DESCRIPTION OF HUMPBACK WHALE USE OF MAALALEA BAY, MAUI, HAWAII

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PAUL H. FORESTELL & ERIC K. BROWN
PACIFIC WHALE FOUNDATION
101 N. Kihei Rd., Kihei, HI 96753

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INTRODUCTION

In 1968 the United States Congress approved funding for a plan to construct improvements to the Maalaea Harbor for light-draft vessels at Maalaea, on the island of Maui in Hawaii (Figure 1). A General Design Memorandum and Final Environmental Impact Statement (FEIS) was prepared, circulated and approved by the Chief of engineers in 1980, but the project remained unfunded until the 1989 Fiscal Year. Although the 1980 FEIS concluded that the construction of the harbor improvements would have no effect on the endangered humpback whale, concerns remained that the associated increase in vessel traffic may have an adverse effect on this species.

The humpback whale (*Megaptera novaeangliae*) is one of the most endangered of the great whales, primarily due to commercial whaling during the first half of this century. According to Rice (1978), a pre-exploitation population estimated at 15,000 humpback whales in the North Pacific was reduced to fewer than 1,200 animals by the mid-1960's. In 1966 the International Whaling Commission approved a prohibition on commercial whaling of this species in the North Pacific. Following passage of the Endangered Species and Conservation Act of 1969 (superseded by the Endangered Species Act of 1973), humpback whales were declared an endangered species in 1970. Currently, the population is estimated as ranging between 2,500 and 3,500 animals (Darling and Morowitz, 1986; Baker and Herman, 1987; Chaloupka, Kaufman, and Forestell, 1989).

A significant portion of the North Pacific population of humpback whales migrates to Hawaii each winter (Johnson and Wolman, 1984). Animals arrive as early as late October, and some are still observed through the end of May. Whales may be reliably observed in the vicinity of the leeward coast of Maui from late December through late April (Kaufman and Forestell, 1986). The Hawaiian Islands comprise one of three general wintering areas for the humpback in the North Pacific. The other two are off the Baja's Pacific coast of Mexico (Urban and Aguayo, 1989), and throughout the islands south of Japan (stretching from Ogasawara through the Northern Marianas to the southeast of Tokyo, and down through the Ryukuan Islands to the southwest) (Helweg, Herman, Yamamoto, and Forestell, 1990; Darling, 1991). The number of whales

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[1] FORESTELL, P.H. AND E.K. BROWN, 1991.
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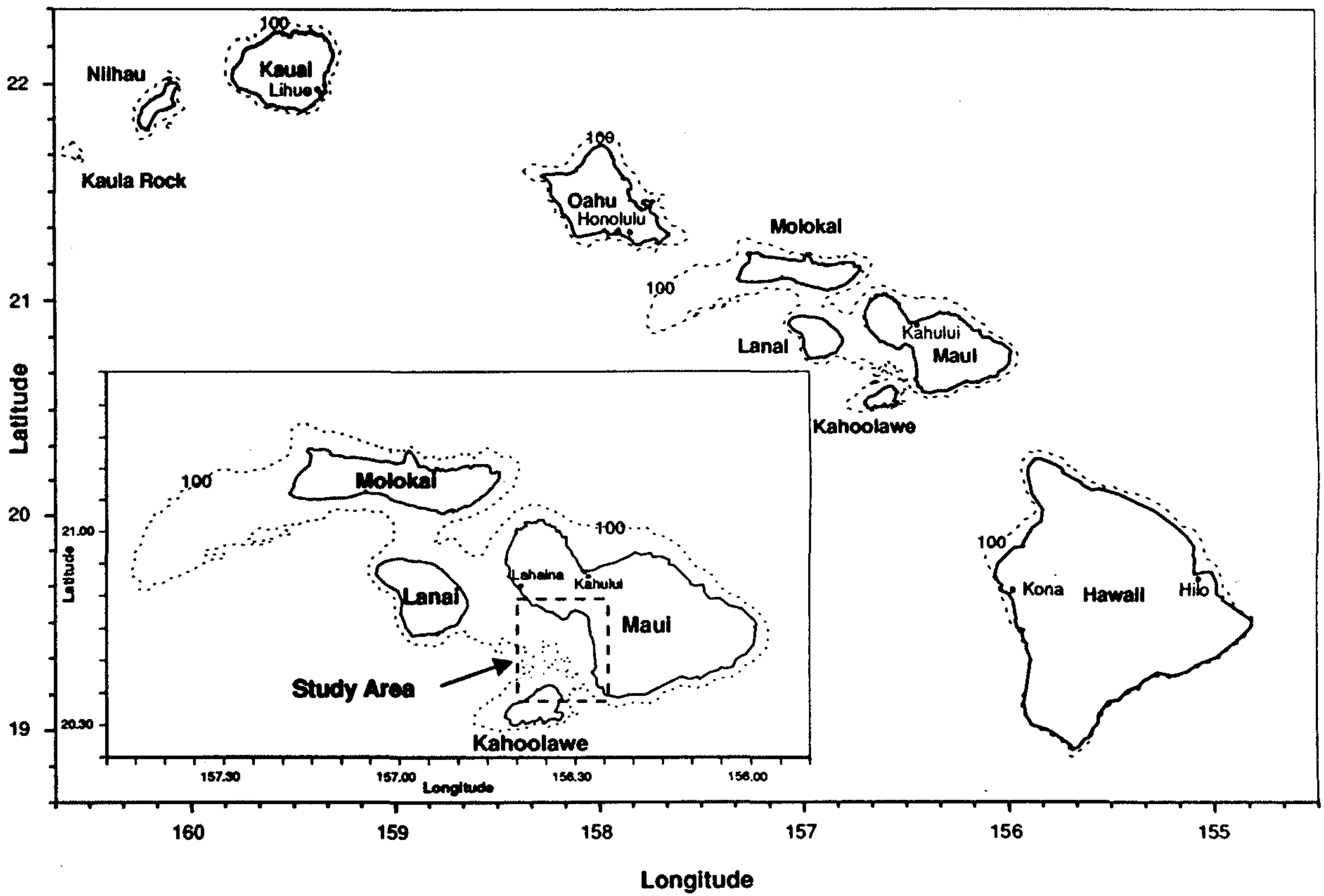

Figure 1: The main Hawaiian Islands showing the Four Island Region as an inset (Depths in Fathoms).

observed in Hawaii in winter exceed the number currently observed either along the Mexican coast or through the islands of Asia (Baker et al., 1986).

The relationship between the humpback whales observed in Hawaii, and those observed in Mexico and Japan is not yet well understood. It is generally considered that discrete feeding stocks occur throughout the lower latitudes in summer, and these co-mingle to some degree in the three high-latitude wintering areas for breeding and calf-rearing during the winter. Whales identified by photograph of unique fluke markings during one winter in Hawaii have been photographed in Mexico in both the same winter (Helweg et al, 1990), and in earlier or later winters (Perry, Baker, and Herman, 1990). Recently, it was reported that a whale observed in Ogasawara in one winter, was photographed near Kauai the following winter (Darling, 1991). However, the number of observed exchanges between wintering areas is quite small relative to the number of identified whales overall.

While in Hawaii, humpback whales may be found in the vicinity of all major islands. They show a general preference for wide, relatively shallow bank areas, leading to especially large concentrations of whales on Penguin Bank, of the northwestern end of Molokai; through the Auau Channel between Maui, Molokai, Lana'i and Kahoolawe; off the Kona Coast of the Big Island, and in the vicinity of Niihau and Kaula Rock (northwest of Kauai) (Wolman and Jurasz, 1977; Rice and Wolman, 1978). Whales are only rarely observed outside the 100-fathom contour during the winter residency period (Herman, Forestell, and Antinoja, 1980).

Under authority of the Marine Mammal Protection Act (MMPA) of 1972, the National Marine Fisheries Service (NMFS) is charged with ensuring the protection and recovery of this species. The MMPA specifically prohibits, among other acts, the harassment of marine mammals, except by federal permit. In 1979 NMFS published a Notice of Interpretation (NOI) to inform the public of activities that would be interpreted as harassment of whales in Hawaii. Unless otherwise exempted by federal permit, the NOI prohibited operation of any aircraft within 1000 feet of a humpback whale, disruption of the normal behavior or prior activity of a whale by any act or omission, or the approach by any means within specified distances of any humpback whale. The specified distances were 100 yards within 200 nautical miles of the islands of Hawaii, except for two areas in which the specified distances were 300 yards. The two 300-yard limit areas are within 2 nautical miles of the mean high-water line between Kaena and Kamaiki Points on Lana'i (i.e. the northeast and southeast coasts of Lana'i) and in Maalaea Bay, inside of a line drawn from Olowalu Point to Puu Olai (Figure 2).

In November of 1986, NMFS published a proposed rule governing approach to humpback whales in Hawaiian waters. As a result of difficulty in prosecuting violators of the guidelines contained in the NOI, NMFS elected to replace the NOI with regulations, thereby enhancing the legal status of the protective measures. Initially, the proposed regulations did not designate calving areas because available data did not support the conclusion that distinct calving areas existed. However, the Marine Mammal Commission argued that the regulations should not be less restrictive than the original guidelines, and NMFS subsequently amended the proposed regulations in November of 1987 to include the original 300-yd restriction in Maalaea Bay and along the northeast coast of Lana'i. The regulations were codified in December, 1988.

