p = 0.037$)(Table 3, Fig. 3). There was weaker evidence for a link between fortnight and distance from shore of single adults (Bonferroni t-test, df = 516, $p = 0.10$). Single adults were distributed in shallower water than adult dyads during fortnight five (Bonferroni t-test, df = 516, $p = 0.0090$); this relationship was weaker for distance from shore (Bonferroni t-test, df = 516, $p = 0.080$).

TABLE 2. Summary of 1988 and 1989 observation efforts

	1988	1989	TOTALS
Observation period	2/9 - 3/29	1/20 - 4/5	
No. observation days	42	50	92
No. scans	110	160	270
No. scan hours	55	80	135
No. pods	246	290	536
No. calf pods	46	45	91
No. single whales	115	126	241
No. dyad pods	67	96	163
No. three or more adult pods	18	23	41
No. unaccompanied cow/calf pairs	21	15	36
No. cow/calf pairs accompanied by one adult	24	21	45
No. cow/calf pairs accompanied by two or more adults	1	9	10

TABLE 3. Least square mean water depth (m) of pod types.
Standard deviations are in parentheses with sample sizes (n) underneath

Fortnight	Inclusive dates	Pod type			
		Calf pod	1 adult	2 adults	3 or more adults
2	15 Jan - 28 Jan	Not applicable n = 0	77 (4.1) n = 25	69 (4.1) n = 26	66 (9.2) n = 5
3	29 Jan - 11 Feb	64 (11.9) n = 3	66 (5.0) n = 17	66 (5.2) n = 16	64 (9.4) n = 5
4	12 Feb - 25 Feb	67 (4.4) n = 22	67 (2.2) n = 87	75 (2.4) n = 71	76 (6.0) n = 12
5	26 Feb - 10 Mar	73 (4.4) n = 22	61 (3.2) n = 43	77 (4.2) n = 24	75 (5.5) n = 14
6	11 Mar - 24 Mar	56 (3.8) n = 15	72 (2.9) n = 52	76 (4.5) n = 21	73 (10.3) n = 4
7	25 Mar - 7 Apr	39 (5.3) n = 25	73 (5.0) n = 17	56 (9.2) n = 5	74 Not applicable n = 1

TABLE 4. Least square mean distance from shore (m) of pod types by fortnight. Standard deviations are in parentheses with sample sizes (n) underneath

Fortnight	Inclusive dates	Pod type			
		Calf pod	1 adult	2 adults	3 or more adults
2	15 Jan - 28 Jan	Not applicable n = 0	2,288 (167.7) n = 25	1,936 (165.3) n = 26	1,809 (375.1) n = 5
3	29 Jan - 11 Feb	1,788 (483.9) n = 3	1,882 (202.9) n = 17	1,859 (209.8) n = 16	1,780 (383.1) n = 5
4	12 Feb - 25 Feb	1,959 (180.0) n = 22	1,978 (89.9) n = 87	2,211 (99.3) n = 71	2,265 (242.6) n = 12
5	26 Feb - 10 Mar	2,162 (179.1) n = 22	1,737 (130.0) n = 43	2,215 (170.9) n = 24	2,176.7 (224.4) n = 14
6	11 Mar - 24 Mar	1,585 (155.6) n = 15	2,094 (118.0) n = 52	2,292 (182.6) n = 21	2,028 (418.3) n = 4
7	25 Mar - 7 April	1,039 (216.8) n = 25	2,180 (202.9) n = 17	1,502 (374.4) n = 5	1,863 Not applicable n = 1

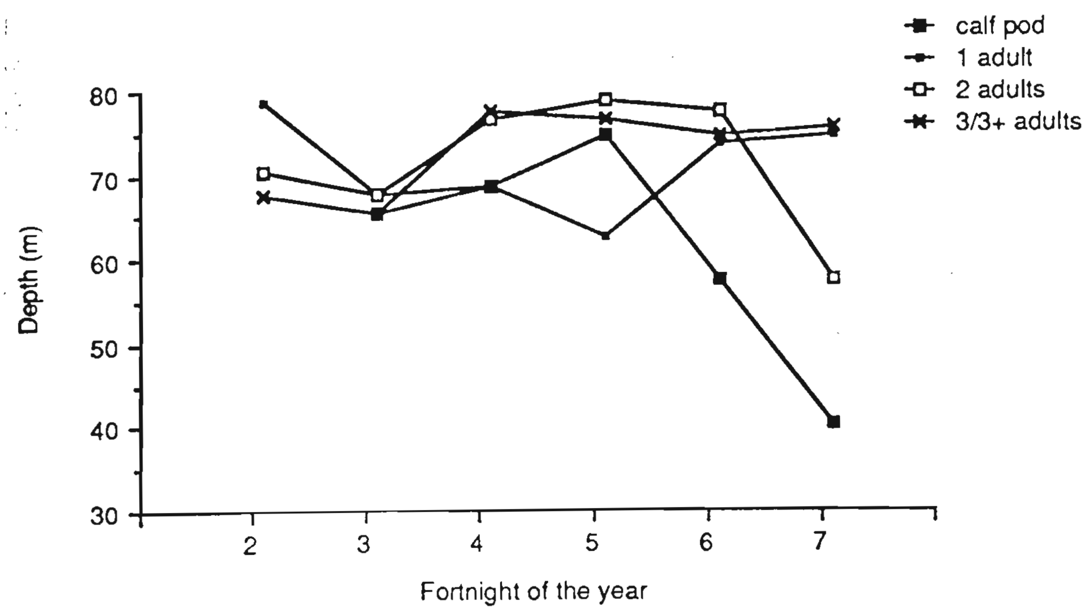

FIG. 3. Mean water depth of pods types by fortnight.

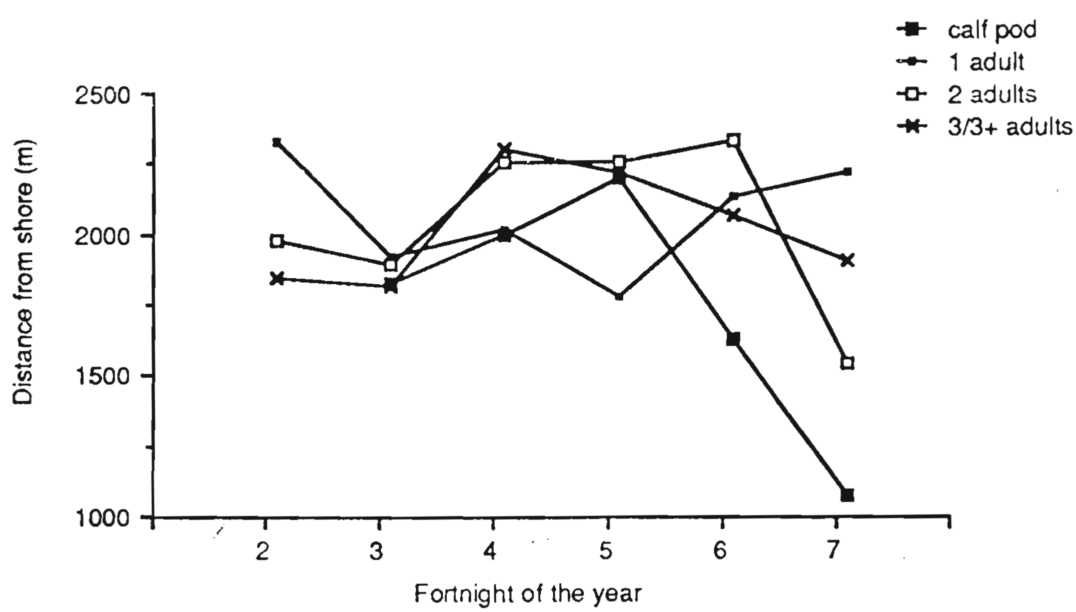

FIG. 4. Mean distance from shore of pod types by fortnight.

There was some indication that the distribution of groups of three or more adults differed from calf pods during fortnights six and seven; however, the sample sizes, particularly toward the end of the study period, may have been too small, thus variances too large, to indicate any meaningful seasonal contrasts in distribution by pod type. For example, during fortnights six and seven, the mean water depth and distance from shore of groups of three or more adults was almost double that of calf pods (Tables 3 and 4); but the variances associated with these means were too great to permit any statistically founded conclusions.

The water depth and distance from shore of humpback pod types was independent of Beaufort number ($F = 1.13$ and 1.48, respectively, df = 6, 524, $p = 0.34$ and 0.18). In addition, there was no significant interaction between the distribution of group types, Beaufort number, and time of day. A test for the interaction of pod type, Beaufort number, and fortnight could not be made due to empty cells resulting in violation of MANOVA procedures.

Diurnal Distribution

Mean separation tests indicated significant relationships between time of day and some pod compositions on distribution; although there was no overall evidence that the mean depth or distance from shore of whales was influenced by the interaction of time of day and pod composition ($F = 1.40$ and 1.51, respectively, df = 3, 528, $p = 0.24$ and 0.21). Pods containing a calf were found in shallower nearshore water than groups of one and two adults during the afternoon (Bonferroni t-test, df = 531, $p = 0.049$ and 0.0036, respectively)(Tables 5 and 6, Figs. 5 and 6). There was some evidence of a contrast in mean depth distribution between calf pods and groups of three or more adults (Bonferroni t-test, df = 531, $p = 0.083$) (Fig. 5, Table 5). Pods with a calf showed no significant difference in depth or distance from shore between the morning and afternoon, however (Bonferroni t-test, df = 531, $p = 0.11$ and 0.20, respectively).

Single adults were the only type of adult group that shifted its distribution across the day: they were observed in significantly shallower water and nearer to shore during the afternoon than the morning (Bonferroni t-test, df = 531, $p = 0.033$). Yet they still occurred in significantly deeper water and farther from shore than pods with a calf during the afternoon.

There was no significant relationship between group type, fortnight, or time of day and the distribution of pods (depth: $F = 1.17$, df = 13, 491, $p = 0.30$; distance: $F = 0.96$, df = 13, 491, $p = 0.49$). The year was also insignificant with respect to water depth or distance from shore of the different group types ($F = 1.59$ and 1.89, respectively, df = 3, 528, $p = 0.19$ and 0.13)

Distribution of Calf Pods Alone in the Study Area

Water depth and distance from shore exhibited by pods containing a calf were independent of the absence ($n = 22$ scans) or presence ($n = 69$ scans) of one or more adult pods in the study area ($F = 0.27$ and 0.09, respectively, df = 1, 82, $p = 0.60$ and 0.76). There was no significant relationship found between fortnight and the presence or absence of one or more adult groups on the distribution of calf pods ($F = 1.34$ and 1.62, df = 3, 82, $p = 0.27$ and 0.19).

TABLE 5. Least square mean water depth (m) of pod types by time of day (morning or afternoon). Standard deviations are in parentheses with sample sizes (n) underneath

Time of day	Pod type			
	Calf pod	1 adult	2 adults	3 or more adults
Morning	63 (3.8) n = 44	72 (2.0) n = 142	69 (2.7) n = 80	72 (6.2) n = 19
Afternoon	56 (3.6) n = 47	66 (2.2) n = 99	71 (2.7) n = 83	70 (5.3) n = 22

TABLE 6. Least square mean distance from shore (m) of pod types by time of day. Standard deviations are in parentheses with sample sizes (n) underneath

Time of day	Pod type			
	Calf pod	1 adult	2 adults	3 or more adults
Morning	1,821 (156.4) n = 44	2,164 (80.9) n = 142	1,952 (110.4) n = 80	2,020 (252.5) n = 19
Afternoon	1,593 (145.4) n = 47	1,889 (89.8) n = 99	2,053 (111.1) n = 83	1,954 (214.4) n = 22

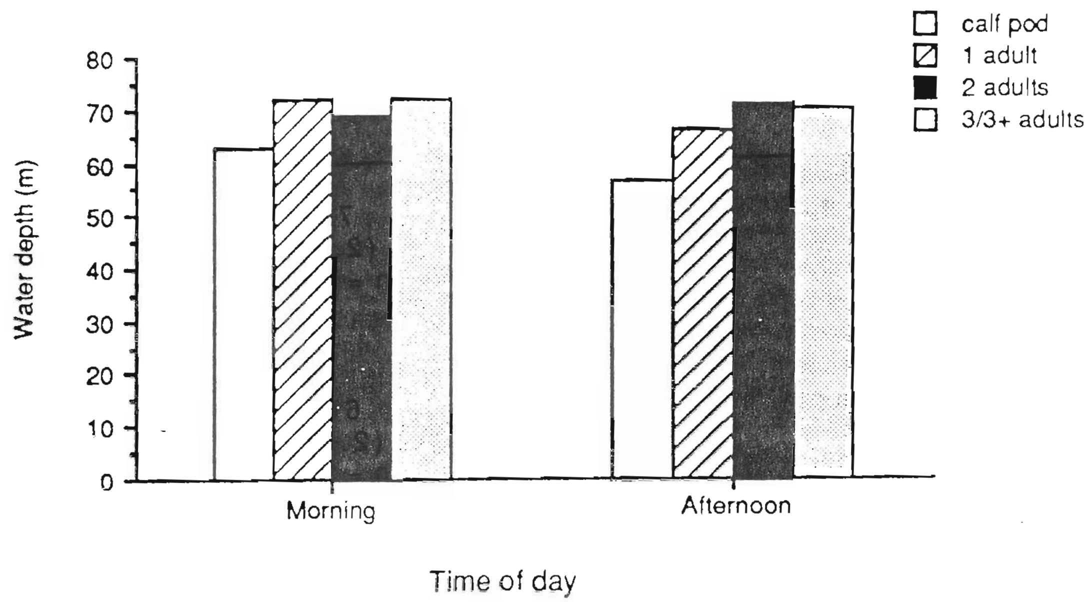

Figure 5. Mean water depth of pod types by time of day.