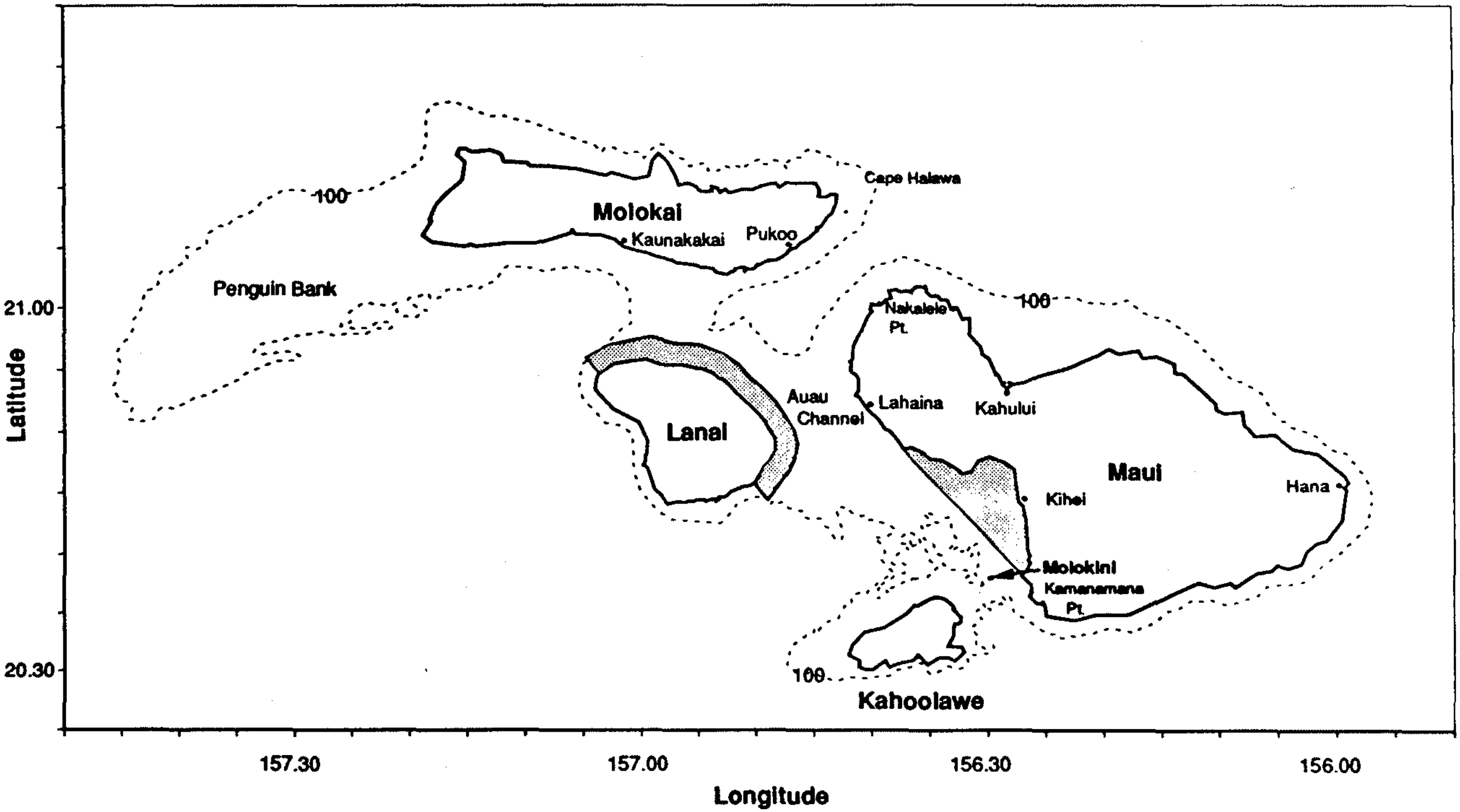

Figure 2:Cow/calf waters in the four-island region as designated by National Marine Fisheries Service.

DESIGNATION OF MAALAEA BAY AS A CALVING AREA

The original rationale for imposing stricter approach limits in Maalaea Bay and along the Lana'i shoreline was based on the perception that these areas were distinct "calving areas" in which greater protection from human disturbance should be afforded. Maalaea Bay has been considered an important area for mothers and calves since early observations (summarized in an unpublished 1980 report prepared by Muller, Carini, and Hudnall, cited by Nitta and Naughton, 1989) documented observations of mother-calf pods from a shore-based lookout near McGregor Pt. The study was prompted by a concern that an inter-island hydrofoil, travelling at high speeds into a passenger terminal at Maalaea Small Boat Harbor, might strike a whale. The study by Muller *et al.* did not compare relative frequencies of mother-calf sightings in Maalaea Bay with other areas, hence it is not possible to infer from their observations whether the area in question constitutes a distinct calving area.

Herman et al. (1980), on the basis of six days of aerial surveys, concluded that there was a wide distribution of calves among various subregions of the islands. In particular, they identified the northeast coast of Lanai, the Kihei region of Maui, the southwest coast of Molokai, and the western half of Penguin Bank. Their conclusions were based on observations of 17 of 38 calves in those areas.

Forestell (1989) found significantly more mother- calf pods throughout the Four Island Area (26) than on Penguin Bank (9) during one season of aerial surveys. The exact locations of mother calf pods were not documented, therefore the relative importance of Maalaea Bay as a calving ground is not apparent from that study.

Glockner-Ferrari and Ferrari (1990) reported on their studies of mothers and calves in the Auau Channel between 1977 and 1988. Their observations sometimes extended throughout all of the channel waters between Maui and Lana'i, from Kaanapali in the north, southward to McGregor Point. However, their primary efforts have concentrated on an area between Kaanapali and Olowalu on the Maui side, out to about half-channel (Glockner and Venus, 1983; Glockner-Ferrari and Ferrari, 1984, 1985, 1987). Their success in studying mothers and calves in this area since 1977 suggests it to be as important an area for mothers and calves as elsewhere in the islands.

Mobley (1991) conducted one year of aerial surveys around all major islands using procedures identical to those employed from 1977 through 1980 by Herman et al. (1980) and Baker and Herman (1981). In comparing his 1990 results with earlier 1977-1980 results, Mobley found increases in the rate of whale observations per hour were on the order of 44 -58% greater for whales overall, and 76-107% greater for pods with calf. His findings agreed with those of Herman et al. (1980), that Penguin Bank and Auau Channel areas are substantially higher in relative frequency of calf sightings. Mobley's 1990 observations found the distribution of calves to be equivalent throughout Maalaea Bay and the Auau Channel, except for a slightly higher incidence of calves along the northeast coast of Lanai. He found no indication that Maalaea Bay was a distinct calving area. Overall, Mobley documented 74 confirmed calf observations, compared with 38 confirmed calf sightings by Herman et al. (1980).

In general, the data with respect to the use of Maalaea Bay by mothers and calves relative to other areas in the islands are inconclusive. While mothers and calves are found there, it has yet to be shown they occur with a frequency any greater than elsewhere.

A secondary issue of importance is whether the designation of Maalaea Bay as a calving area, and the subsequent stricter distance regulations imposed by NMFS, actually afford the whales any greater level of protection from human activity. Finally, a systematic description of the abundance and distribution of whales and boats in the general vicinity of Maalaea Bay will provide a data-base on humpback whales for use in ongoing management decisions.

Periodic systematic observations of whale distribution and abundance patterns in this area will facilitate both short- and long-term observations of quantitative and qualitative changes over time. The data will permit ongoing monitoring of changes in humpback whale patterns which may be associated with identifiable changes in human patterns. Ultimately, mitigation of potential impacts will be most successful if there is an opportunity to assess current patterns, and monitor future changes in those patterns.

SCOPE OF THE PRESENT REPORT

The Pacific Whale Foundation has conducted annual aerial surveys throughout the Four Island Area (i.e., the waters bounded by the islands of Molokai, Lana'i, Kahoolawe, and Maui) including Maalaea Bay during five winter seasons since 1985. In addition, two years of systematic surveys from small boats have been carried out in Maalaea Bay and adjacent waters. In September of 1991 the US Army Engineer District in Honolulu issued Purchase Order No. DACW83-91-P-0601 for a report describing the use of Maalaea Bay and the immediate vicinity by humpback whales. The scope of work for the report was to:

1. Review currently available information on humpback whale behavior and use of Maalaea Bay.

2. Provide summary and analysis of data collected from aerial and small boat surveys on:

   a. location of whales, as a function of time of day, time of season, depth, and pod composition;

   b. locations of boats, as a function of time of day, time of season, and type of vessel, as well as the frequency of observations of vessels within .25 mi of whales;

   c. general activity of whales as a function of location, pod composition, and time of year.

3. Prepare written report documenting references cited, scope of work, methodology employed, quantification of results, and discussion of findings relative to the planned expansion of the Maalaea Small Boat Harbor.

As detailed in the present report, all phases of the proposed study effort have been completed.

METHODS

STUDY AREA

The study area was comprised of two regions: the waters inside Maalaea Bay, and an equal-sized area outside of but adjacent to Maalaea Bay. The border between the two regions was the line developed by NMFS to demarcate the calf resting area. Each equal-sized region was further divided into 3 equal-sized subregions. The six sub-regions were developed by integrating the areas of 60 trapezoids determined from NOAA chart 19347 along a line drawn directly from Hekili Point to Pu'u Olai. Each sub-region is approximately 13 mi^2 (Figure 3).

VESSEL SURVEYS

Survey Platforms and Apparatus: Surveys were conducted from a 16' fiberglas Radon equipped with a 40-hp Tohatsu engine (1989), a 13' Boston Whaler with a 25-hp Johnson outboard (1989), a 14' Zodiac inflatable equipped with a 25-hp Johnson outboard (1989 and 1991) or a 16' Achilles hard-bottom inflatable equipped with a 75-hp Yamaha outboard. Each boat carried a crew complement of four people: a driver, a recorder, and two observers. Each survey was accompanied by at least one experienced

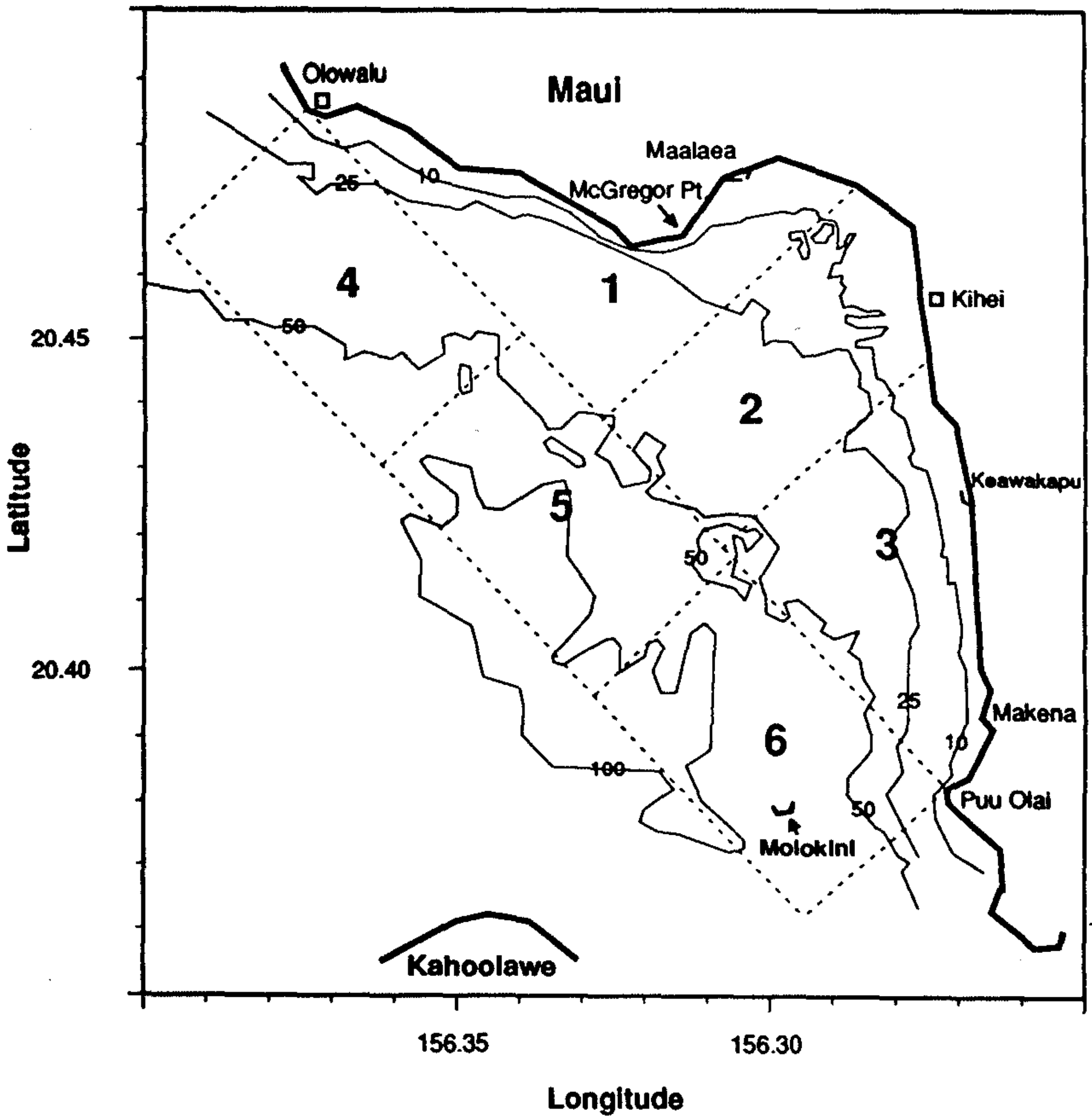

Figure 3: The study area, showing major landmarks on Maui and the depth contour in fathoms.

researcher, with three or more years of relevant field experience. Additional personnel were drawn from volunteers, who received a minimum of two days training in field protocol and observation techniques. Many of the volunteers had prior relevant experience, and all became easily familiar with the demands of the current project.

Generally, at least two boats operated each day. Locations were determined with the aid of a Morin 2000 hand-held compass. Readings were taken on a minimum of 3 pre-selected prominent landmarks. The particular landmarks used depended upon the sub-region being surveyed. Data were recorded by hand on prepared forms, and later coded for computer entry into an Excel spreadsheet.

Survey Period: Surveys were conducted on a daily basis, weather permitting, during a 16-wk period from January 10 through April 26 in 1989, and from January 10 through April 30, 1991. Because Maalaea Bay is frequently exposed to strong, gusty trade winds in the late-afternoon period, surveys were generally conducted between 0800 and 1600 hrs each day. Surveys were not conducted in conditions of Beaufort Sea State 5 or greater (Windspeed > 16 mph; extensive whitecapping with moderate waves). Sampling was constrained to ensure that each of the six sub-regions was surveyed an equivalent number of times within each two week period.

Survey transects: Daily surveys were conducted along randomly-determined, pre-selected transects running parallel to the line demarcating the division between the 100-yd and 300-yd areas designated by NMFS. Surveys ran either east to west, or west to east, with equal frequency. Survey transects were randomly selected from a computer-generated listing of all possible survey transects through the study area at 50 possible points along border. The computer model used to generate the sampling scheme was developed in the Smart Spreadsheet for PCs. Sub-regions were surveyed according to a quasi-random schedule, with all sub-regions surveyed equally often during each two week period of the study.

During each daily survey, the survey boat was launched from Keawakapu Small Boat Ramp, just south of Kihei, and proceeded to that day's pre-determined starting point. The survey boat approached the starting point indirectly, in a somewhat circuitous manner, to avoid coming within one mile of the transect line that was to be surveyed, in order to minimize the impact of the survey vessel on subsequent sighting probabilities.

Once the vessel reached the starting point, an approximate 15 minute "stabilization" period was initiated prior to beginning the survey transect. During this period the starting point, (as with all subsequent location data) was determined with the aid of a hand-bearing compass. A minimum of three readings was taken, using prominent landmarks as noted on NOAA charts of the area. The recorder also noted sea state, wind direction, wind speed, visibility, and cloud cover periodically during the survey.

Survey time: Survey time was defined as time spent underway along the survey transect, at a constant speed of approximately 5 knots with two observers maintaining continual surveillance over their respective observation area. Observers were instructed to scan the area directly ahead of the survey boat, around to a position at either 4 or 8 o'clock (depending upon which side of the boat they were monitoring), and indicate to the driver and recorder each whale or boat observed within 1.6 km of the survey boat (visually estimated).

Each time a pod of whales was seen, the driver assumed responsibility for maintaining visual contact with the pod, while the observers continued their systematic scan of the observation area. Once the driver determined the survey boat was at its closest point of approach to the observed pod, survey time was suspended. The location of the boat was documented through three compass readings. The pod of whales that had been seen was then approached closely enough to verify the number of whales in the pod, and whether or not a calf was present.

If additional pods were observed in the interval between the first sighting and the suspension of survey time, the driver would approach all pods seen in order of proximity to the boat once survey time was suspended. However, whales observed during suspended survey periods were not included in survey observations, because it was not possible to determine to what degree observation of such whales was biased by remaining in the same general area.

For purposes of the present study, a boat-whale interaction was operationally defined as any occasion on which a vessel was seen within .4 km of a whale, regardless of what the boat was doing. (The only exception was an occasion on which the boat was either at anchor or on a mooring). Because of time constraints, it was not possible to suspend survey effort each time a boat was observed near a whale in order to document precisely the nature of the interaction. The distance of .4 km was selected because it is consistent with other studies conducted in Hawaii (Herman et al., 1980; Bauer and Herman, 1986; Forestell, 1989). The survey vessel was not included as a vessel within .4 km, regardless of its location relative to the pod.

Once the relevant data were collected, the boat resumed its original heading, and survey procedures were re-instated. Only time actually underway along the transect searching for whales was considered survey time. In general, each time the boat changed directions (either to approach whales or to resume survey) survey time was suspended and its location was documented by taking three compass readings.

As an additional precaution to maintain as accurate a record as possible of the survey boat's daily course, the boat would stop after twenty minutes of no observations or course changes. Survey time would be briefly suspended, and the boat's location determined through three compass readings. This permitted later determination of how much survey time was actually spent in each of the 6 sub-regions during the course of the study.

AERIAL SURVEYS

Aerial surveys were conducted bi-weekly from January through May, 1985 - 1991, using procedures from Forestell (1989). A single-engine, high-wing Cessna 172, outfitted with standard navigational equipment, flew along a pre-determined transect at constant air speed (90 knots) and altitude (300 m). The aircraft did not leave the transect during the survey period. The transect (Figure 4) was designed to provide complete coverage of the survey area, and maintain as much similarity as possible to transects used by Herman et al. (1980) and Baker and Herman (1981). Each survey required approximately two hours to complete, and included the near-shore and mid-channel areas between Maui, Molokai, Lana'i and Kahoolawe, (the Four-Island Area). Only whales observed in the boat survey study area (Sub-regions 1 through 6) are considered in the present report.