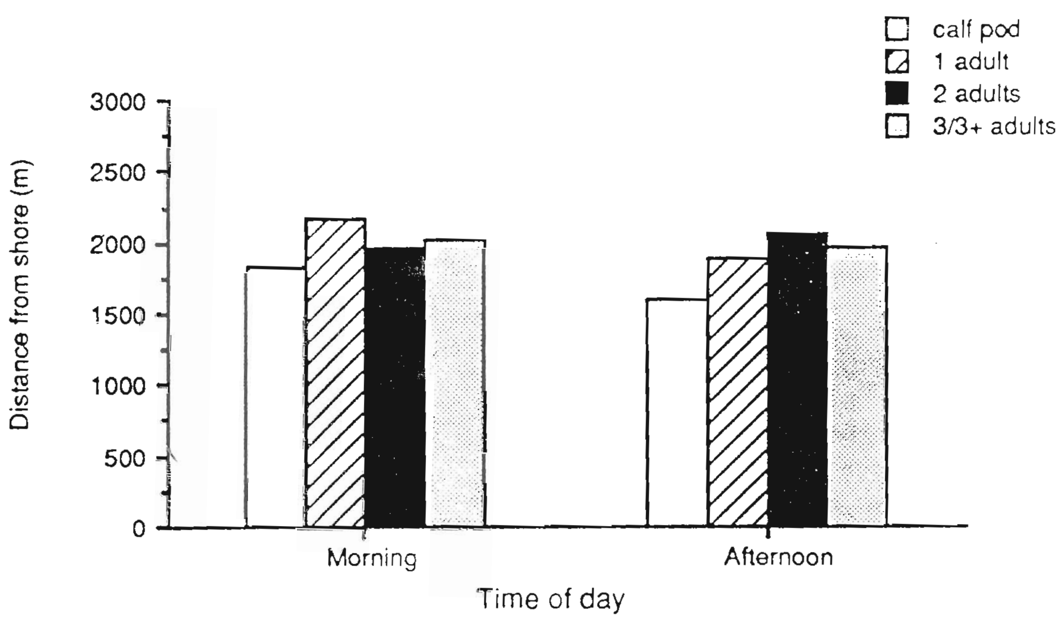

Figure 6. Mean distance from shore of pod types by time of day.

Inter-pod Distance

Distances between pods with a calf and all other groups (mean = 2,560 m, SD = 1,340, n = 158) were significantly greater than distances between adult groups (mean = 2,170 m, SD = 1,188, n = 128) based on scans when a calf was present in the study area ($F = 6.59$, df = 1, 284, $p = 0.011$). Inter-pod distance between calf pods and other groups was independent of either fortnight or the particular pod type: other calf pods (n = 15), single adults (n = 79), dyads (n = 53), or three or more adults (n = 21) ($F = 1.50$, df = 9, 152, $p = 0.15$)

Abundance of Whales, Pods, and Social Groups

In both 1988 and 1989, the peak number of whales observed per hour (WOH) occurred during the fourth fortnight from 12 to 25 February (Fig. 7). The peak was higher in 1988 (12.3 WOH) than in 1989 (8.9 WOH). The number of WOH more than doubled between the third (29 January to 11 February) and fourth fortnights (12 to 25 February) in 1988 and 1989, and gradually declined through the remaining observation period in both years. There was a decrease in WOH between the second (15 to 28 January) and fourth (12 to 25 February) fortnights of observations in 1989.

The peak number of pods observed per hour (POH) coincided with the peak of WOH during the fourth fortnight both in 1988 and 1989 (Figs. 8 and 9). Group types included in this analysis were calf, one adult, two adult, and three or more adult pods. The number of POH was higher during 1988 than 1989 during every fortnight. Both in 1988 and 1989, the number of POH doubled between the third and fourth fortnight, was nearly halved in the fifth fortnight, and decreased during the remaining fortnights. Peak of POH for single adults and two adults coincided with peak counts of all whales (12 to 25 February) in both 1988 and 1989. Peak counts of calf pods occurred later, during the sixth fortnight (26 February to 10 March) of 1988 and the fifth fortnight of 1989. POH for three or more adults fluctuated little until a drop during the last fortnight of observations.

Relative abundance of single adult pods in 1988 and 1989 generally fluctuated between 40% and 50% across the observation period (Fig. 10). Pods of three or more adults composed between 8% to 12% of all pods across the breeding season in both years until the seventh fortnight (25 March to 7 April), when there were fewer (Fig.11). The highest peak of 17% for pods of three or more adults occurred in 1988 during the third fortnight (29 January to 11 February); their relative abundance dropped to 0% by the end of the breeding season. Pods of two adults decreased in relative abundance across the season in both years: from 34% to 8% in 1988 and from 46% to 12% in 1989 (Fig. 12).

In contrast to groups of two adults, calf pods increased in relative abundance across the study period (Fig. 13). By the last fortnight of observations, from 25 March to 7 April, calf pods had increased to comprise 33% and 46% of all pods in 1988 and 1989, respectively. The percentage of both escorted and unescorted cow/calf pairs also increased across the breeding season in both years until the last fortnight of observations, when the percentage of unescorted cow/calf pairs decreased (Figs. 14 and 15). Overall, more cow/calf pairs were accompanied by at least one adult (n = 55) than not (n = 36). In 1989 no cow/calf pairs were accompanied at the beginning of the season, while all cow/calf pairs were accompanied by the end of the breeding season.

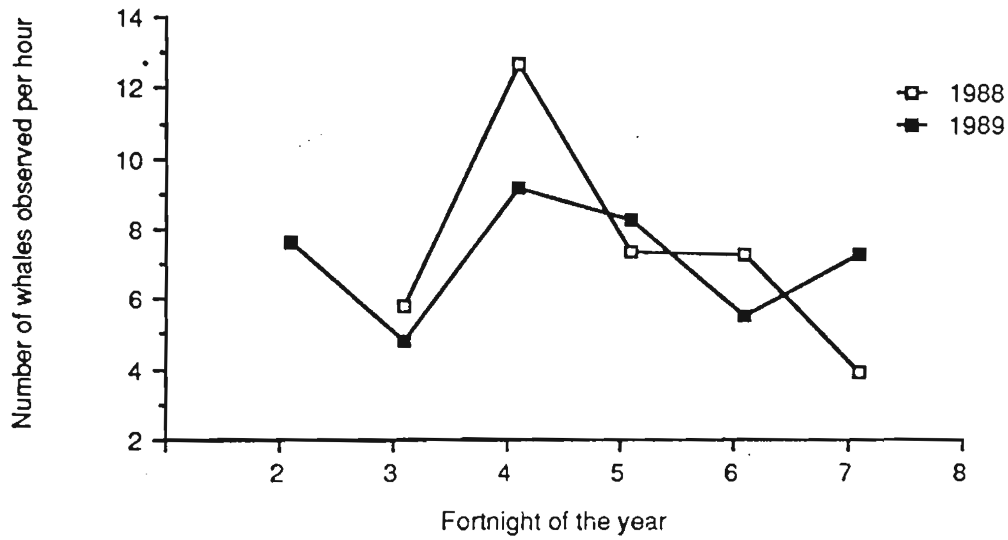

FIG. 7. Number of whales observed per hour per fortnight in 1988 and 1989.

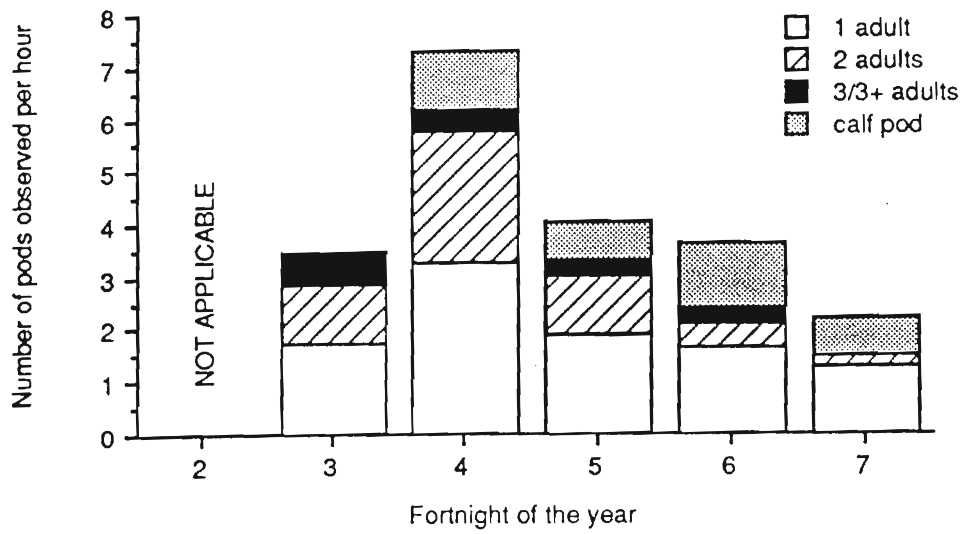

FIG. 8. 1988: Number of pods observed per hour by group type per fortnight.

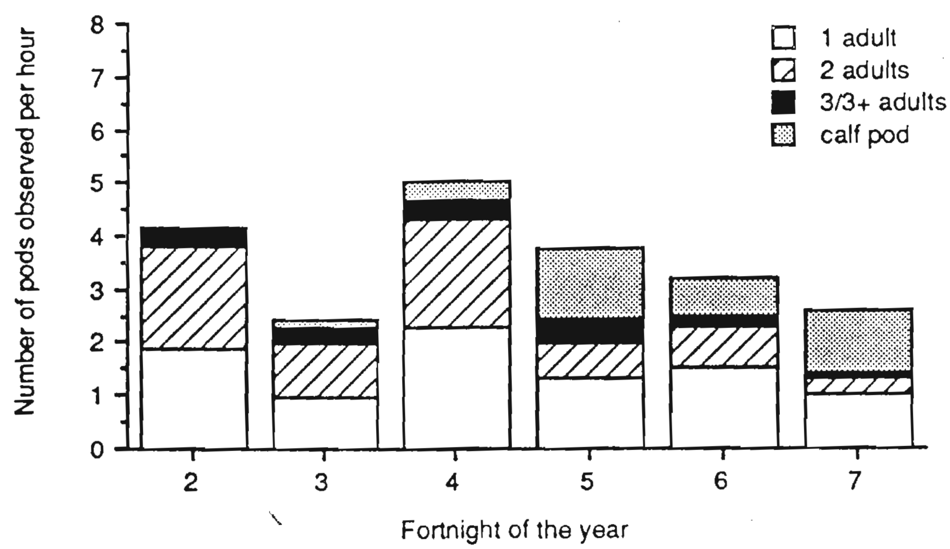

FIG. 9. 1989: Number of pods observed per hour by group type per fortnight.

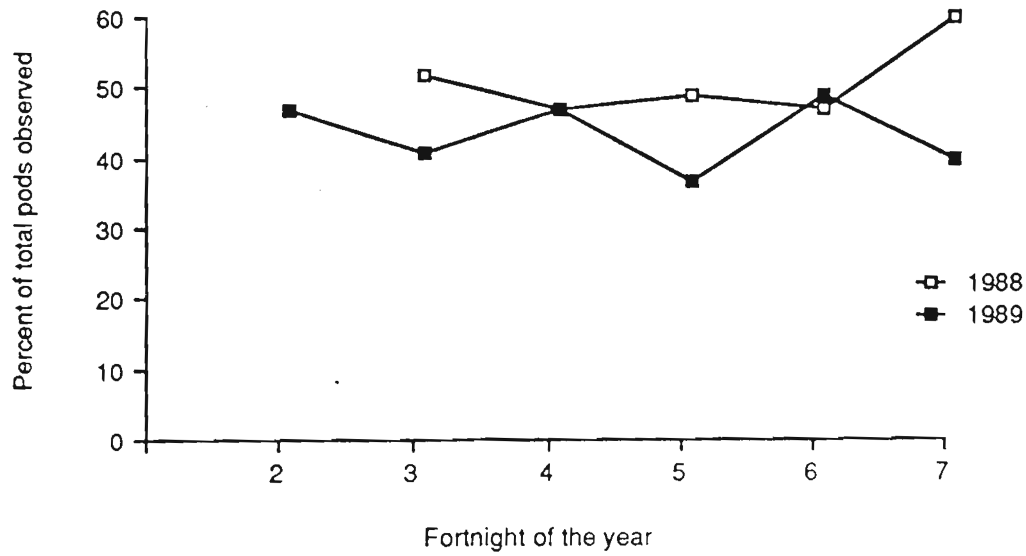

FIG. 10. Lone adults: Relative percent abundance by fortnight and year.

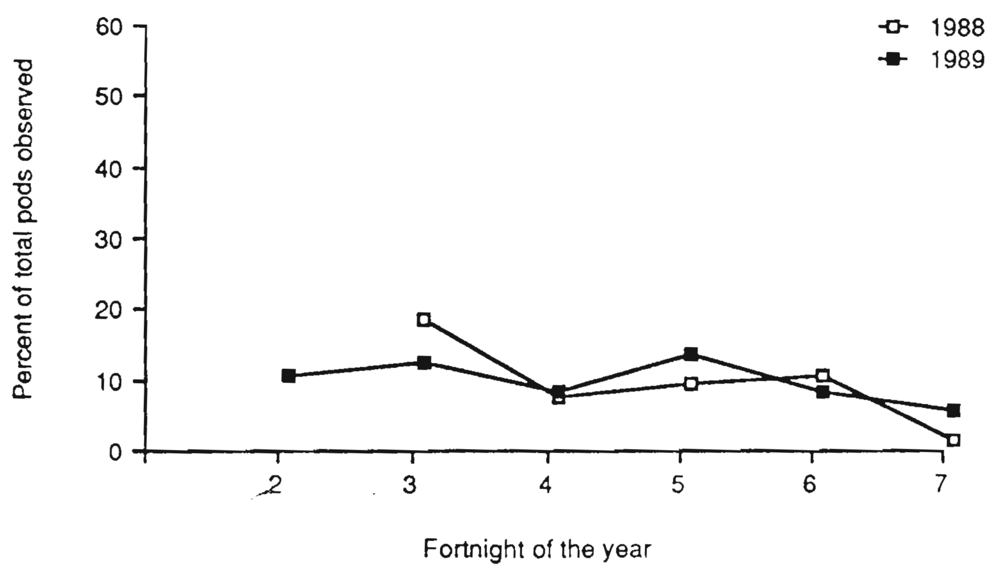

FIG. 11. Three or more adults: Relative percent abundance by fortnight and year.