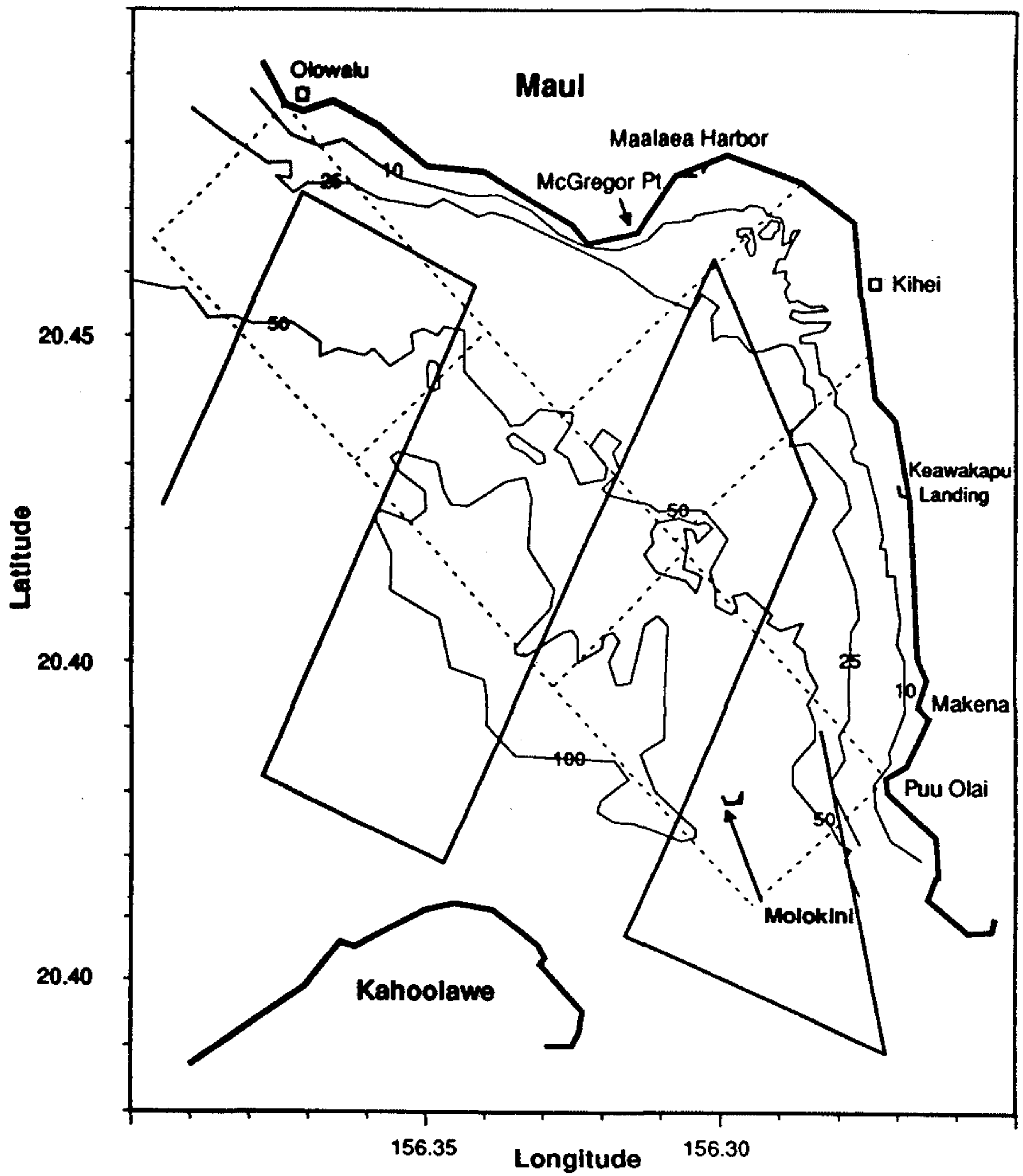

Figure 4: The aerial survey transect used during all surveys from 1985 - 1991 .

Two back-seat observers scanned their respective sides of the aircraft out to a distance of 2.4 km in a sweep 30^{o} - 90^{o} from dead ahead. The aircraft wing-struts were marked with black tape to provide a straight-line sighting aid, when lined up with a mark on the observer's window, in estimating distances of 2.4 km, 1.6 km, and .8 km (after Scott and Winn, 1980). Sighting cue and pod location relative to the aircraft were recorded on a standardized data form for each observation. Weather and sea state were also recorded. These aerial surveys have been ongoing since 1985, and provide data on changes in patterns during those years. The data also allow comparison with aerial surveys conducted by the University of Hawaii from 1977 - 1980 (Herman et al.,1980; Baker and Herman, 1981; and Forestell, Herman, and Kaufman, 1985).

ANALYSIS

Location data for the survey vessel and aircraft, and all whales and boats observed during survey time were entered into an Excel spreadsheet for the Macintosh. Survey time spent in each sub-region, and data on pod composition, boat type and activity, date, time of day, and weather conditions were also entered into the data base. Pod and boat locations were plotted using longitude and latitude, derived either from compass bearings or from data on time, location and direction and distance to the pod or boat from the survey vessel. The alogorithms used to generate the longitude and latitude readings for aerial surveys were developed by Michael Hoffhines of QED Software (Hoffhines, 1991).

Charts of the study area, including depth contours and landmarks, were constructed using Delta Graph. Statistical analyses were carried out on selected portions of the data using Fastat for the Macintosh.

RESULTS

GENERAL FINDINGS

Table 1 presents a summary of observations during small vessel surveys for each month of study in 1989 and 1991. In 1989, there were 309 adults, 25 sub-adults, and 65 calves observed (total = 399 whales) during 158.1 hours of vessel survey. In 1991 there were 714 adults, 49 sub-adults, and 186 calves observed (total = 949) during 190.3 hours of vessel survey. There was a substantial increase in the observation rate (number of whales per hour), from 2.52 whales observed for each hour of survey effort in 1989, to 4.99 in 1991. The proportion of calves (.163 in 1989 and .196 in 1991) also increased, although this may have been due to a greater relative survey effort in April of 1991, since April is typically a time when mother and calf pods predominate. It is not clear what factors were associated with the difference in abundance across the two years. Continuation of survey effort in future would help determine the natural fluctuation of such patterns.

Figure 5 shows locations of all pods of whales observed in 1989. Figure 6 shows locations of all pods of whales observed in 1991. Note that each plot in Figures 5 and 6 represent one pod of whales, which may have included from one to several animals. There appeared to be a tendency for whales to be distributed along the 25-fathom contour inside Maalaea Bay, and along the 50-fathom contour outside the Bay. Given the general preference of humpback whales for relatively shallow, near-shore areas, it should not be surprising to find their distribution influenced by bottom contour. This finding is consistent with earlier work by Forestell (1989), which showed a significantly larger number of whales over the northwesterly edge of Penguin Bank (cf. Figure 2) which averages 25 fathoms in depth, compared with the nearshore end of the Bank, which averages 40 fathoms.

The distribution data from Figures 5 and 6 suggest that humpback whales moved, both inside and outside the Bay, along the major contours in a general SSE to NNW direction (or vice versa), rather than in a distinct pattern across the contours, for example from north to south. On the other hand, when one looks at the distribution of boat locations in 1991 (Figure 7), it is clear that the boat distribution followed a distinct north to south pattern, from Maalaea Small Boat Harbor to Molokini and back, with considerable traffic along the Kihei coast from the boat ramp at Keawakapu to the boat ramp at Makena. One of the first things that becomes clear from the present data is that the general movement patterns of whales, and those of humans, are somewhat more perpendicular to each other, rather than parallel or random, within the study area.

CALF DISTRIBUTION

One of the primary goals of the study was to determine whether more calves were found inside Maalaea Bay than outside. Table 2 summarizes the number of observations of whales and boats and hours of survey effort in each of the six sub-regions during 1989 and 1991. It can be seen that the amount of time spent in each sub-region varied, ranging from 21.5 hours in sub-region 4 during 1989, to 33.6 hours in sub-region 2 during 1991. In order to remove any effect of differences in observations due to differences in amount of effort, the number of observations has been divided in each case by the amount of time spent surveying, in order to determine the observation rate, defined as the rate at which observations were made per hour of survey effort. Note that observation rate is determined on the basis of survey time, rather than amount of time on the water.

TABLE 1: TOTAL SURVEY TIME, NUMBERS OF WHALES AND BOATS OBSERVED, AND AVERAGE HOURLY RATE AT WHICH ADULTS, CALVES, AND BOATS WERE OBSERVED DURING EACH MONTH OF SURVEY IN 1989 AND 1991.

MONTH	YEAR	SURVEY HOURS	TOTAL PODS	TOTAL WHALES	TOTAL CALVES	ADULTS PER HR*	CALVES PER HR	TOTAL BOATS	BOATS PER HR
JAN	1989	43.0	39	70	7	1.21	.16		
	1991	37.8	43	90	20	2.06	.13	95	2.51
FEB	1989	31.1	62	137	20	2.47	.64		
	1991	41.0	119	303	44	4.39	1.07	212	5.17
MAR	1989	59.0	73	151	33	.93	.56		
	1991	45.4	132	310	73	2.03	1.61	170	3.75
APR	1989	25.0	17	41	5	.84	.20		
	1991	66.1	129	246	64	.98	.97	202	3.05
Sub-	1989	158.1	191	399	65	1.30	.41		
Total	1991	190.3	405	949	186	2.18	.98	679	3.57
TOTAL		348.4	596	1348	251	1.78	.72		

* INCLUDES ONLY WHALES OBSERVED IN PODS THAT DID NOT CONTAIN A CALF.

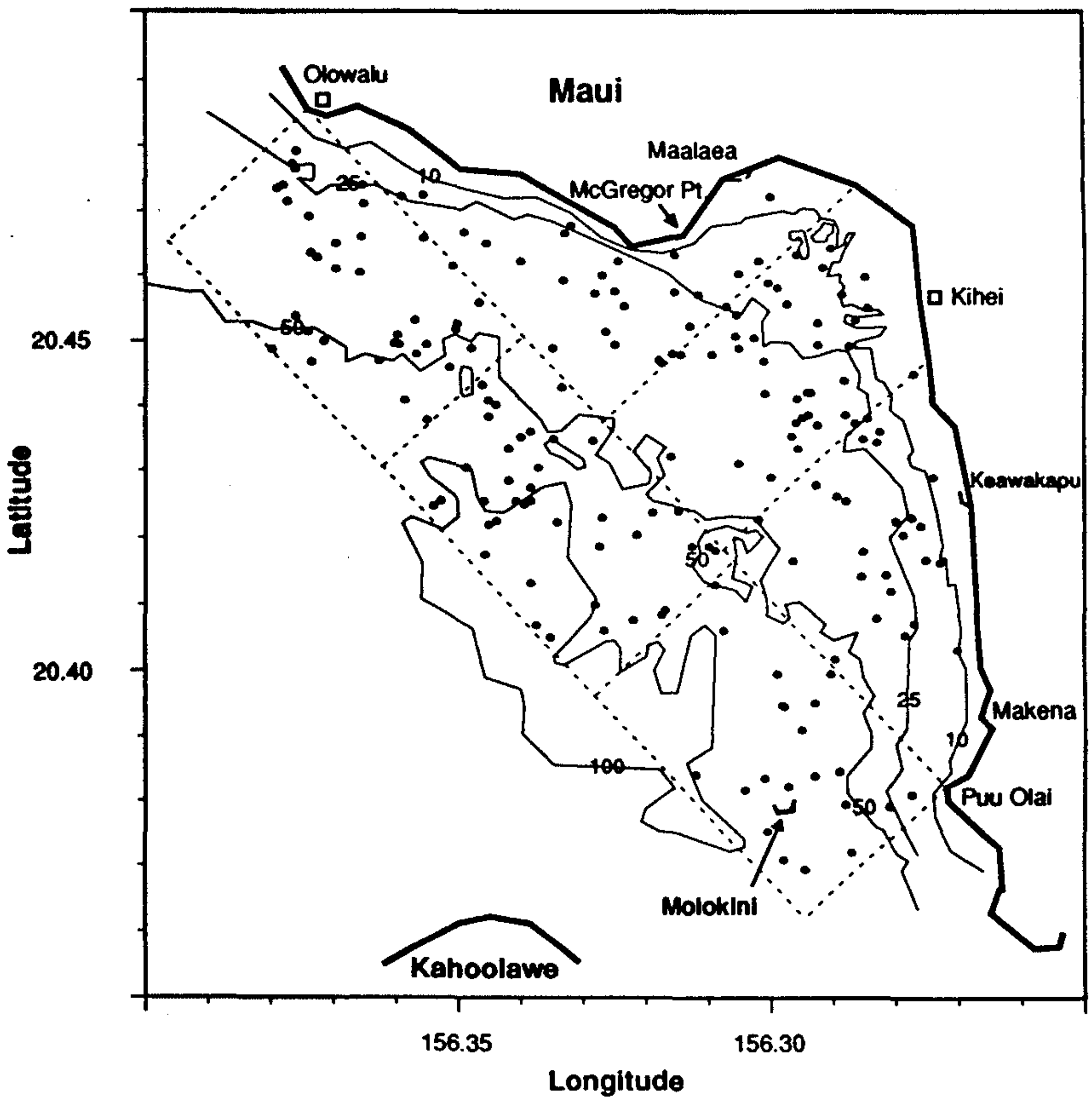

Figure 5: Location of all pods of whales observed during small boat surveys in 1989 (n=191).

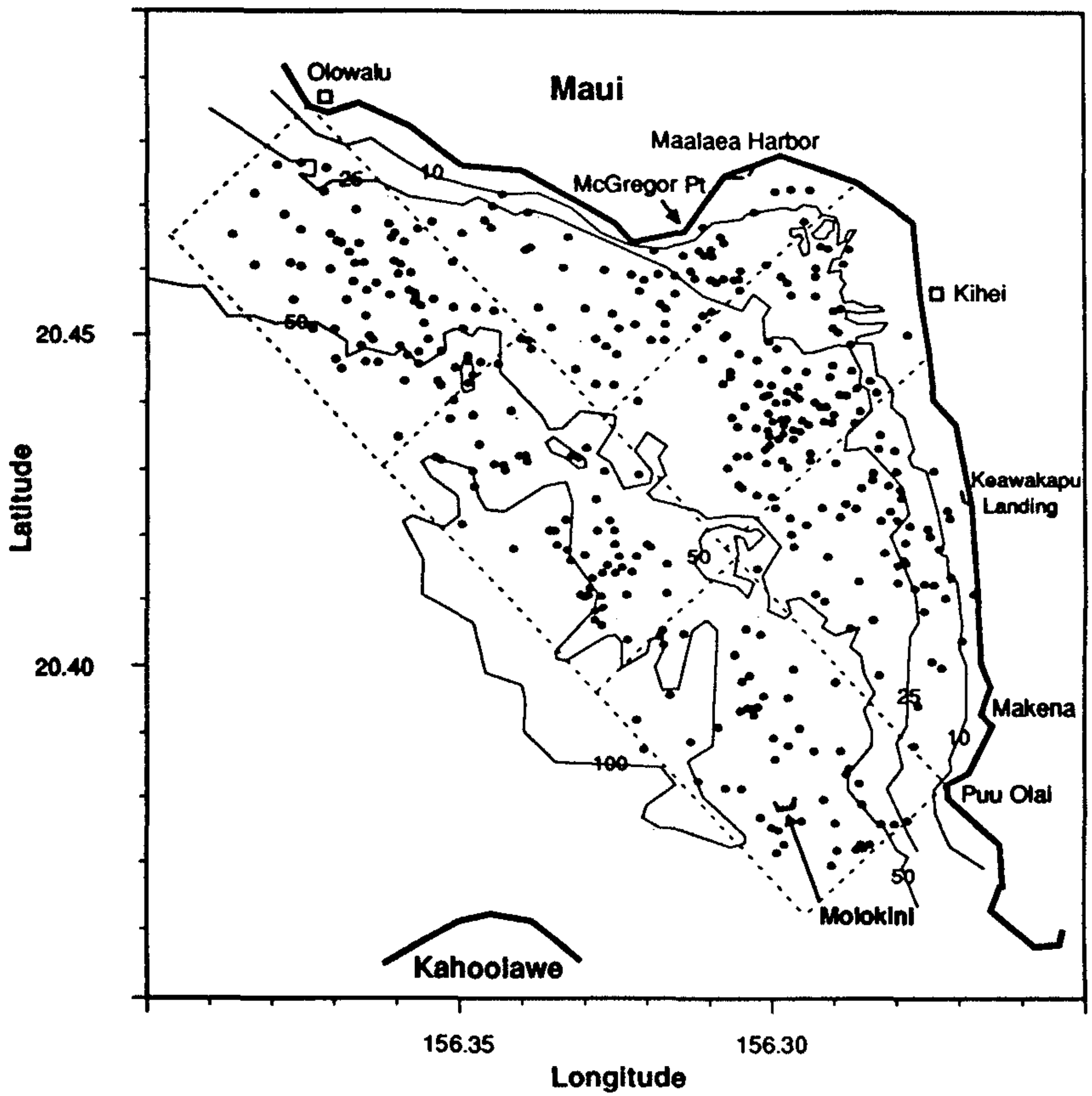

Figure 6: Location of all pods of whales observed during small boat surveys in 1991 (n=405).

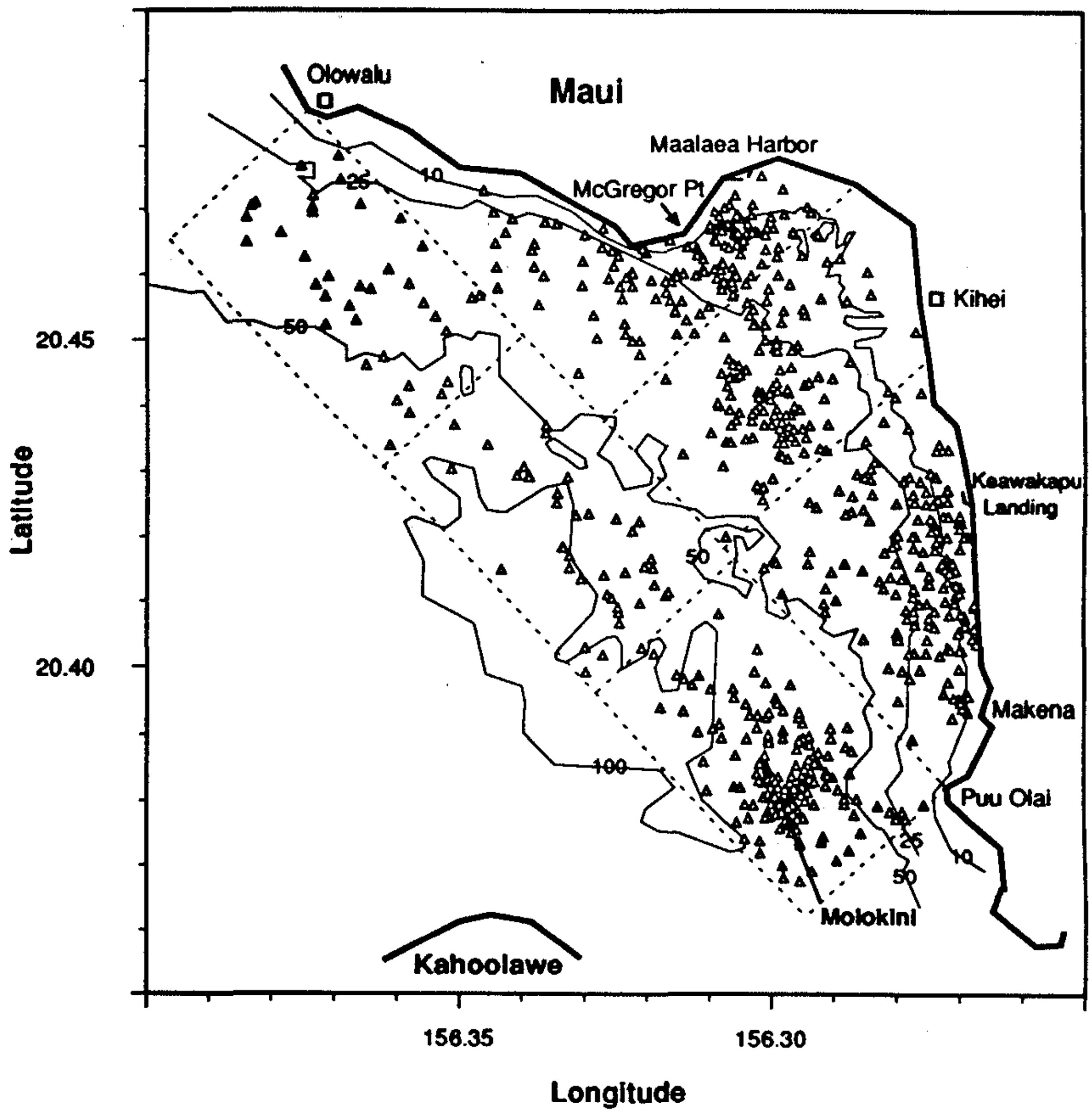

Figure 7: Location of all boats observed during small boat surveys in 1991 (n=679).