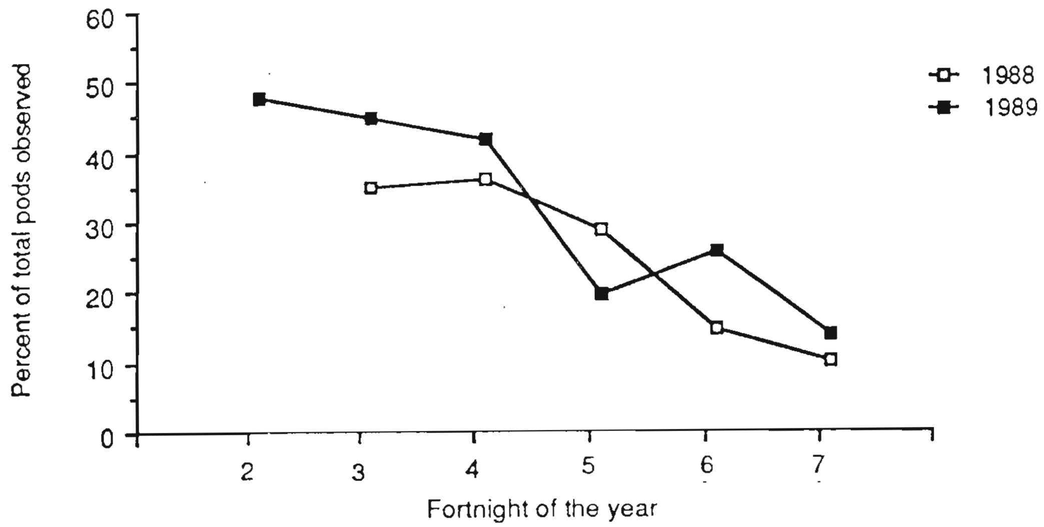

FIG. 12. Two adults: Relative percent abundance by fortnight and year.

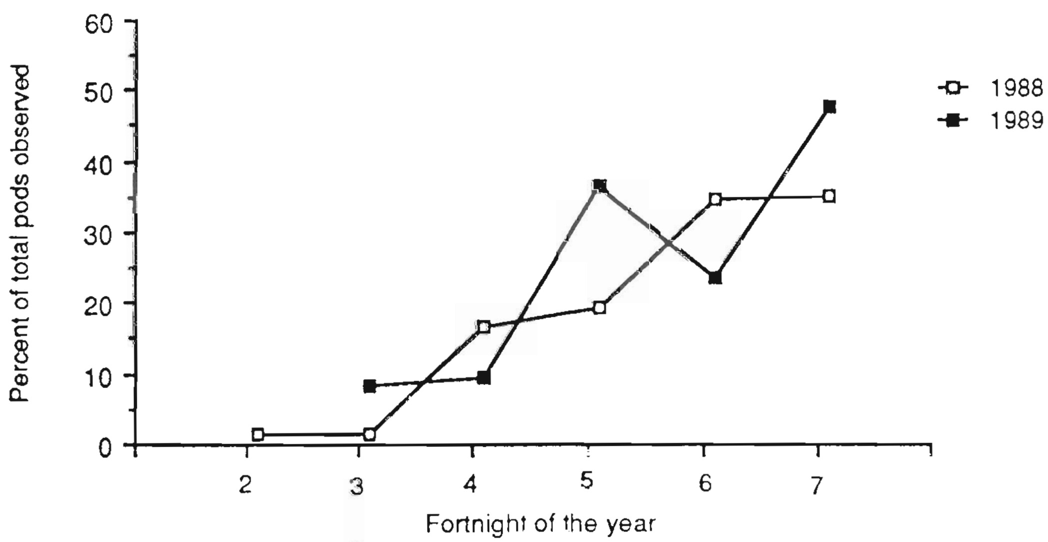

FIG. 13. Calf pods: Relative percent abundance by fortnight and year.

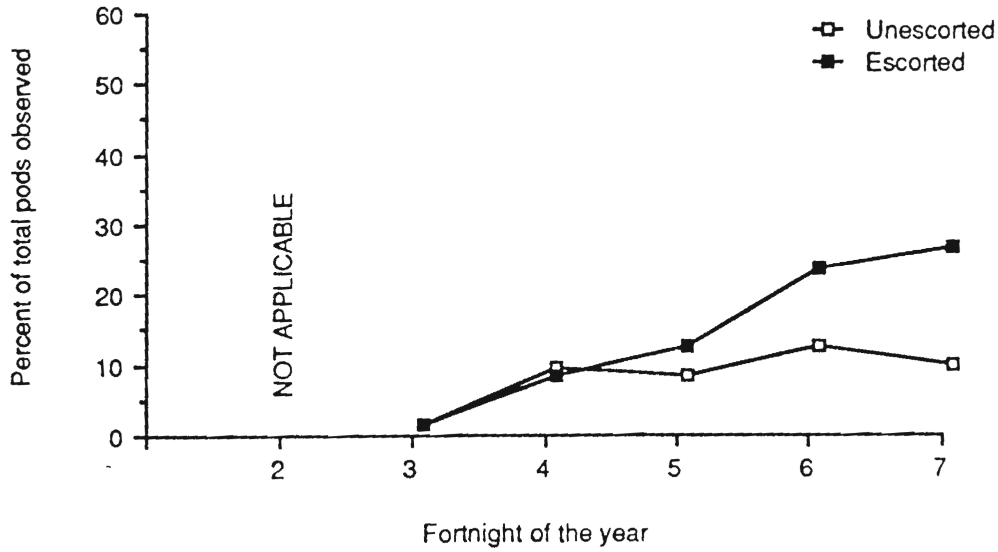

FIG. 14. 1988: Relative percent abundance of unescorted and escorted cow/calf pairs by fortnight.

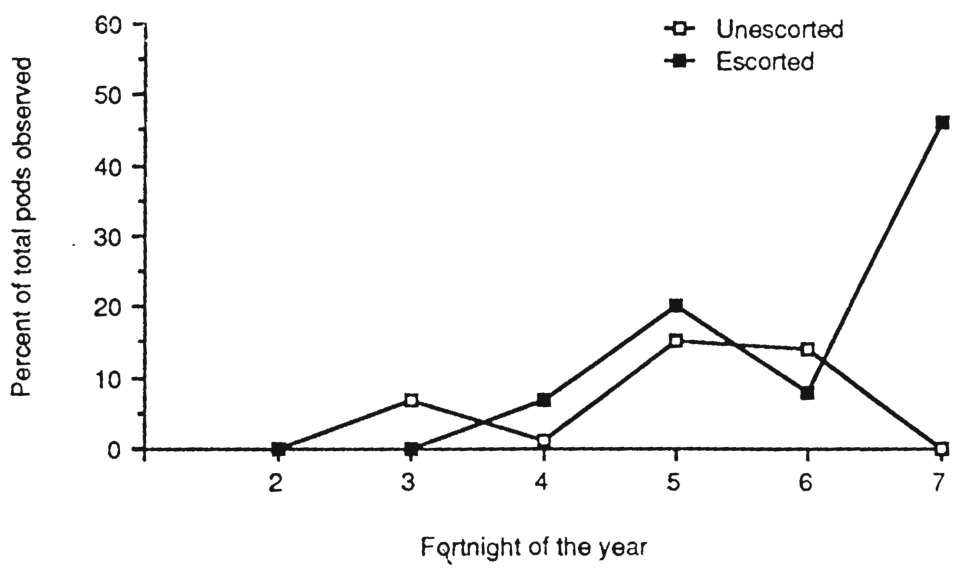

FIG. 15. 1989: Relative percent abundance of unescorted and escorted cow/calf pairs by fortnight.

Calf pods were further classified into unescorted cow/calf pairs, cow/calf pairs escorted by one adult, and cow/calf pairs escorted by two or more adults to compare relative abundance within and between years. In 1988 the number of unescorted cow/calf pairs decreased after the initial peak during the fourth fortnight (9 pairs); in 1989, the number rose across the season until a drop from 8 to 0 pods between the sixth and seventh fortnights (Figs. 16 and 17). In 1988 the number of cow/calf pairs escorted by one adult increased across the season, peaking in the sixth fortnight (12 pods) then dropping to 1 by the end of observations (seventh fortnight). This pattern was similar for cow/calf/one adult pods in 1989 except that the peak number (7 pods) occurred during the seventh fortnight with no subsequent decrease observed. Only one cow/calf pair was accompanied by more than one adult in 1988 (fourth fortnight). In 1989 a total of 9 cow/calf pairs was accompanied by more than one adult; this number peaked (5 pods) during the last fortnight of observations.

Occurrence and Presence of Vessels

The water depth and distance from shore of whale group types appeared to be independent of the presence or absence of one or more vessels in the study area ($F = 0.06$ and 0.56, respectively, $df = 3, 528$, $p = 0.98$ and 0.64). The mean number of vessels in the study area per scan in 1988 ($n = 103$ scans where number of vessels was noted) and 1989 ($n = 160$ scans) was 3.2 ($SD = 2.58$) and 1.6 ($SD = 1.57$), respectively ($n = 329$ and 243 vessels, respectively). For both years combined, the mean number of vessels per scan was 2.2 ($SD = 2.18$).

At least one vessel was present in the study area during 72% (190) of the total 263 scans in both years. The greatest number of vessels in the study area for each year during one scan was 12 on 5 March 1988, and 8 on 18 March 1989. No vessels were observed in the study area during 18 (17%) of 103 scans in 1988; in 1989 no vessels were sighted in 55 (34%) of 160 scans.

The majority (67%) of the 572 vessels sighted in 1988 and 1989 were stationary ($n = 386$). Of the 220 (38%) vessels whose function could be identified (based on visual cues or observer familiarity with the vessel), 132 (23%) were fishing vessels, 52 (9%) were dive boats, 16 (3%) were permitted whale research vessels, and 13 (2%) were commercial whalewatching vessels; 7 (1%) were visibly anchored or moored. The function of the remaining 352 vessels (62%) was undetermined.

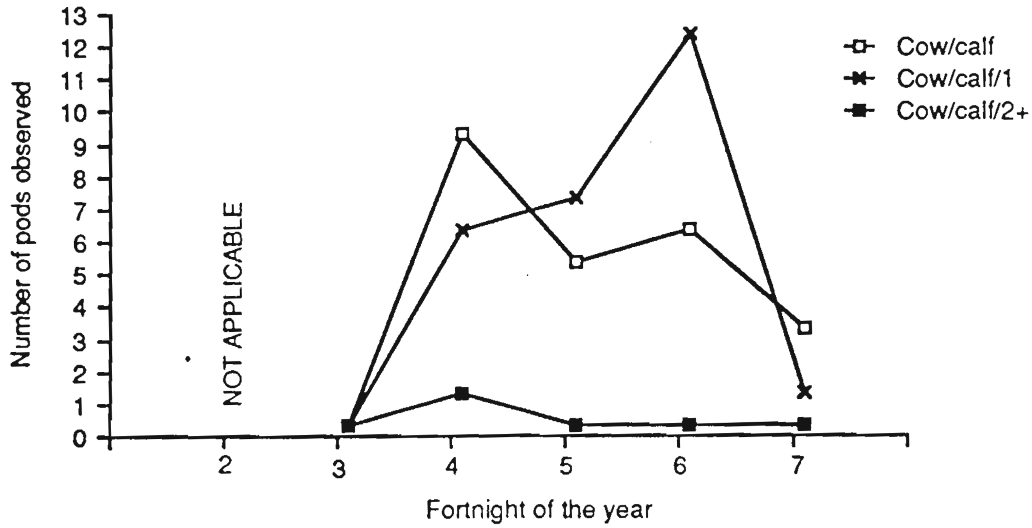

FIG. 16. 1988: Relative number of calf pod types by fortnight.

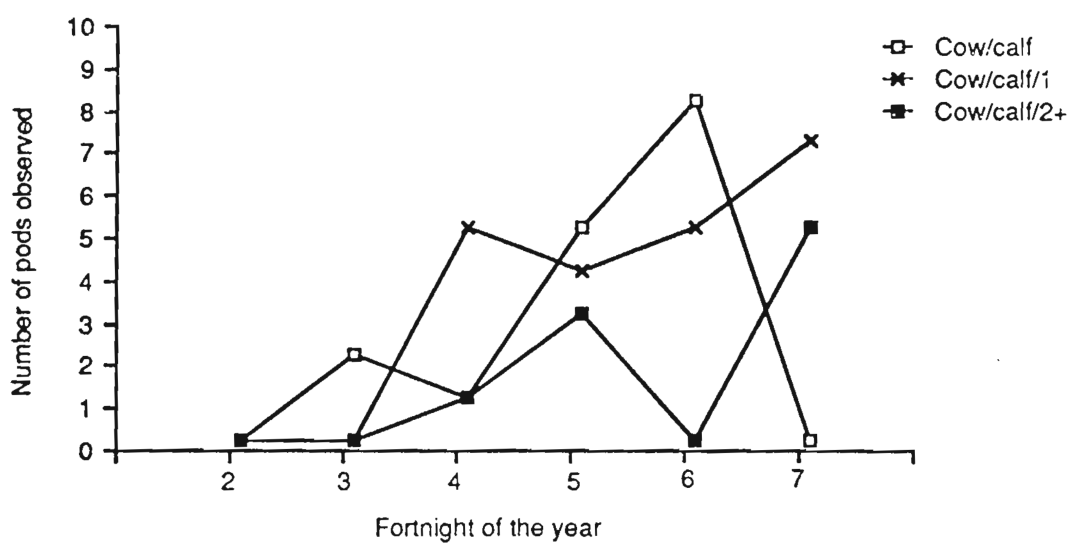

FIG. 17. 1989: Relative number of calf pod types by fortnight.

DISCUSSION

The results of this study indicate that humpback whale distribution off the western coast of the island of Hawaii was characterized by selective habitat segregation by group size and composition based on fortnight of the breeding season and time of day. Groups with a calf were distributed in significantly shallower water and closer to shore than presumably sexually active adult groups without a calf (1) during the afternoon, throughout the study period, and (2) throughout the day during the late winter/early spring. For the remainder of the study period, the distribution of calf pods and adult groups appeared homogeneous.

Behavioral constraints probably play an important role in distribution. The interactions between different social groups with reproductive motivations which may vary temporally are likely to influence distribution and segregation patterns. The differing influences of these factors are discussed by group type in the following subsections. For a more detailed discussion of behavioral implications of these study results, see Smultea (1991).

Habitat Selection Based on Fortnight of the Breeding Season

Pods Containing a Calf

Groups with a calf were distributed in significantly shallower water and closer to shore than non-calf groups during the late breeding season (11 March to 7 April). Cows with calves may select shallow nearshore water at this time at least partially to minimize encounters with courting adults. It appears that during the first half of the breeding season, the likelihood of sexual harassment is decreased and that habitat selection by maternal humpbacks may be less influenced by the distribution of sexually active adults (and hence depth and distance from shore). For example, during peak abundance of whales and pods during fortnights four and five (12 February to 10 March), there was no significant difference in the distribution of calf pods and adult groups found in offshore deep water. Assuming that most cows give birth at this time (Herman et al. 1980; Tyack and Whitehead 1983) and that postpartum estrous does not occur until approximately one month later (Chittleborough 1958), cows with calves should not represent a worthwhile reproductive opportunity to males during January and February. This would be particularly so since this is when most non-lactating females are sexually receptive.

At the end of the winter season, segregated distribution would be more likely to occur between courting adults and calf pods based on changes in reproductive conditions, relative abundance, and behavioral motivations of the different groups. There is evidence that sexual-harassment pressure on humpback cows with calves increases after the peak breeding season. This may have influenced the shift by calf pods during the last two fortnights of observations (11 March to 7 April) to water significantly shallower and closer to shore than adult groups, which predominated in deep offshore areas.

Indirect evidence for increased sexual harassment of maternal females at the end of the breeding season consists of the following: (1) subsequent to the peak of whale and pod abundance observed in this study, there was a greater tendency for cow/calf pairs to be accompanied by one or more adults (Herman and Antinoja 1977; Herman et al. 1980; Tyack and Whitehead 1983; Mobley and Herman 1985; Forestell 1989; Helweg 1989). Studies indicate that such escorts tend to be males, which are believed to be sexually active until migration (Chittleborough 1955; Darling 1983; Tyack and Whitehead 1983; Baker and Herman 1984; Glockner-Ferrari and Ferrari 1985; Mobley and Herman 1985); (2) most non-lactating females in estrous have left the wintering grounds by the end of the peak breeding season (Chittleborough 1958, 1965; Dawbin 1966), while cows with calves peaked in relative abundance at this time; prospecting male humpbacks may attempt to maximize their reproductive opportunities by escorting cows with calves (Tyack and Whitehead 1983; Baker and Herman 1984; Mobley and Herman 1985), particularly in the latter half of the observation period when non-parturient estrous females have left Hawaii.

During late winter/early spring, as a result of increased sexual-harassment pressure from males still found predominantly in deep offshore water, cows with calves may preferentially seek shallower nearshore water than adult groups to reduce social interactions of the calf. It may be of best interest to a cow and calf to avoid other adults: surface-active groups of aggressive adults may potentially separate cows from calves or even cause injury or death to calves (Baker 1985; Swartz 1986). High-speed swimming and chasing often result when humpback cow/calf pairs are escorted by more than one adult (Tyack and Whitehead 1983). Avoidance of harassment from vigorously courting and socializing adults was cited as a major factor influencing habitat segregation by gray whale cow/calf pairs (Jones and Swartz 1984; Swartz 1986) and is probably important in habitat selection by humpback mothers with calves.

Pods of Three or More Adults

The distribution of groups of three or more adults, which tend to be comprised of one focal female and multiple male suitors aggressively competing for access to the female (Tyack and Whitehead 1983; Baker and Herman 1984; Silber 1986), did not fluctuate significantly on a diurnal or within-season basis: they tended to be consistently found in deep offshore water. Active, aggressive courting groups of three or more adults may selectively avoid shallow nearshore water where threats of collisions with coral exist (Mattila et al. 1989). Moreover, since these groups already contain a female, they probably are influenced little by the distribution of smaller groups. Rather, their distribution may be self-perpetuating as groups of three or more adults frequently join one another (Tyack 1982; Tyack and Whitehead 1983).

Pods of Two Adults

The distribution of pairs of adult humpbacks was probably more affected by other social groups than pods of three or more adults. Dyads tend to join larger groups and avoid singers (Tyack 1982; Tyack and Whitehead 1983). This suggests that the location of dyads in deep offshore water may have been a function of the preferred location of larger breeding groups.

Knowing the gender of adult pairs would be key to understanding and interpreting their distribution and behavior. Unfortunately, little information exists on the relative frequency of these associations because of the difficulty of sexing humpback whales. Dyads can theoretically be composed of three gender combinations: two females, two males, or a male and female, each of which may be influenced by different behavioral and ecological factors. The likelihood of a dyad being composed of two adult females appears minimal, however, particularly at the end of the breeding season, based on the following: (1) two mature females have rarely, if ever, been documented together (Baker 1985); (2) a female tends to be escorted by multiple males; and (3) most non-lactating, mature females have left the wintering grounds at the end of the breeding season. It thus appears likely that male-male dyads may increase in March and April based on a decrease in the proportion of females and an increase in the proportion of males at this time (Nishiwaki 1959, 1960), although both male-male and male-female dyads are known to occur (Tyack 1982; Darling 1983).

There was some indication that pairs of adults shifted their mean depth distribution to shallower waters (mean = 56 m, SD = 9.2, n = 5) during fortnight seven relative to the previous fortnight (mean = 76 m, SD = 4.5, n = 21), although this trend was insignificant. Since the actual number of dyads observed during fortnight seven was small, a larger sample size would be necessary to fully interpret the results. The tendency for dyads to occur in shallow nearshore water during early spring may have resulted from an attempt to follow calf pods to shallow water at the end of the breeding season to increase encounter rates with potentially postpartum cows in estrous. Alternatively, dyads at this time may represent a courting male and female attempting to avoid other males. Without knowing the sexual composition of dyad groups, however, their distribution patterns remain difficult to interpret.

Pods of One Adult

It is probable that the distribution of single adults, like that of dyads, was influenced by habitat preferences of other groups. Single adults were found in significantly deeper water and farther from shore during fortnight two (15 to 28 January) relative to fortnight five. This shift may have been related to an alternative reproductive strategy. Single adult humpbacks tend to be singers, and consequently males (Winn and Winn 1978; Tyack 1982; Whitehead, pers. comm. in Tyack 1982; Darling 1983). A preference for deep offshore water may have been an attempt to enhance propagation of song over long distances (Whitehead and Moore 1982) to reach whales which were distributed less abundantly and less densely during the early breeding season (Herman and Antinoja 1977; Herman et al. 1980; Baker and Herman 1984; Forestell 1989; Helweg 1989). In addition, singers most frequently join non-singing lone adults (Tyack 1982) and may have been attracted to other singletons distributed within the same habitat parameters.

The distribution of single adults in this study differed markedly from that reported for singers on Silver Bank in the Caribbean: Whitehead (pers. comm. in Tyack 1982) observed singing humpbacks predominantly in deep water over smooth sea floors near the 100 m depth contour, while Whitehead and Moore (1982) found that singers preferred shallow water between 20 to 30 m in depth. Tyack (1982), however, noted no apparent habitat preference by singers off the island of Maui. I observed the deepest seasonal, mean depth of single whales during fortnight two (77 m), which was less than that reported by Whitehead (100 m). I observed the shallowest mean depth distribution during fortnight five (61 m), which was greater than that reported by Whitehead and Moore (20 to 30 m). In addition, Ladron de Guevara et al. (1991) found that singers were distributed closer to shore than other adults groups. None of these studies examined habitat preferences of singers based on a diurnal, within-season, or yearly basis, which may influence distribution. Differences in bottom topography may also have resulted in different preferred distributions. Although most single whales are males, and singers are generally lone males, I could not confirm that singletons were males or singers, or that they were mature adults. This uncertainty likely influenced distribution to an undetermined extent, potentially accounting for some of the aforementioned contrasts in the distribution patterns of single adults.

Diurnal Habitat Selection

In addition to fortnight, relationships were found between distribution of humpback groups and time of day. Diurnal as well as within-season distribution may be related to social stimuli between group types. Calf pods occurred in shallower water and closer to shore than adult groups during the afternoon, a contrast which was not apparent in the morning. Bauer (1986) and Helweg (1989) found that the number and size of breeding groups and aggressive surface activity in general increase in the afternoon. Cows may move to shallow nearshore habitat in the afternoon to minimize harassment when the likelihood of encountering aggressive courting groups increases.

While large courting groups may repel cows with calves in the afternoon, they may attract other adult groups. Pods of three or more adults are often joined by adult pairs and larger groups (Tyack 1982; Tyack and Whitehead 1983; Mobley et al. 1988). Thus, these groups may be attracted to deep offshore waters in the afternoon to increase encounters with breeding groups of three or more adults, which predominate in such habitat.

Single adults, like cows with calves, also appeared to move to shallower nearshore water relative to larger groups of adults in the afternoons. Singing may be an alternative mating strategy to outright physical competition for females, which characteristically occurs among groups of three or more adults. Lone, oftentimes singing adults may move to shallow nearshore water during afternoons as an alternative form of contacting conspecifics to reduce competition. Yet the difference in mean depth distribution of single adults between morning (mean = 72 m) and afternoon (mean = 66 m), although significant, was not remarkable.

Distribution of Calf Pods Alone in the Study Area

The distribution of calf pods alone in the study area did not differ significantly from when adults were present. This observation could suggest that cows with calves may not actually be "alone", and may be responding to sounds produced by social groups and singing males present outside the study area but undetected by observers. For example, Tyack (1982) has shown that humpbacks respond to singing humpbacks as far as 10 km away, and Tyack and Whitehead (1983) found that singing humpbacks respond to large whale groups up to at least 9 km away. Alternatively, other unassessed environmental factors or predators may be more influential on the distribution of calf pods than the presence of other adult whales.

Inter-pod Distance

There is additional evidence, based on results of inter-pod spacing and intraspecific behavior, that distribution of humpbacks is related to social factors. The distance between calf pods and all other groups was greater than that between adult groups, supportive of selective segregation and intraspecific avoidance. This is consistent with observations that cows with calves avoid contact with other whales and move away from active social groups and their sounds (Tyack 1982; Tyack and Whitehead 1983; Mobley et al. 1988).

Comparisons in Cow/Calf Distribution: Hawaii and Maui

The mean depth locations of humpback group types in this study were generally comparable with recent results off Maui, but contrasted the distribution of cows with calves reported there during earlier years. The range of mean depth locations of calf pods by fortnight (39 to 73 m) off Hawaii was largely analogous to the overall mean depths of calf pods recorded during 1990 aerial surveys near the Maui (50.9 m) and Penguin Bank (31.6 m) regions (Forsyth et al. 1991). These combined results indicate that cows with calves tend to be found in deeper water than that reported by Glockner-Ferrari and Ferrari (1990) off western Maui during the late 1970s. From 1977 to 1979, Glockner-Ferrari and Ferrari (1990) found that 78% of humpback cows with calves predominated in waters within the 19 m (10 fathom) depth curve and within an estimated 0.4 km from shore. Off the western coast of Hawaii, I observed few calf pods within this depth (7% of 91 pods) and distance from shore (1% of 91 pods). Cows with calves were encountered by Glockner-Ferrari and Ferrari (1990) within these parameters with decreasing frequency between 1980 and 1988; by 1988 only 1.5% of 203 cows with calves were found within the same parameters. The latter results are more compatible with results of my Hawaii study. Glockner-Ferrari and Ferrari associated increasingly high levels of human-related activities, including vessel traffic and jet skiing, with decreasing numbers of calf pods in nearshore shallow habitat after 1979; however, no prior systematic baseline information on the distribution and abundance of these activities was available for comparison.

It is possible that deeper depth locations of calf pods near Hawaii, and more recently off Maui, than during the 1970s off Maui may be related to displacement by increased levels of human activity and nearshore development. Yet it appears unlikely that the few, generally stationary fishing boats in the Hawaii study area were associated with the distribution patterns of calf pods there. It is plausible, however, that deeper depth and farther distance from shore locations of cows with calves near Hawaii than during earlier years off Maui may represent behavioral response and adaptation to increased human activities in other areas (i.e. off Oahu and Maui), resulting in displacement from preferred habitat throughout the calving grounds. For example humpbacks are known to move between Hawaiian Islands (Baker and Herman 1981; Cerchio et al. 1991).

Other potential contributors to observed differences in habitat-use patterns of cows and calves, specifically near the Hawaii study area and Maui, would be variations in ocean-bottom topography including the extent of coral heads, the amount of protected leeward areas, or possibly currents or water clarity. All these factors could potentially affect the availability of preferred habitat but remain quantitatively unassessed. The lesser extent of shallow, nearshore leeward water (Fig. 1) and the presence of coral heads at the Hawaii study site may discourage calf pods from inhabiting shallow coastal waters. In addition, the Glockner-Ferrari and Ferrari (1990) and Forsyth et al. (1991) studies did not consider temporal influences on distribution.

Abundance of Whales, Pods, and Social Groups

Results suggest that the island of Hawaii was utilized by a higher proportion of cows with calves than has previously been reported for the area. This proportion was more similar to that reported for Maui, an area believed to be the primary calving grounds in the Hawaiian Islands. From 1977 to 1980, Bauer (1986) reported that 10% of all humpback pods contained a calf off Hawaii based on 23 aerial surveys between early January and mid-March. I found a higher (18% of all pods), relative percent abundance of calf pods off Hawaii from mid-January to early April in 1988 and 1989. This proportion was more comparable to a 21% figure reported by Mobley and Herman (1985) for Maui over similar dates in 1980. This indicates that the island of Hawaii may be more important as a nursery area than has been heretofore described, and that its use by cow/calf pairs may be increasing over time. A simultaneous investigation of relative abundance of calves across the major Hawaiian Islands could indicate whether an increase off Hawaii is associated with an overall increase in birth rates, or perhaps a displacement from other Hawaiian Islands.