TABLE 2: TOTAL SURVEY TIME, NUMBERS OF WHALES AND BOATS OBSERVED, AND AVERAGE HOURLY RATE AT WHICH ADULTS, CALVES, AND BOATS WERE OBSERVED IN EACH SUB-REGION DURING 1989 AND 1991.

YEAR	SUB-REGION	SURVEY HOURS	TOTAL PODS	TOTAL WHALES	TOTAL CALVES	ADULTS PER HR*	CALVES PER HR	TOTAL BOATS	BOATS PER HR
1989	1	22.0	25	45	6	1.27	.27		
	2	30.4	37	75	18	.92	.59		
	3	26.8	27	50	11	.75	.41		
	4	21.5	40	94	14	2.05	.65		
	5	31.2	39	76	5	2.05	.16		
	6	26.2	23	59	11	.80	.42		
SUB-TOTAL		158.1	191	399	65	1.30	.41		
1991	1	31.2	64	142	32	1.70	1.02	134	4.29
	2	33.6	95	244	54	2.85	1.61	125	3.72
	3	32.0	56	130	26	1.60	.81	166	5.20
	4	29.0	76	175	32	2.62	1.10	38	1.31
	5	31.5	59	142	25	2.32	.79	43	1.37
	6	33.0	55	116	17	2.00	.52	173	5.24
SUB-TOTAL		190.3	405	949	186	2.10	.98	679	3.57
TOTAL		348.4	596	1348	251	1.78	.72		

* INCLUDES ONLY WHALES OBSERVED IN PODS THAT DID NOT CONTAIN A CALF.

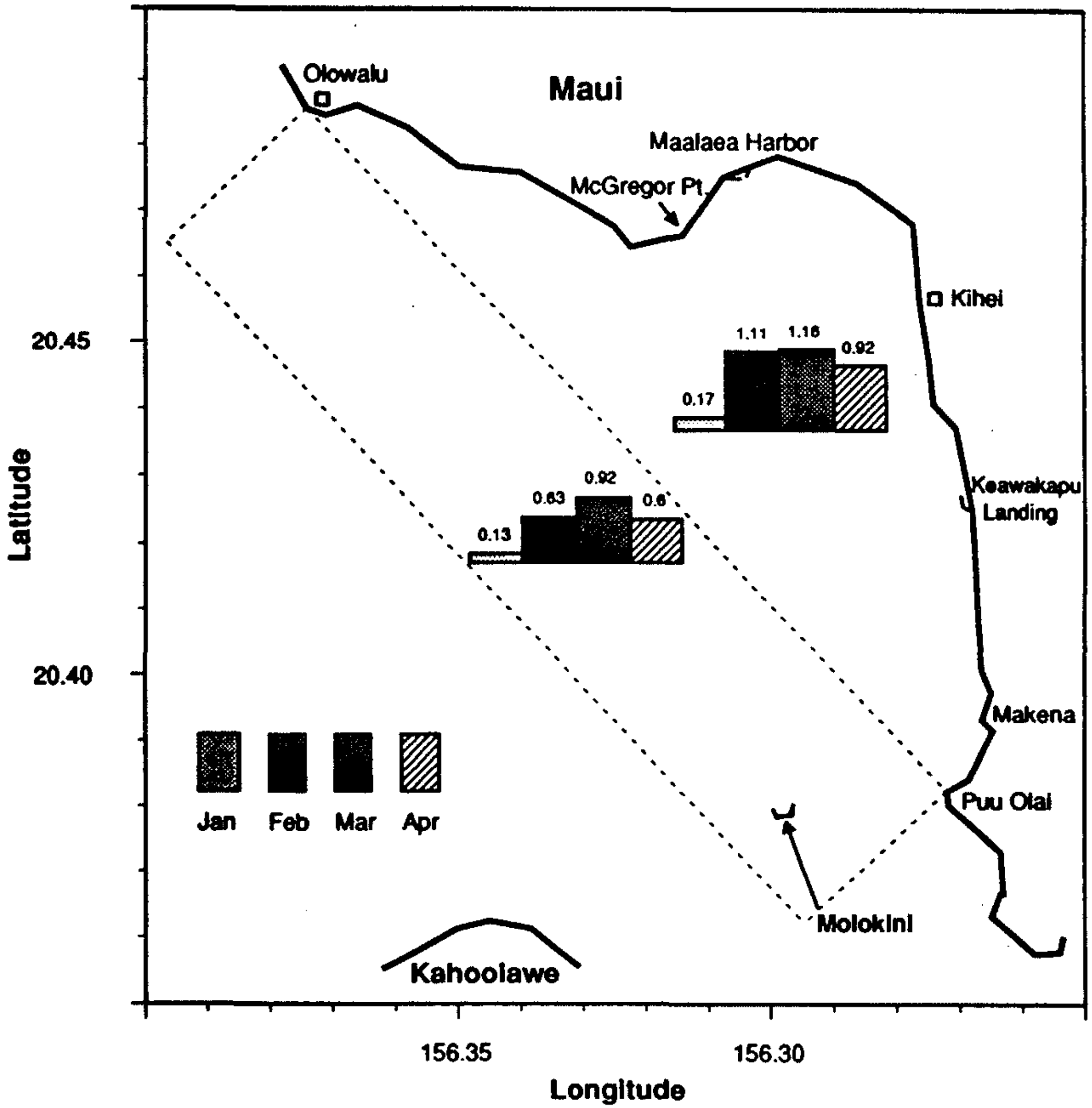

Figure 8: Rate (Whales/Hr.) at which calves were observed both inside and outside of Maalaea Bay in each month during small boat surveys in 1989 and 1991.

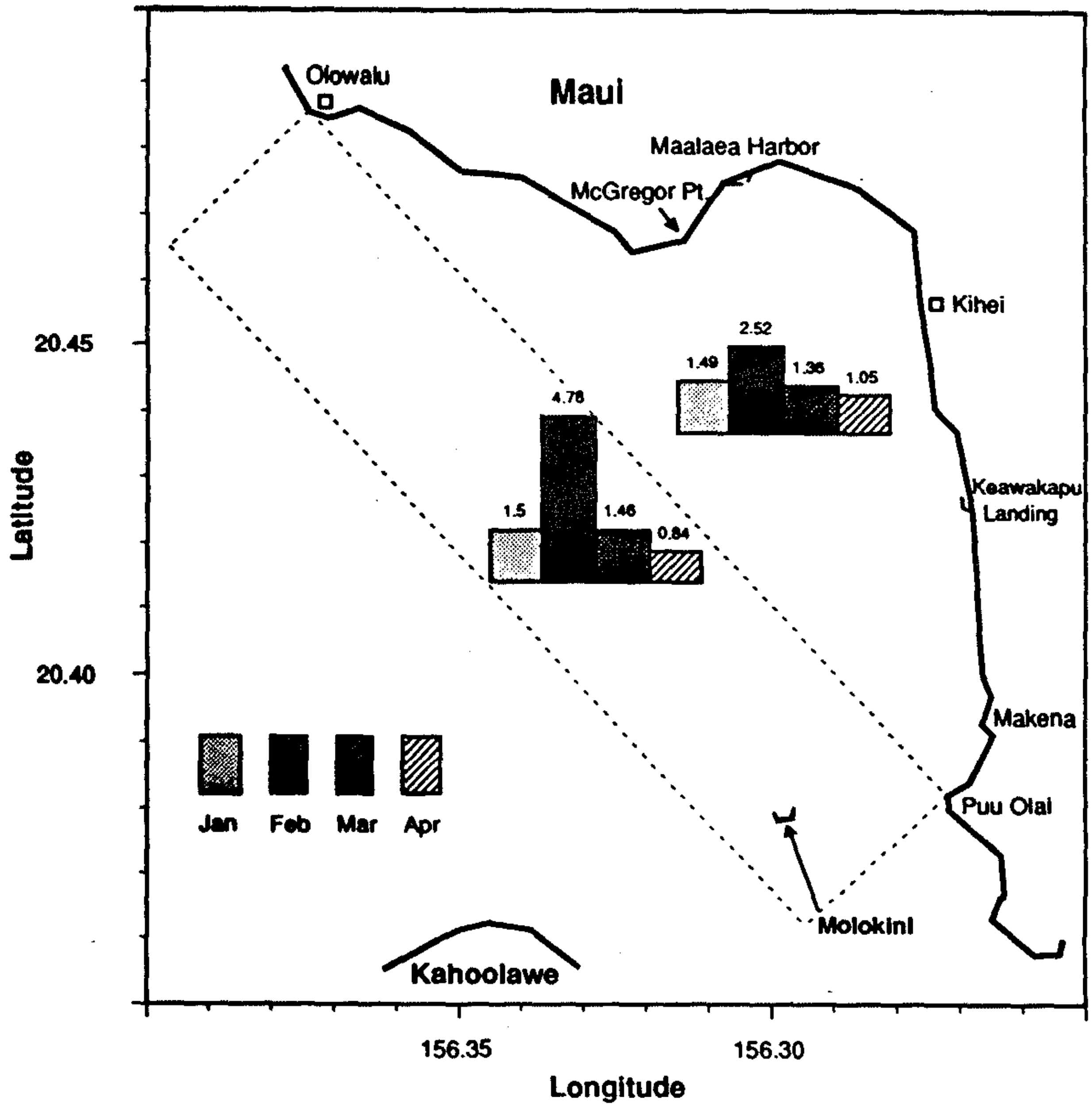

Figure 9: Rate (Whales/Hr.) at which adults not accompanying a calf were observed both inside and outside of Maalaea Bay in each month during small boat surveys in 1989 and 1991.