Seasonal trends in the relative abundance of individual whales, pods, and group types were generally consistent with those reported by other researchers near the Hawaiian Islands (Herman and Antinoja 1977; Herman et al. 1980; Baker and Herman 1984; Mobley and Herman 1985; Forestell 1989). Peaks in seasonal abundance occurred earlier off Hawaii (fortnight four) than Helweg (1989) reported for Maui in 1987 and 1988 (fortnight six). This finding was in line with other studies in the Hawaiian Islands (Herman and Antinoja 1977; Herman et al. 1980; Baker and Herman

1981; Helweg 1989). However, aerial surveys in 1985 (Forestell 1989) indicated that humpback abundance peaked earlier (fortnight three) off Maui than I found off Hawaii in 1988 and 1989.

Contrasts also occurred in the timing of abundance peaks off Hawaii. I found that the peak number of whales and pods occurred during the fourth fortnight (12 to 25 February) in both 1988 and 1989 while Helweg (1989) reported an earlier peak during the third fortnight (January 29 to February 11) in 1988 at two study sites located approximately 35 km and 45 km north-northeast of the Kuili cinder cone on Hawaii. This difference may have reflected within-season and yearly shifts in abundance, which are known to occur in Hawaii, especially between islands (Herman et al. 1980; Baker and Herman 1981).

Observations from this study were consistent with trends on the wintering grounds suggesting that as the relative abundance of breeding groups decreases, the proportion of calf pods increases, reflecting the departure of most adults and the prolonged stay of cows with calves (Chittleborough 1958; Herman et al. 1980; Forestell 1989; Helweg 1989). Seasonal fluctuations in the relative percent abundances of pods with a calf, and one adult, two adult, and three or more adult pods were comparable to those reported by Helweg (1989) for Hawaii and Maui combined in 1987 and 1988.

Ecological Aspects of Habitat Selection

Energy Conservation

Energy conservation, critical to humpback cows nursing their calves, may influence distribution. Cows feed rarely, if at all, in Hawaii while calves must gain sufficient insulation and energy reserves for migration. Shallow, inshore leeward waters may minimize energy expenditure and injury by allowing the cow/calf pair to rest while avoiding stressful, offshore wind, wave, and current conditions (Whitehead and Moore 1982; Mattila and Clapham 1989). Energy conservation and shallow nearshore habitat may be particularly important just prior to migration of humpback cows with calves in late March and April. Thomas and Taber (1984) proposed that southern right whale cows with calves maintained low activity levels before migration to conserve energy. These observations suggest the importance of suitable habitat protected from wind in habitat selection.

Humpback cow/calf pairs may also minimize energy expenditure by avoiding surface-active, fast-traveling courting groups in deep water, who may disrupt nursing bouts. Such high swimming speeds are likely an undesirable energy drain on both the cow and calf. Nursing sessions in gray and southern right whales are interrupted at the approach of adult whales (Swartz and Jones 1980; Thomas and Taber 1984) and the same behavioral response may occur among maternal humpback whales. Avoiding other whales may allow cows and calves to engage in less-stressful activities which are more conducive to the calf's level of development (Thomas and Taber 1984). Lone or singly escorted humpback cow/calf pairs in nearshore shallow water spend most of their time slowly traveling, intermittently resting and nursing in leeward areas (Tyack 1982; Whitehead and Moore 1982; Glockner and Venus 1983). These studies indicate the potential importance for cows to seek relative solitude in nearshore shallow water for successful nursing and calf-rearing.

Segregation as a Function of Predation

Inshore waters may be critical in providing protection for calves from predators such as sharks and killer whales (*Orcinus orca*) (Chittleborough 1953). Some smaller, generally pelagic odontocetes found in waters near Hawaii, such as false killer whales

(*Pseudorca crassidens*), pygmy killer whales (*Feresa attenuata*) and pilot whales (*Globicephala macrorhynchus*) (Minasian et al. 1987), have been observed to attack dolphins, primarily during fishing operations and in captivity (Perryman and Foster 1980; D. McSweeney 1988, West Coast Whale Research Foundation, Honokohau, HI, pers. comm.). These species could also potentially attack young humpbacks. Predators may be of threat particularly where the 183 m (100 fathom) contour line is relatively close to shore, such as near the Kuili study site and much of the Hawaii coast. Shallow waters, especially near surf zones, may be of advantage by confounding the echolocation capabilities of odontocetes and minimizing the vulnerability of cow/calf pairs to attack from below (Würsig and Würsig 1980; Thomas and Taber 1984). Predator avoidance may be of less concern to groups of adult humpbacks found predominantly in deep waters.

The Influence of Other Environmental Factors

Other factors which may affect humpback distribution that were not addressed in this study include ocean-bottom topography, water temperature, currents, salinity, water visibility, and underwater noise levels, including intraspecific vocalizations and vessel noises. For example, Glockner-Ferrari and Ferrari (1985) noted that humpbacks off west Maui seemed to avoid muddy waters associated with agricultural runoff, which suggests that water clarity may affect the distribution of whales. The effect of this and other factors remain to be adequately and systematically assessed.

Occurrence and Presence of Vessels

The presence of relatively low levels of vessel activity and occurrence in this study did not appear to be significantly related to the overall mean depth or distance from shore of the humpback groups observed from the Kuili cinder cone. Bauer and Herman (1986) similarly reported no correlation between the number of vessels and the mean distance of humpbacks from shore or whale sighting rates using similar scan sample techniques off Maui. These analysis techniques represent crude measurements of gross trends in relative distribution and abundance of whales and vessels, however, and are not capable of recognizing more subtle changes in behavior and movement of humpbacks known to occur in response to vessels (See Baker et. al. 1982, 1983; Bauer 1986; Bauer and Herman 1986; Baker and Herman 1989). In addition, the above-mentioned studies found that the reaction of various whale groups to vessels was dependent on a number of factors unmeasured in this study, including the relationship between underwater ambient noise levels and such vessel characteristics as type, speed, density, heading, and proximity to whales.

In a study of whale-vessel interactions in Hawaii, Bauer (1986) suggested that humpbacks are probably not overtly disturbed by single infrequent interactions with vessels; this was the predominant although infrequent type of vessel-whale interaction I observed from the Kuili cinder cone. That most of the vessels appeared to be stationary fishing boats during this study suggests that vessel engines were likely not operating during scans, were relatively non-intrusive, and probably did not result in discernable changes in whale distribution. Chronic or repetitive vessel-whale interactions appear more likely to consistently evoke apparent disturbance reactions among humpbacks (Bauer 1986).

Results should not be interpreted as an indication that vessels did not affect humpbacks, as this could not be assessed due to limited time and resources. Rather, the primary purpose of collecting data on vessels was to provide baseline information on vessel and whale occurrence at the Kuili cinder cone site in order to facilitate interpretation and comparison of future potential changes in habitat-use patterns of humpbacks related to changes in vessel abundance. Detailed information on the movements of individual whales relative to different operational characteristics of vessels, along with monitoring of associated underwater noise levels, are needed to better interpret relationships between vessels and the distribution and behavior of whales.

When examining vessel-whale interactions, both direct and indirect influences of vessels should be assessed. For example, bait used in long-line fishing may attract sharks and thereby potentially increase predation pressure on young calves. The risk of entanglement of whales in fishing gear, including nets and long lines, should also be considered (Baker et al. 1989). Relatively few (8%) fish landed in Hawaii are caught in areas where humpback whales tend to concentrate (less than 4.8 km from shore); however, the number of fishing vessels has been increasing in the Hawaiian Islands, and vessel-whale interactions will probably become more frequent (Tinney 1988).

Sightability of Pods and Observed Distribution of Whales

It is possible that not all whales in the study area were observed, particularly as distance from the land station increased; although the distribution of calves was believed to be a true phenomenon and not an artifact of sighting bias based on a combination of documented cow/calf behavior, results of vessel-based verification of observations from land, and land-based observations by other researchers. Of particular concern would be the possibility that the fewer number of calves observed in offshore waters could be inversely related to increasing distance from shore and decreasing sightability/visibility; however, no validation beyond that made opportunistically with research vessels was available to calculate potential correction factors for the number of whales sighted. It was assumed, based on the high degree of agreement between simultaneous land- and boat-based whale counts, that the number of whales potentially missed in the area did not significantly influence distribution results. In addition, cows with calves generally spend more time at the surface than other whales (Bauer 1986), thereby increasing their likelihood of being spotted.

Management Implications and Recommendations

There is evidence that increased and chronic vessel use and development of nearshore areas of the Hawaiian Islands could potentially displace humpback whales from preferred habitat (Herman et al. 1980; Glockner-Ferrari and Ferrari 1985, 1987, 1990; Salden 1988; Tinney 1988; Forestell 1989). Gray whales reportedly abandoned breeding/calving lagoons during commercial shipping and associated dredging operations from 1957 to 1967, and then returned six years after this activity had ceased (Gard 1976; Bryant et al. 1984). These studies indicate the potentially critical or long-term effects of chronic disturbance on habitat selection. If the probability of successful humpback calving and calf-rearing is greater in shallow nearshore water than in deeper offshore water during certain periods of the breeding/calving season or day, increasing human use of coastal waters could affect the viability of North Pacific humpback whale populations by displacing pregnant females or females with calves from preferred habitat. Species requiring specific nursery habitats or environmental conditions would be particularly vulnerable to human disturbances that increase neonatal or postnatal mortality (Oldfield 1988).

A comparative baseline to evaluate the potential influence of increasing human use of waters on the distribution of wintering humpback whales near the Kuili cinder cone has been established through this study. The construction of two small boat marinas and eight hotel/condominium resorts has been proposed for the relatively undeveloped coastline near the study site. Continued monitoring of the study area through completion of planned development would help to evaluate any cause-effect relationships between human-related activities and whale distribution in nearshore areas. These relationships must also be differentiated from within-season and diurnal fluctuations in habitat utilization patterns.

This study contributes knowledge useful for addressing management considerations affecting humpback whales in Hawaii. The information on whale habitat utilization may contribute to the formulation of the National Recovery Plan for the humpback whale by the National Marine Fisheries Service (NMFS), which includes identification of critical habitat and environmental requirements (Baker et al. 1989). Several areas off Maui and Lanai are designated by the NMFS as special cow/calf habitat, and are subject to stricter, 274-m, vessel-to-whale approach limits than the 91-m limit enforced in other areas. However, there is minimal information that identifies and defines special habitat requirements of humpback whales. The Hawaii State Department of Transportation has limited jet skiing and parasailing to specified areas and seasons to avoid ocean-use conflict, including conflict with whales (Anonymous 1990); nonetheless, specific habitat critical to humpbacks and ramifications of these potential disturbances remain to be adequately described and evaluated.

The results of this study indicate quantitatively that humpback pods which contained a calf were found in shallow nearshore water (1) during the afternoon throughout the study period, and (2) throughout the day from 11 March to 7 April. Thus, until more information is available to characterize habitat preferences of humpbacks, all nearshore shallow waters where humpbacks are known to occur should receive special protection and consideration as potentially critical habitat. Effects of coastal development and aquatic activities should be thoroughly evaluated in order to mitigate potential disturbance and displacement of humpbacks from preferred habitat. As relatively little is known about habitat requirements of humpbacks, evaluation of human impact should include the collection of distributional data on whales before and after instigation of human-related activities which could alter patterns of habitat use by humpback whales.

Areas for Future Research

While this study has attempted to answer several questions with respect to habitat selection and distribution of humpback whales in a relatively small area off the island of Hawaii, there are still many questions which remain to be answered. For example, do the same temporal distribution patterns occur near other islands of Hawaii or other regions where humpbacks concentrate during the winter? The following are some suggested areas of research which remain to be addressed in order to characterize habitat utilization patterns of humpback whales in Hawaii and to evaluate potential effects of human-related impacts.

(1) Simultaneous aerial surveys should be conducted to assess the relative abundance of calves across the major Hawaiian Islands in order to determine whether apparent displacement from certain areas is associated with increases in the usage of other islands or regions of Hawaii.

(2) Aerial survey data collected in the Hawaiian Islands should be re-examined to identify and compare past and present temporal patterns of distribution relative to depth and distance from shore of different sex, age, and reproductive classes of humpbacks.

(3) Differential effects of various types of human-related aquatic activities on the behavior and distribution of whales need to be assessed. For example, while parasailing and jet ski activities have been banned from certain coastal areas

during the period that humpbacks occur in Hawaii, there are virtually no data to support a differential response by whales to these activities as opposed to other vessel traffic. Differential responses could possibly be determined by using hydrophone arrays to simultaneous record and locate vessels and thrillcraft relative to positions and movements of whales.

(4) The effects of the presence of adult whales, their activities, and their associated underwater vocalizations on habitat selection by cows with calves remain to be fully interpreted. Hydrophone arrays may be helpful in correlating the location and underwater sound characteristics of whales with the behavior and location of other whales.

(5) Aerial photogrammetry or photo-identification studies are desirable to assess the role of calf maturity in habitat selection and distribution of cow/calf pairs.

(6) Comparisons of the distribution of whales in coastal areas where the water is deep versus shallow may shed light on the relative importance of water depth versus distance from shore in habitat selection.

(7) Aerial observations of relatively undisturbed areas are necessary to comprehensively describe distributional trends of humpbacks, especially of cows with calves, in offshore areas beyond land-based visibility. Aerial and vessel surveys are also important to verify sighting capabilities of land-based observers as a function of distance from shore. Combined aerial, vessel, and land-based observations of humpbacks may provide a model for estimating potential errors and assessing accurate distribution numbers, as has been done for migrating gray whales (Reilly et al. 1983; Poole 1984; Reilly 1984).

(8) Intensive photographic identification or radio-tagging studies are needed to assess site fidelity, within-season range, and duration of stay of different age, sex, and reproductive classes of humpbacks while on the breeding grounds, particularly of cows with calves.

(9) Descriptions of the behavioral and morphological development of humpback calves and of cow/calf interactions modeled after studies of southern right whales by Taber and Thomas (1982), Thomas and Taber (1984), and Thomas (1986) are desirable to better understand behavioral dynamics of cows and calves, their environmental requirements, and the potential effects of human-induced activities on calves of various age.

CONCLUSIONS

Humpback groups with a calf occurred in significantly shallower water and nearer to shore than did non-calf groups during the afternoon hours throughout the study period. During the late breeding season (11 March to 7 April), the same distribution pattern was observed throughout the day. During the remainder of the study period, groups with a calf were found primarily in offshore deep water and were not distributed differently from non-calf groups. The distribution of groups with a calf when alone in the study area did not differ significantly from when non-calf groups were present. However, groups with a calf occurred at greater distances from all other groups than did non-calf groups from one another, supporting results of previous studies that cows with calves avoid interactions with other whales. Consistent with trends observed in the Hawaiian Islands, the peak abundance of whales off the Hawaii study area was followed by a decrease in the relative abundance of adult groups and an increase in the relative abundance of calf pods; cow/calf pairs were also more frequently accompanied by another whale as the breeding season progressed. Peak abundance of whales and pods occurred earlier in the Hawaii study area in 1988 and 1989 than off Maui in 1988, and later than the peak reported for Hawaii in 1988 in a region 35-45 km north-northeast of the study site.

Groups with a calf preferred shallower nearshore water than adult groups without calves within certain temporal parameters which were possibly related to changes in reproductive conditions and relative abundance of humpback social groups. These relationships could have served as the impetus for differential temporal segregation. For example, groups with a calf occurred in shallower nearshore water than non-calf groups at times when (1) sexually active males may have been more attracted to cows with calves, resulting in increased harassment pressure on females with calves, and (2) aggressive interactions between adults and adult group size tend to increase. Cows with calves may move to shallow nearshore habitat at these times to evade sexually active adults and their associated behaviors in order to avoid (1) potential separation of calves from cows or even injury or death to calves, (2) interruption of nursing bouts, (3) energy expenditure, or (4) premature social interactions of the calf. Cows with calves may also prefer nearshore shallow habitat to avoid predators and more turbulent offshore sea conditions.

There is still much to be learned about the behavioral ecology of humpback whales. Without ascertaining the age, sex, and reproductive status of individually identified whales, interpretation of temporal shifts in distribution patterns remain unclear. General trends have been identified and quantified, which provide a foundation for future studies: further refining and solidifying of these trends are desirable. Although the study site represents a relatively small portion of the Hawaiian humpback wintering ground, results lend insight into the general environmental requirements of humpbacks. More studies are needed to assess the temporal distribution of humpbacks in other areas. Such knowledge is important as an aid in improving management schemes involving humpback whales and their marine habitat.

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APPENDIX A

Mean swimming speeds (km/h) by pod type adapted from Bauer (1986)

Pod type	Mean swim speed	Standard deviation	Sample size	Range of speed
Unescorted cow/calf pair	4.1	1.88	54	0.8 - 8.4
Lone singer	3.9	2.89	18	0.6 - 11.4
Non-singing lone adult	4.6	1.95	26	0.8 - 8.1
Pods of two or more adults without a calf	4.9	2.35	43	0.9 - 10.8

APPENDIX B

Definitions of (a) Beaufort numbers (adapted from Anonymous 1977) and (b) sighting conditions

(a)

Beaufort number	Sea condition	Wave height (m)	Wind speed (km/h)
0	Smooth and mirror-like.	0	0 - 2
1	Scale-like ripples, no foam crests.	0.3	2 - 6
2	Small short wavelets. Crests appear glassy and do not break.	0.6	7 - 12
3	Large wavelets. Some crests break. Occasional white foam crests with glassy appearance.	0.9	13 - 19
4	Small waves become longer. Fairly frequent white foam crests.	1.2	20 - 31
5	Moderate waves more pronounced, long form. Many white foam crests. May be spray.	1.8	32 - 40

(b)

Sighting condition	Description	Definition
1	Excellent	Clear or cloudy skies, Beaufort number < 3
2	Good	Clear or cloudy skies, Beaufort number = 3
3	Poor	Haze or glare obscuring > 5% of study area, or Beaufort number > 3

APPENDIX C

Summary of humpback whale sightings*

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year **	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/9/88	14:03	4	0	A	3	95.2	2820	3	1
2/10/88	7:45	1	0	M	3	40.3	1040	2	0
2/10/88	8:16	1	0	M	3	86	2440	2	0
2/10/88	8:16	1	0	M	3	64.1	1590	2	0
2/10/88	9:46	2	0	M	3	60.4	1340	2	0
2/10/88	10:10	2	0	M	3	76.9	2230	2	0
2/10/88	12:03	4	0	A	3	51.2	1700	2	?
2/10/88	12:07	2	0	A	3	64.1	2120	2	?
2/10/88	12:08	2	0	A	3	45.8	880	2	?
2/10/88	12:17	1	0	A	3	65.9	1780	2	?
2/10/88	12:18	1	0	A	3	51.2	1380	2	?
2/11/88	18:01	1	0	A	3	84.2	2740	3	?
2/12/88	12:03	2	0	A	4	53.1	820	2	3
2/12/88	13:46	1	0	A	4	53.1	980	2	2
2/12/88	13:48	2	0	A	4	91.5	2520	2	2
2/12/88	14:01	3	0	A	4	71.4	2220	2	2
2/14/88	12:40	1	0	A	4	53.1	840	3	5
2/14/88	12:49	1	0	A	4	58.6	1250	3	5

* Each row represents a single sighting of one group.

** For definition, see Table 1, page 9.

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/14/88	12:51	2	0	A	4	82.4	2680	3	5
2/14/88	14:42	2	1	A	4	67.7	2180	2	5
2/14/88	14:45	2	1	A	4	31.1	880	2	5
2/14/88	14:49	3	0	A	4	73.2	1840	2	5
2/14/88	14:51	2	0	A	4	76.9	2080	2	5
2/14/88	15:09	2	0	A	4	87.8	2630	2	5
2/14/88	17:30	2	0	A	4	58.6	1240	1	2
2/14/88	17:30	2	0	A	4	58.6	1280	1	2
2/14/88	17:32	2	0	A	4	84.2	2000	1	2
2/14/88	17:41	2	1	A	4	49.4	1100	1	2
2/14/88	17:44	1	0	A	4	53.1	1820	1	2
2/14/88	17:44	2	0	A	4	34.8	860	1	2
2/14/88	17:46	2	1	A	4	42.1	1290	1	2
2/14/88	17:57	2	0	A	4	100.7	3750	1	2
2/14/88	17:58	2	0	A	4	43.9	1300	1	2
2/15/88	7:34	1	0	M	4	47.6	1190	1	?
2/15/88	7:37	1	0	M	4	100.7	2870	1	?
2/15/88	8:10	1	0	M	4	65.9	1660	1	?
2/15/88	8:12	2	0	M	4	71.4	2480	1	?
2/15/88	8:14	2	0	M	4	39.4	980	1	?
2/15/88	8:15	3	0	M	4	86	2850	1	?
2/15/88	9:41	1	0	M	4	36.6	1060	1	?
2/15/88	9:43	1	0	M	4	80.5	2540	1	?

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/15/88	9:51	1	0	M	4	34.8	870	1	?
2/15/88	9:52	1	0	M	4	78.7	2000	1	?
2/15/88	11:35	1	0	M	4	53.1	1120	2	?
2/15/88	11:37	2	0	M	4	93.3	2410	2	?
2/15/88	11:56	1	0	M	4	16.5	740	2	?
2/16/88	15:13	1	0	A	4	53.1	1990	3	3
2/16/88	15:30	1	0	A	4	40.3	950	3	3
2/16/88	15:44	1	1	A	4	71.4	2070	3	3
2/16/88	15:45	2	0	A	4	102.5	3070	3	3
2/16/88	17:07	1	0	A	4	36.6	850	2	0
2/16/88	17:12	2	0	A	4	89.7	2920	2	0
2/16/88	17:14	2	0	A	4	75	2680	2	0
2/16/88	17:30	1	1	A	4	65.9	1780	2	0
2/16/88	17:42	1	0	A	4	102.5	3550	2	0
2/16/88	17:44	2	0	A	4	75	2370	2	0
2/17/88	7:07	3	0	M	4	67.7	2000	2	8
2/17/88	7:19	3	1	M	4	78.9	2060	2	8
2/17/88	7:50	1	0	M	4	76.9	2400	2	8
2/17/88	8:01	1	0	M	4	86	2490	2	8
2/17/88	8:08	2	0	M	4	86	2370	2	8
2/17/88	8:26	1	1	M	4	60.4	1030	2	8
2/17/88	9:11	2	0	M	4	87.8	2640	2	9
2/17/88	9:30	1	1	M	4	58.6	1070	2	9

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/18/88	17:31	1	0	A	4	51.2	1700	2	0
2/18/88	17:37	2	1	A	4	45.8	1380	2	0
2/18/88	17:46	2	0	A	4	104.3	4380	2	0
2/19/88	15:57	2	0	A	4	69.5	1550	3	0
2/19/88	16:11	1	0	A	4	69.5	1330	3	0
2/19/88	16:15	2	0	A	4	67.7	2450	3	0
2/19/88	16:21	1	1	A	4	47.6	1500	3	0
2/19/88	16:25	1	0	A	4	54.9	1530	3	0
2/19/88	16:27	1	0	A	4	76.9	2540	3	0
2/19/88	17:44	2	1	A	4	31.1	870	2	0
2/19/88	17:55	2	0	A	4	62.2	2080	2	0
2/19/88	18:15	1	0	A	4	65.9	1960	2	0
2/21/88	8:13	1	0	M	4	80.5	2720	1	1
2/21/88	8:17	1	0	M	4	64.1	1820	1	1
2/21/88	8:27	1	1	M	4	113.5	3580	1	1
2/21/88	8:51	1	1	M	4	95.2	3340	1	1
2/21/88	12:27	2	0	A	4	82.4	2710	1	1
2/21/88	12:51	3	0	A	4	71.4	1960	1	1
2/22/88	13:22	2	0	A	4	98.8	2800	2	1
2/22/88	13:27	1	1	A	4	62.2	1670	2	1
2/22/88	13:36	1	0	A	4	54.9	1700	2	1
2/22/88	13:36	1	0	A	4	36.6	1020	2	1
2/22/88	13:36	1	0	A	4	31.1	720	2	1

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/22/88	13:37	2	0	A	4	51.2	1570	2	1
2/22/88	13:40	2	0	A	4	64.1	1260	2	1
2/24/88	8:08	1	0	M	4	62.2	1310	1	2
2/24/88	8:31	2	0	M	4	87.8	2580	1	2
2/24/88	8:32	1	0	M	4	87.8	2640	1	2
2/24/88	8:41	2	0	M	4	86	770	1	2
2/24/88	10:03	2	0	M	4	73.2	2470	2	5
2/24/88	10:05	2	0	M	4	53.1	1700	2	5
2/24/88	10:09	1	0	M	4	93.3	3160	2	5
2/24/88	10:11	1	0	M	4	69.5	1720	2	5
2/24/88	10:25	1	0	M	4	60.4	1020	2	5
2/24/88	10:32	2	0	M	4	58.6	980	2	5
2/24/88	11:56	1	0	M	4	62.2	1390	2	3
2/24/88	11:58	1	0	M	4	73.2	2150	2	3
2/24/88	12:28	1	0	A	4	104.3	3810	3	3
2/24/88	12:35	1	0	A	4	42.1	1270	3	3
2/24/88	12:36	1	0	A	4	54.9	1780	3	3
2/24/88	12:39	1	0	A	4	54.9	1820	3	3
2/25/88	13:05	3	0	A	4	38.4	1070	3	2
2/25/88	13:07	1	1	A	4	71.4	1850	3	2
2/25/88	13:09	2	0	A	4	71.4	1590	3	2
2/25/88	13:26	1	0	A	4	53.1	1350	3	2
2/25/88	15:10	1	0	A	4	67.7	1440	3	0

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/25/88	15:17	1	0	A	4	75	2280	3	0
2/25/88	15:42	1	0	A	4	45.8	1290	3	0
2/25/88	15:44	2	0	A	4	78.7	2300	3	0
2/25/88	15:46	1	0	A	4	51.2	1670	3	0
2/25/88	17:21	1	0	A	4	80.5	2440	3	2
2/25/88	17:28	1	0	A	4	91.5	2480	3	2
2/25/88	17:34	2	0	A	4	69.5	1890	3	2
2/26/88	8:05	1	0	M	5	87.8	2620	2	4
2/26/88	8:08	1	0	M	5	87.8	2820	2	4
2/26/88	8:21	3	0	M	5	86	2810	2	4
2/26/88	8:41	1	0	M	5	40.3	1180	2	4
2/26/88	9:45	1	0	M	5	53.1	1580	2	5
2/26/88	9:57	1	1	M	5	102.5	2980	2	5
2/27/88	14:25	2	0	A	5	87.8	2340	3	3
2/27/88	16:44	2	0	A	5	119	3340	2	3
2/27/88	16:48	2	1	A	5	91.5	2400	2	3
2/27/88	16:58	1	0	A	5	38.4	1010	2	3
2/29/88	7:23	1	0	M	5	47.6	1460	1	0
2/29/88	7:34	1	0	M	5	34.8	600	1	0
2/29/88	9:03	1	0	M	5	78.7	1880	2	3
2/29/88	9:40	1	0	M	5	89.7	3290	2	3
2/29/88	9:53	2	0	M	5	73.2	1780	2	3
3/1/88	7:28	2	0	M	5	64.1	2080	1	0