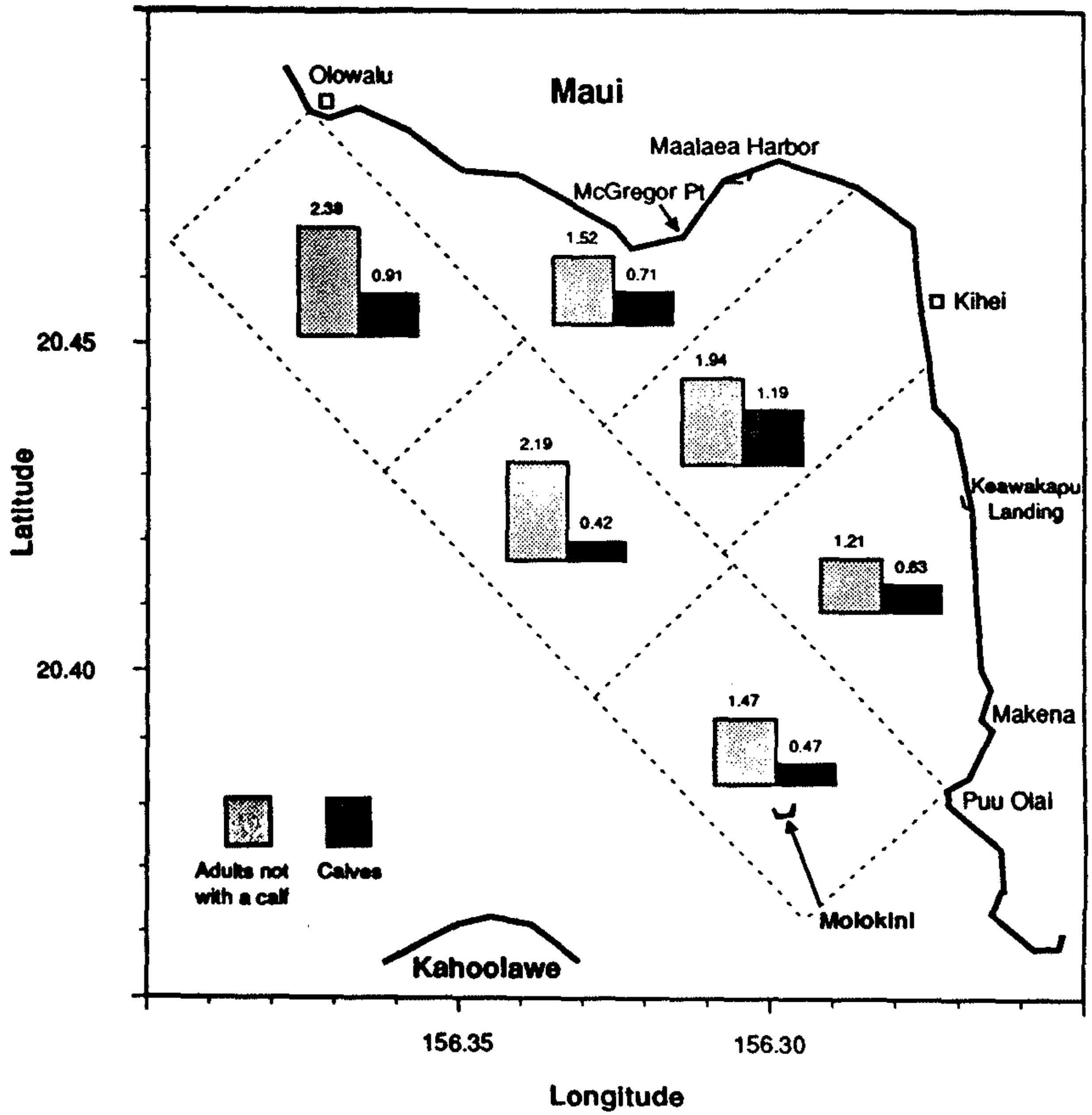

Figure 10: Rate (Whales/Hr.) at which calves and adults not accompanying a calf were observed in the six sub-regions of the study area during small boat surveys in 1989 and 1991.

IMPACT OF VESSEL TRAFFIC

An additional factor of importance in considering humpback whale activity in the study area is the boat traffic that was observed (Figure 7). We looked at two aspects of boat impacts: the relationship between boat density and whale density in each sub-region, and the frequency and location of boat - whale interactions.

Temporal Distribution of Whales and Boats: To determine the nature of the relationship between whale and boat density, we looked at the changes in distribution of each across three two-hour time periods of the day: from 0900 - 1100 hrs., from 1100 - 1300 hrs., and from 1300 - 1500 hrs. The amount of survey effort conducted between 0700 hrs. and 0900 hrs., and after 1500 hrs. was insufficient to justify inclusion of those time periods in our analysis.

Figures 11 through 19 show the locations of boats, pods without a calf, and pods with a calf observed in each two-hour block of time between 0900 and 1300 hrs. during the 1991 survey effort. It should be noted that the amount of total survey effort tended to decrease across the two-hour blocks, since weather conditions were more likely to deteriorate later in the day than earlier. Therefore, the differences in numbers of plots in Figures 11 through 19 reflect differences in survey time as well as any other effects.

In general, it can be seen that early in the day, boats were concentrated primarily in sub-regions 3 and 6. This was associated with the popularity of Molokini Crater as a snorkel destination for tourists. Between 0900 and 1000 hrs., boats that had left Maalaea Small Boat Harbor between 0700 and 0800 had arrived at Molokini, and smaller boats from Keawakapu Boat Ramp and Makena Landing were on their way out for diving and snorkeling trips.

Between 1100 and 1300 hrs., boats were returning to Maalaea and Keawakapu, and sub-regions 1, 2 and 3 showed the largest relative use by boats. Finally, between 1300 and 1500, smaller boats from Keawakapu and Makena were off the water, while larger boats (particularly those engaged in whalewatching) out of Maalaea Bay were still out, particularly in sub-regions 1 and 2.

The distribution of boats, calves, and whales not accompanying calves can be better understood by adjusting for survey effort. The rate at which boats, calves, and whales not accompanying calves were observed during each time block in each sub-region are presented in Table 3. The two sub-regions with the highest rates for boats and whales in each time block are as follows:

From 0900 - 1100: boats were highest in sub-regions 3 and 6;
calves were highest in sub-regions 1 and 2;
whales not with calves were highest in sub-regions 4 and 5.

From 1100 - 1300: boats were highest in sub-regions 1 and 3;
calves were highest in sub-regions 2 and 4;
whales not with calves were highest in sub-regions 2 and 5.

From 1300 - 1500: boats were highest in sub-regions 1 and 2;
calves were highest in sub-regions 2 and 4;
whales not with calves were highest in sub-regions 3 and 4.