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/1/88	7:34	1	0	M	5	87.8	3000	1	0
3/1/88	9:06	2	0	M	5	53.1	1050	1	6
3/1/88	9:19	1	0	M	5	104.3	2920	1	6
3/1/88	9:31	1	0	M	5	97	3390	1	6
3/1/88	11:32	1	0	M	5	64.1	1780	2	4
3/2/88	13:35	1	0	A	5	58.6	1900	2	4
3/2/88	13:49	2	0	A	5	54.9	1020	2	4
3/2/88	15:10	1	0	A	5	16.5	470	3	0
3/2/88	15:30	1	0	A	5	64.1	1800	3	0
3/2/88	16:57	2	0	A	5	78.7	2490	3	0
3/3/88	7:45	2	0	M	5	49.4	2210	1	4
3/3/88	9:34	1	1	M	5	51.2	1560	1	9
3/3/88	11:42	1	0	M	5	65.9	1570	1	7
3/3/88	11:43	1	0	M	5	82.4	2400	1	7
3/3/88	12:04	1	0	A	5	36.6	980	1	7
3/3/88	12:19	1	0	A	5	36.6	1020	1	7
3/3/88	12:22	1	1	A	5	84.2	3050	1	7
3/4/88	13:06	1	0	A	5	87.8	2360	2	6
3/4/88	17:12	1	1	A	5	69.5	2050	2	1
3/4/88	17:51	3	0	A	5	64.1	1720	2	1
3/5/88	7:34	1	1	M	5	71.4	2440	1	4
3/5/88	7:44	1	0	M	5	27.5	530	1	4
3/5/88	7:57	3	0	M	5	32.9	580	1	4

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/5/88	9:54	2	1	M	5	73.2	1820	1	12
3/5/88	9:54	1	0	M	5	75	2380	1	12
3/5/88	10:04	2	1	M	5	98.8	3630	1	12
3/5/88	10:54	2	1	M	5	100.7	3620	1	8
3/7/88	13:40	3	0	A	5	86	3260	2	8
3/7/88	13:41	2	1	A	5	69.5	1370	2	8
3/7/88	13:41	3	0	A	5	67.7	1410	2	8
3/7/88	15:02	2	1	A	5	108	3800	2	2
3/7/88	15:04	2	0	A	5	86.8	2420	2	2
3/7/88	17:30	1	0	A	5	98.8	2810	2	1
3/7/88	17:33	2	0	A	5	58.6	1440	2	1
3/8/88	7:22	1	0	M	5	49.4	1900	1	0
3/8/88	9:20	1	0	M	5	56.7	1300	1	6
3/8/88	9:38	1	0	M	5	98.8	3600	1	6
3/8/88	11:28	1	0	M	5	60.4	1100	1	7
3/8/88	11:31	2	0	M	5	49.4	1320	1	7
3/8/88	11:40	2	0	M	5	106.1	3200	1	7
3/9/88	7:19	2	0	M	5	97	2790	1	1
3/9/88	9:52	1	0	M	5	67.7	1390	2	5
3/9/88	11:16	1	0	M	5	67.7	1380	2	6
3/10/88	15:12	2	0	A	5	75	1840	3	2
3/10/88	15:43	2	0	A	5	76.9	2490	3	2
3/10/88	17:20	2	0	A	5	58.6	1830	2	0

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/10/88	17:25	1	0	A	5	53.1	1850	2	0
3/10/88	17:36	2	0	A	5	75	1880	2	0
3/10/88	17:42	2	0	A	5	80.5	2390	2	0
3/11/88	7:07	1	0	M	6	95.2	3570	1	3
3/11/88	7:28	3	0	M	6	64.1	2130	1	3
3/11/88	9:58	1	0	M	6	86	2680	1	4
3/11/88	11:13	1	0	M	6	84.2	2930	1	5
3/11/88	11:17	2	1	M	6	76.9	2300	1	5
3/12/88	13:42	4	0	A	6	86	2910	3	4
3/12/88	13:47	1	0	A	6	40.3	1130	3	4
3/12/88	15:11	2	0	A	6	67.7	1630	3	2
3/12/88	15:13	2	0	A	6	91.5	2980	3	2
3/12/88	16:32	3	0	A	6	71.4	1900	3	0
3/12/88	16:49	2	1	A	6	65.9	1720	3	0
3/13/88	13:46	1	0	A	6	60.4	1780	3	2
3/14/88	8:14	1	0	M	6	106.1	4020	1	1
3/14/88	9:17	2	0	M	6	67.7	1520	2	2
3/16/88	7:41	1	0	M	6	56.7	1510	2	1
3/16/88	7:51	1	0	M	6	67.7	1500	2	1
3/16/88	7:57	1	0	M	6	104.3	3380	2	1
3/16/88	10:57	1	1	M	6	25.6	1000	2	2
3/16/88	11:00	6	0	M	6	71.4	1740	2	2
3/16/88	11:10	1	0	M	6	104.3	3860	2	2

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/17/88	15:20	2	1	A	6	76.9	2310	2	2
3/17/88	17:11	2	1	A	6	73.2	1950	2	0
3/17/88	17:17	1	0	A	6	71.4	1780	2	0
3/19/88	13:32	1	0	A	6	67.6	1910	2	1
3/19/88	13:47	1	0	A	6	64.1	1500	2	1
3/19/88	13:53	2	0	A	6	100.7	3200	2	1
3/19/88	13:58	2	1	A	6	62.2	1260	2	1
3/19/88	15:17	1	0	A	6	62.2	1230	2	3
3/19/88	15:32	2	0	A	6	43.9	1100	2	3
3/19/88	17:29	1	1	A	6	25.6	930	2	1
3/19/88	17:34	1	0	A	6	60.4	1280	2	1
3/19/88	17:36	1	0	A	6	47.6	900	2	1
3/19/88	17:46	1	1	A	6	40.3	1000	2	1
3/19/88	17:53	2	0	A	6	71.4	1580	2	1
3/20/88	7:44	2	1	M	6	58.6	1400	1	0
3/20/88	8:06	1	0	M	6	62.2	1470	1	0
3/20/88	9:40	2	1	M	6	5.5	470	1	3
3/20/88	9:46	2	1	M	6	12.8	960	1	3
3/20/88	9:50	2	0	M	6	87.8	2680	1	3
3/20/88	11:16	3	0	M	6	104.3	4030	2	4
3/20/88	11:31	1	0	M	6	62.2	1600	2	4
3/21/88	13:24	1	1	A	6	82.4	1870	2	6
3/21/88	15:31	2	1	A	6	69.5	1820	2	3

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/21/88	17:19	1	0	A	6	100.7	2670	2	2
3/22/88	9:24	1	0	M	6	60.4	1680	2	6
3/22/88	9:48	2	1	M	6	43.9	1520	2	6
3/22/88	11:09	1	0	M	6	49.4	1090	3	7
3/23/88	7:11	1	1	M	6	62.2	1460	1	2
3/23/88	7:19	1	0	M	6	78.7	2610	1	2
3/23/88	9:36	1	1	M	6	45.8	1390	2	2
3/23/88	11:03	1	0	M	6	82.4	2660	2	7
3/23/88	11:19	1	0	M	6	82.4	1400	2	7
3/25/88	14:02	2	1	A	7	25.6	670	2	3
3/25/88	14:09	2	0	A	7	107.8	3320	2	3
3/25/88	14:21	2	1	A	7	62.2	1600	2	3
3/25/88	15:15	2	0	A	7	31.1	810	2	4
3/25/88	15:43	1	1	A	7	32.9	850	2	4
3/25/88	15:47	1	0	A	7	36.6	900	2	4
3/26/88	7:12	1	0	M	7	78.7	1720	1	1
3/26/88	7:36	1	0	M	7	106.1	3500	1	1
3/29/88	13:21	1	0	A	7	67.7	1550	3	6
3/29/88	15:12	1	0	A	7	62.2	2250	2	5
3/29/88	16:47	1	0	A	7	40.3	1230	2	1
3/29/88	17:10	1	0	A	7	67.7	1740	2	1
1/20/89	9:18	1	0	M	2	89.7	3080	1	1
1/20/89	10:53	1	0	M	2	128.1	3640	2	2

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
1/20/89	11:07	1	0	M	2	58.6	2370	2	2
1/20/89	11:14	2	0	M	2	76.9	1780	2	2
1/20/89	11:17	2	0	M	2	67.7	1780	2	2
1/20/89	11:41	1	0	M	2	49.4	1480	2	2
1/20/89	13:05	2	0	A	2	67.7	1660	3	2
1/20/89	13:19	1	0	A	2	80.5	2490	3	2
1/20/89	13:20	2	0	A	2	78.7	2400	3	2
1/20/89	13:29	1	0	A	2	76.9	2040	3	2
1/21/89	13:49	1	0	A	2	42.1	570	2	2
1/21/89	13:50	1	0	A	2	73.2	1780	2	2
1/21/89	15:11	1	0	A	2	49.4	1120	3	2
1/21/89	15:15	2	0	A	2	62.2	1180	3	2
1/21/89	15:39	2	0	A	2	49.4	1570	3	2
1/21/89	15:41	2	0	A	2	71.4	2030	3	2
1/22/89	9:06	2	0	M	2	75	1640	2	2
1/22/89	9:15	2	0	M	2	109.8	4170	2	2
1/22/89	9:18	3	0	M	2	78.7	2150	2	2
1/22/89	9:33	1	0	M	2	58.6	1620	2	2
1/22/89	9:33	2	0	M	2	43.9	1250	2	2
1/22/89	11:06	5	0	M	2	75	2060	2	2
1/22/89	11:18	1	0	M	2	78.7	2430	2	2
1/22/89	13:05	1	0	A	2	128.1	3470	3	3
1/22/89	13:09	1	0	A	2	93.3	2580	3	3

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
1/22/89	13:12	2	0	A	2	69.5	1620	3	3
1/23/89	13:25	1	0	A	2	40.3	1000	3	0
1/23/89	13:46	1	0	A	2	78.7	2560	3	0
1/23/89	15:27	1	0	A	2	75	2140	3	0
1/23/89	17:16	1	0	A	2	71.4	2220	2	0
1/23/89	17:17	1	0	A	2	95.2	3500	2	0
1/23/89	17:30	2	0	A	2	51.2	1300	2	0
1/23/89	17:43	1	0	A	2	65.9	1530	2	0
1/24/89	7:11	3	0	M	2	51.2	1160	1	0
1/24/89	7:17	1	0	M	2	69.5	1610	1	0
1/24/89	7:50	2	0	M	2	73.2	1810	1	0
1/24/89	9:22	2	0	M	2	95.2	3160	2	2
1/24/89	9:37	2	0	M	2	53.1	1020	2	2
1/24/89	9:42	1	0	M	2	54.9	1980	2	2
1/24/89	13:01	2	0	A	2	73.2	2030	3	0
1/26/89	7:30	1	0	M	2	87.8	2800	2	1
1/26/89	11:09	1	0	M	2	98.8	3510	2	0
1/26/89	13:01	1	0	A	2	73.2	1960	3	0
1/28/89	11:37	2	0	M	2	73.2	2540	1	2
1/28/89	15:04	2	0	A	2	76.9	1800	1	4
1/28/89	15:04	2	0	A	2	73.2	2240	1	4
1/28/89	15:06	3	0	A	2	87.8	2760	1	4
1/28/89	15:37	2	0	A	2	49.4	1950	1	4

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
1/28/89	15:37	4	0	A	2	36.6	950	1	4
1/28/89	15:40	2	0	A	2	84.2	2940	1	4
1/28/89	16:59	2	0	A	2	76.9	2140	1	0
1/28/89	17:01	2	0	A	2	56.7	1220	1	0
1/28/89	17:06	1	0	A	2	87.8	3030	1	0
1/28/89	17:08	2	0	A	2	67.7	2400	1	0
1/28/89	17:16	2	0	A	2	71.4	1730	1	0
1/28/89	17:17	2	0	A	2	62.2	1380	1	0
1/30/89	7:33	1	0	M	3	60.4	1360	2	0
1/30/89	7:52	1	0	M	3	86	2740	2	0
1/30/89	11:54	1	0	M	3	64.1	1530	2	1
1/30/89	13:27	1	0	A	3	73.2	2180	2	0
2/1/89	7:35	2	0	M	3	73.2	2040	2	0
2/1/89	7:44	2	0	M	3	76.9	1720	2	0
2/1/89	9:06	2	0	M	3	76.9	2390	2	0
2/1/89	9:22	1	1	M	3	86	2820	2	0
2/1/89	13:05	2	0	A	3	67.7	1440	2	0
2/1/89	13:10	4	0	A	3	43.9	900	2	0
2/5/89	13:03	2	0	A	3	104.3	3920	3	3
2/5/89	15:02	3	0	A	3	42.1	1080	3	0
2/6/89	7:06	2	0	M	3	60.4	1970	2	0
2/6/89	7:18	2	0	M	3	32.9	900	2	0
2/7/89	13:17	2	0	A	3	69.5	1480	2	0

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/7/89	13:49	1	0	A	3	87.8	2980	2	0
2/7/89	13:55	1	0	A	3	40.3	870	2	0
2/7/89	15:01	2	0	A	3	102.5	3750	2	2
2/7/89	15:21	3	0	A	3	86	2300	2	2
2/7/89	17:18	2	0	A	3	43.9	1270	2	0
2/7/89	17:19	1	0	A	3	45.8	1320	2	0
2/7/89	17:24	1	0	A	3	89.7	690	2	0
2/7/89	17:28	1	0	A	3	29.3	3320	2	0
2/7/89	17:32	2	0	A	3	58.6	1360	2	0
2/7/89	17:49	1	1	A	3	36.6	650	2	0
2/8/89	7:25	1	0	M	3	87.8	2120	2	0
2/8/89	9:02	2	0	M	3	34.8	740	2	1
2/8/89	13:30	1	0	A	3	67.7	2050	3	0
2/12/89	11:23	2	0	M	4	62.2	2150	2	1
2/12/89	11:39	1	0	M	4	89.7	2610	2	1
2/12/89	12:58	1	0	A	4	89.7	2930	3	1
2/12/89	12:59	1	0	A	4	58.6	1400	3	1
2/12/89	13:21	2	1	A	4	93.3	3500	3	1
2/12/89	15:05	3	0	A	4	75	2150	3	2
2/12/89	15:36	2	0	A	4	51.2	1430	3	2
2/12/89	17:15	2	1	A	4	56.7	1200	3	0
2/12/89	17:15	1	0	A	4	82.4	2480	3	0
2/12/89	17:25	1	0	A	4	89.7	3270	3	0

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/12/89	17:26	2	0	A	4	87.8	2970	3	0
2/12/89	17:29	1	0	A	4	89.7	3060	3	0
2/12/89	17:30	1	0	A	4	78.9	2160	3	0
2/12/89	17:31	2	0	A	4	89.7	3090	3	0
2/13/89	7:06	1	0	M	4	64.1	1800	1	0
2/13/89	7:07	1	0	M	4	91.5	3090	1	0
2/13/89	7:08	2	0	M	4	40.3	1200	1	0
2/13/89	7:13	2	0	M	4	82.4	2590	1	0
2/13/89	7:22	1	1	M	4	80.5	2000	1	0
2/13/89	7:27	4	0	M	4	62.2	1350	1	0
2/13/89	7:29	3	0	M	4	104.3	3350	1	0
2/13/89	9:02	3	0	M	4	78.7	1690	1	1
2/13/89	9:04	2	0	M	4	71.4	2340	1	1
2/13/89	9:12	2	0	M	4	76.9	2030	1	1
2/13/89	9:14	1	0	M	4	49.4	840	1	1
2/13/89	9:30	1	0	M	4	82.4	2900	1	1
2/13/89	9:34	2	0	M	4	87.8	2860	1	1
2/13/89	9:52	1	0	M	4	62.2	2030	1	1
2/13/89	11:17	1	0	M	4	64.1	2040	2	2
2/13/89	11:22	1	0	M	4	65.9	1340	2	2
2/13/89	11:29	2	0	M	4	106.1	3190	2	2
2/14/89	11:24	1	0	M	4	87.8	2810	2	3
2/14/89	11:27	1	0	M	4	75	2020	2	3

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/14/89	11:39	1	0	M	4	84.2	2090	2	3
2/14/89	11:42	2	0	M	4	36.6	720	2	3
2/14/89	13:17	2	0	A	4	42.1	540	2	2
2/14/89	13:27	2	0	A	4	51.2	1240	2	2
2/14/89	13:30	1	0	A	4	53.1	1680	2	2
2/14/89	15:01	1	0	A	4	82.4	2670	3	0
2/14/89	15:12	1	0	A	4	86	2710	3	0
2/14/89	15:13	1	0	A	4	53.1	1820	3	0
2/14/89	15:27	1	0	A	4	47.6	890	3	0
2/14/89	15:29	1	0	A	4	69.5	1620	3	0
2/14/89	17:07	2	1	A	4	58.6	1340	2	0
2/14/89	17:14	1	0	A	4	45.8	870	2	0
2/14/89	17:19	1	0	A	4	91.5	2310	2	0
2/15/89	7:14	2	0	M	4	71.4	1500	2	0
2/15/89	7:23	2	0	M	4	95.2	2500	2	0
2/15/89	9:26	1	0	M	4	75	2700	2	1
2/17/89	11:31	3	1	M	4	89.7	3370	1	3
2/17/89	11:34	2	0	M	4	56.7	820	1	3
2/17/89	11:53	2	0	M	4	84.2	2030	1	3
2/17/89	13:09	1	0	A	4	43.9	1680	1	0
2/17/89	13:25	2	1	A	4	60.4	2020	1	0
2/17/89	13:28	3	0	A	4	106.1	4380	1	0
2/17/89	13:40	2	0	A	4	86	2680	1	0

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/17/89	15:08	2	0	A	4	97	3680	2	1
2/17/89	15:10	1	0	A	4	36.6	930	2	1
2/17/89	15:20	3	0	A	4	75	2260	2	1
2/18/89	7:13	2	0	M	4	69.5	1910	1	1
2/18/89	7:32	2	0	M	4	53.1	1770	1	1
2/18/89	7:40	2	1	M	4	87.8	3120	1	1
2/18/89	7:48	1	0	M	4	32.9	900	1	1
2/18/89	9:02	1	0	M	4	34.8	700	1	4
2/18/89	9:04	2	0	M	4	65.9	1680	1	4
2/18/89	9:28	2	0	M	4	84.2	2380	1	4
2/18/89	9:29	1	0	M	4	102.5	3900	1	4
2/18/89	11:07	2	0	M	4	111.6	4080	1	8
2/18/89	11:11	2	0	M	4	78.7	2190	1	8
2/19/89	7:06	2	0	M	4	84.2	2800	1	1
2/19/89	7:10	2	0	M	4	34.8	940	1	1
2/19/89	9:23	2	0	M	4	75	2650	1	2
2/19/89	11:04	1	0	M	4	102.5	4410	2	6
2/19/89	11:13	2	0	M	4	93.3	3470	2	6
2/19/89	11:31	1	0	M	4	91.5	3100	2	6
2/19/89	11:42	2	0	M	4	87.8	2210	2	6
2/21/89	13:20	1	0	A	4	71.4	2180	3	0
2/21/89	15:03	2	0	A	4	76.9	2120	2	2
2/21/89	15:10	2	0	A	4	120.8	3760	2	2

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
2/23/89	7:05	1	0	M	4	75	1720	1	0
2/23/89	9:33	1	0	M	4	76.9	2490	1	3
2/23/89	11:06	1	0	M	4	95.2	3330	2	2
2/23/89	11:09	1	0	M	4	98.8	3480	2	2
2/23/89	11:10	2	0	M	4	108	3820	2	2
2/23/89	11:21	2	0	M	4	76.9	2400	2	2
2/23/89	11:24	1	0	M	4	80.5	2800	2	2
2/23/89	11:29	1	0	M	4	71.4	2340	2	2
2/23/89	12:57	2	0	A	4	89.7	2910	2	3
2/26/89	9:08	2	0	M	5	87.8	2480	2	1
2/26/89	9:21	1	1	M	5	36.6	820	2	1
2/26/89	11:04	3	0	M	5	80.5	2340	2	4
2/26/89	11:07	2	1	M	5	58.6	1240	2	4
3/1/89	11:17	3	0	M	5	78.7	1890	2	0
3/1/89	11:30	1	0	M	5	47.6	1340	2	0
3/1/89	11:54	1	0	M	5	27.5	990	2	0
3/5/89	13:34	1	1	A	5	64.1	1280	2	3
3/5/89	13:59	1	0	A	5	91.5	3140	2	3
3/5/89	17:22	3	0	A	5	87.8	2150	2	0
3/6/89	7:13	2	0	M	5	76.9	2060	2	0
3/6/89	9:50	1	0	M	5	49.4	1250	3	1
3/6/89	11:23	2	1	M	5	43.9	1300	2	3
3/6/89	11:32	3	0	M	5	69.5	1670	2	3

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/9/89	9:05	1	0	M	5	73.2	1950	2	3
3/9/89	9:08	1	0	M	5	27.5	860	2	3
3/9/89	9:18	1	1	M	5	82.4	2060	2	3
3/9/89	9:28	2	0	M	5	108	3850	2	3
3/9/89	11:08	3	1	M	5	98.8	3620	2	3
3/9/89	11:15	1	0	M	5	102.5	2800	2	3
3/9/89	11:37	1	0	M	5	29.3	870	2	3
3/9/89	15:05	1	0	A	5	40.3	880	3	2
3/9/89	15:33	2	0	A	5	86	2770	3	2
3/9/89	16:43	2	1	A	5	97	3580	3	0
3/9/89	16:45	1	0	A	5	49.4	1380	3	0
3/9/89	17:00	2	0	A	5	78.7	2390	3	0
3/9/89	17:03	1	0	A	5	71.4	1880	3	0
3/9/89	17:05	2	1	A	5	31.1	730	3	0
3/10/89	7:22	2	0	M	5	73.2	1790	2	0
3/10/89	9:47	2	1	M	5	80.5	1780	2	2
3/10/89	11:06	3	1	M	5	53.1	980	2	4
3/10/89	13:20	3	1	A	5	49.4	1910	2	3
3/10/89	17:13	1	0	A	5	75	1680	2	0
3/11/89	7:02	1	0	M	6	95.2	3290	1	0
3/11/89	7:04	1	0	M	6	75	2320	1	0
3/11/89	7:05	1	0	M	6	5.5	390	1	0
3/11/89	7:27	2	0	M	6	78.7	2560	1	0

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/11/89	7:31	1	0	M	6	76.9	2520	1	0
3/11/89	9:25	1	0	M	6	64.1	1770	1	3
3/11/89	11:04	1	1	M	6	65.9	1200	2	5
3/11/89	11:14	1	0	M	6	73.2	2110	2	5
3/11/89	11:29	1	0	M	6	98.8	3550	2	5
3/11/89	13:03	2	0	A	6	67.7	2010	3	4
3/12/89	11:31	1	1	M	6	82.4	2630	1	6
3/12/89	11:37	1	1	M	6	18.3	730	1	6
3/12/89	15:01	1	1	A	6	45.8	1000	3	2
3/12/89	15:05	1	0	A	6	73.2	2080	3	2
3/12/89	15:23	1	1	A	6	86	3020	3	2
3/13/89	7:18	1	0	M	6	62.2	1540	3	0
3/13/89	7:39	1	0	M	6	82.4	2040	3	0
3/13/89	9:06	2	0	M	6	78.7	2260	2	2
3/13/89	11:00	3	0	M	6	82.4	2530	3	3
3/13/89	11:14	1	0	M	6	64.1	1930	3	3
3/13/89	11:23	1	0	M	6	87.8	2460	3	3
3/13/89	12:50	3	0	A	6	51.2	1000	3	2
3/13/89	12:51	2	0	A	6	71.4	2060	3	2
3/13/89	12:57	2	0	A	6	56.7	1660	3	2
3/15/89	7:00	1	1	M	6	53.1	1130	3	0
3/15/89	7:10	1	0	M	6	53.1	1650	3	0
3/15/89	8:59	1	0	M	6	29.3	860	2	1

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/17/89	7:04	1	0	M	6	51.2	1490	1	0
3/17/89	7:05	2	1	A	6	76.9	2430	1	0
3/17/89	7:09	2	0	M	6	43.9	1040	1	0
3/17/89	9:27	2	1	M	6	73.2	2020	1	0
3/17/89	9:30	1	0	M	6	95.2	3390	1	0
3/17/89	11:06	2	1	M	6	62.2	1880	2	1
3/17/89	12:58	2	1	M	6	71.4	2280	3	2
3/17/89	13:18	1	0	A	6	87.8	2940	3	2
3/18/89	11:18	1	0	M	6	62.2	1780	3	2
3/19/89	11:19	3	0	M	6	82.4	2600	3	2
3/18/89	11:27	2	0	M	6	47.6	1200	3	2
3/18/89	11:36	1	1	M	6	69.5	1970	3	2
3/18/89	13:35	2	0	A	6	89.7	3040	3	0
3/18/89	15:21	3	0	A	6	76.9	1980	3	1
3/18/89	15:32	1	0	A	6	40.3	900	3	1
3/19/89	13:30	1	0	A	6	69.5	1790	2	2
3/19/89	13:46	1	0	A	6	73.2	2060	2	2
3/19/89	15:17	2	0	A	6	75	2400	2	2
3/19/89	15:21	1	0	A	6	78.7	2520	2	2
3/19/89	17:10	1	1	A	6	43.9	1080	2	1
3/20/89	7:35	1	0	M	6	104.3	3890	1	0
3/20/89	7:38	1	0	M	6	91.5	3390	1	0
3/20/89	9:10	2	0	M	6	43.9	1290	1	4

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/20/89	9:25	1	0	M	6	75	1630	1	4
3/20/89	11:03	2	0	M	6	100.7	3680	3	4
3/20/89	11:05	1	0	M	6	71.4	1750	3	4
3/21/89	11:40	2	0	M	6	104.3	3190	2	1
3/21/89	13:20	2	0	A	6	93.3	3500	3	1
3/21/89	15:40	2	1	A	6	54.9	1580	2	1
3/23/89	7:31	1	0	M	6	89.7	3010	1	0
3/23/89	7:31	2	0	M	6	104.3	3600	1	0
3/23/89	13:08	1	0	A	6	89.7	2460	2	4
3/26/89	7:35	1	0	M	7	49.4	1080	1	0
3/26/89	11:17	1	0	M	7	93.3	2470	2	0
3/26/89	12:50	1	0	A	7	73.2	1760	3	0
3/26/89	13:14	1	0	A	7	56.7	1950	3	0
3/27/89	7:09	3	1	M	7	38.4	1120	1	1
3/27/89	7:19	2	0	M	7	40.3	1080	1	1
3/27/89	7:22	2	0	M	7	29.3	580	1	1
3/27/89	9:00	3	1	M	7	64.1	1120	2	2
3/27/89	9:16	2	0	M	7	71.4	1670	2	2
3/28/89	11:13	3	1	M	7	45.8	970	1	7
3/28/89	11:23	1	0	M	7	54.9	820	1	7
3/28/89	11:27	1	0	M	7	75	2660	1	7
3/28/89	11:33	2	1	M	7	12.8	500	1	7
3/28/89	13:01	3	0	A	7	73.2	1830	2	2

APPENDIX C (cont.)

Date	Time	No. of adults	No. of calves	Morning (M) or Afternoon (A)	Fortnight of the year	Water depth (m)	Distance to shore (m)	Beaufort number	Number of vessels present
3/28/89	13:03	2	1	M	7	7.3	250	2	2
3/28/89	13:04	2	1	A	7	49.4	1590	2	2
3/28/89	13:09	1	0	A	7	89.7	3200	2	2
3/28/89	15:12	2	1	A	7	16.5	280	2	4
3/28/89	15:23	3	1	A	7	31.1	880	2	4
3/28/89	16:45	3	1	A	7	38.4	1220	2	1
3/28/89	16:50	1	0	A	7	82.4	2690	2	1
3/28/89	17:09	2	1	A	7	16.5	460	2	1
3/31/89	9:42	1	0	M	7	87.8	3070	3	2
4/4/89	7:27	2	1	M	7	65.9	1490	2	2
4/4/89	9:18	1	0	M	7	115.3	4330	2	1
4/5/89	7:24	2	1	M	7	67.7	2250	1	0