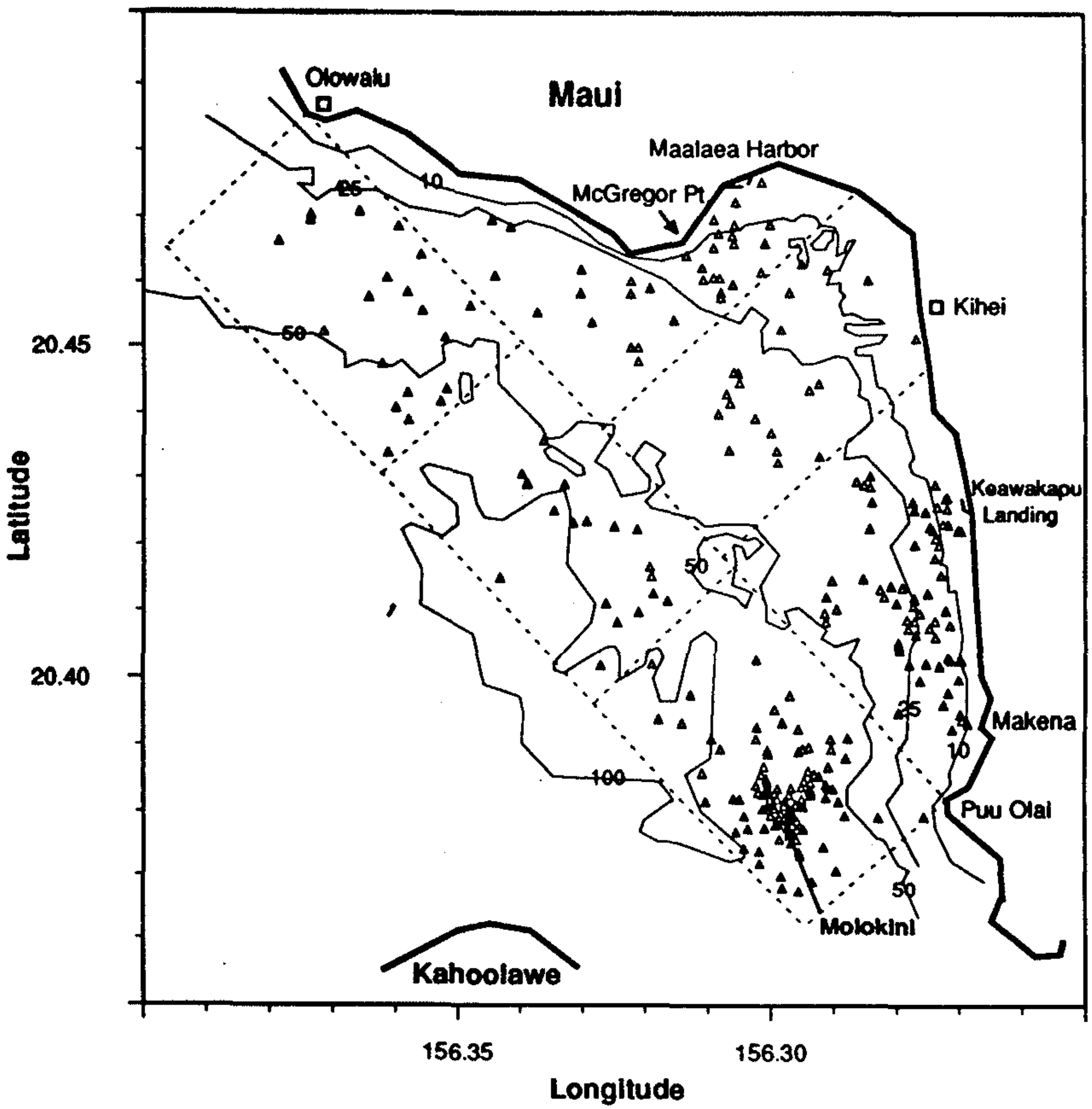

Figure 11: Location of boats observed during small boat surveys in 1991 from 9:00-11:00 (n=272).

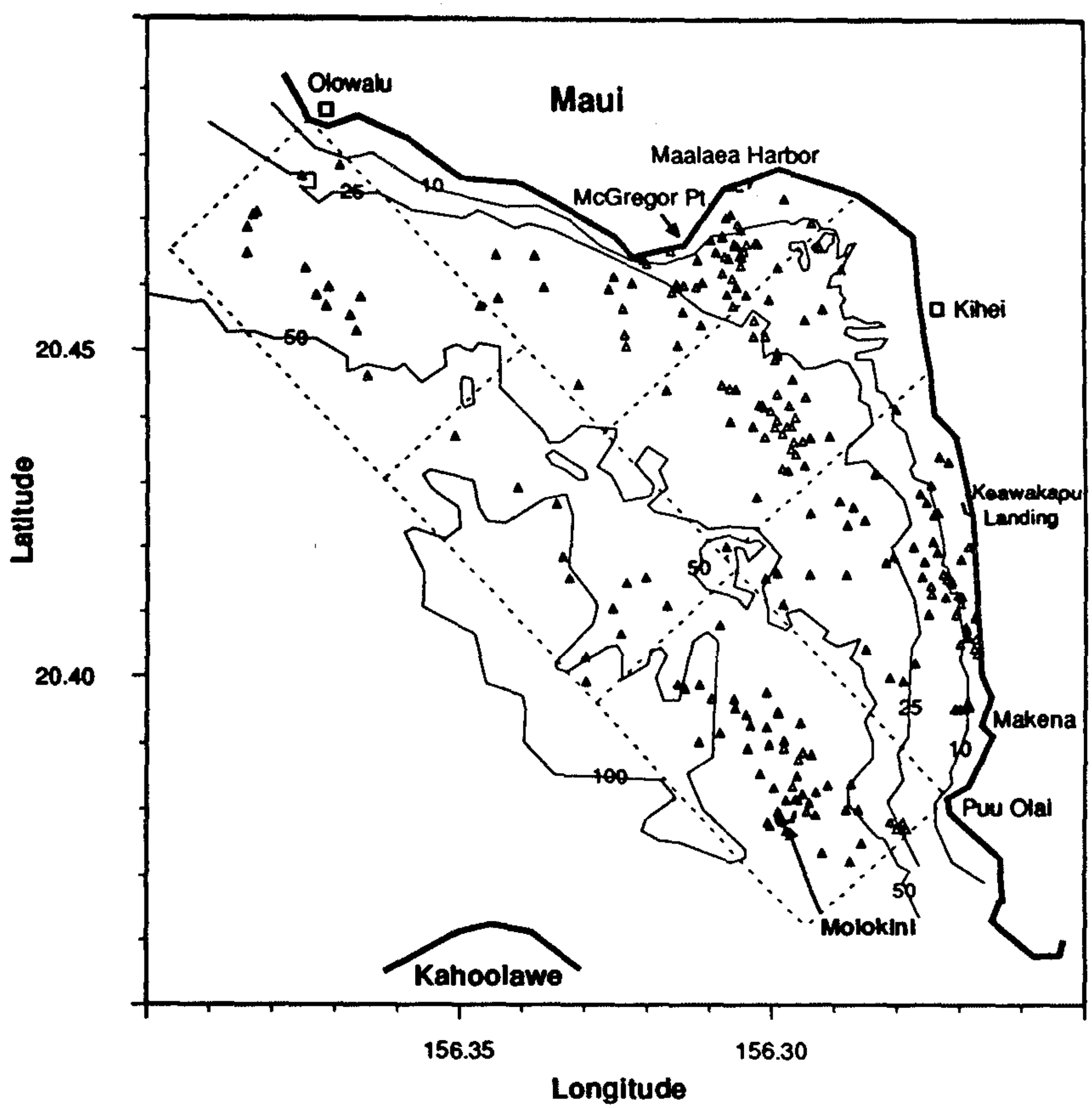

Figure 12: Location of boats observed during small boat surveys in 1991 from 11:00-13:00 (n=240).

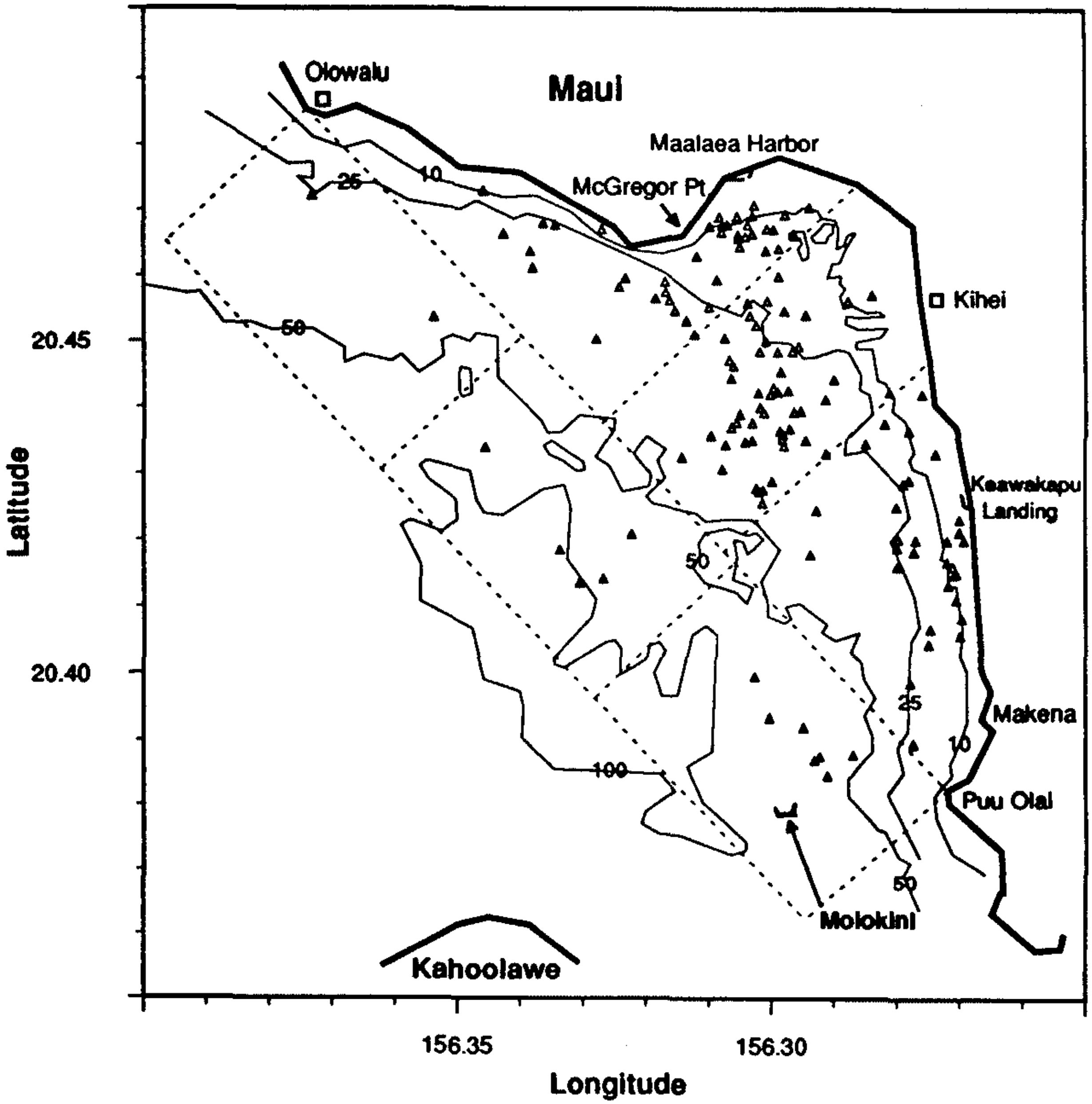

Figure 13: Location of boats observed during small boat surveys in 1991 from 13:00-15:00 (n=140).

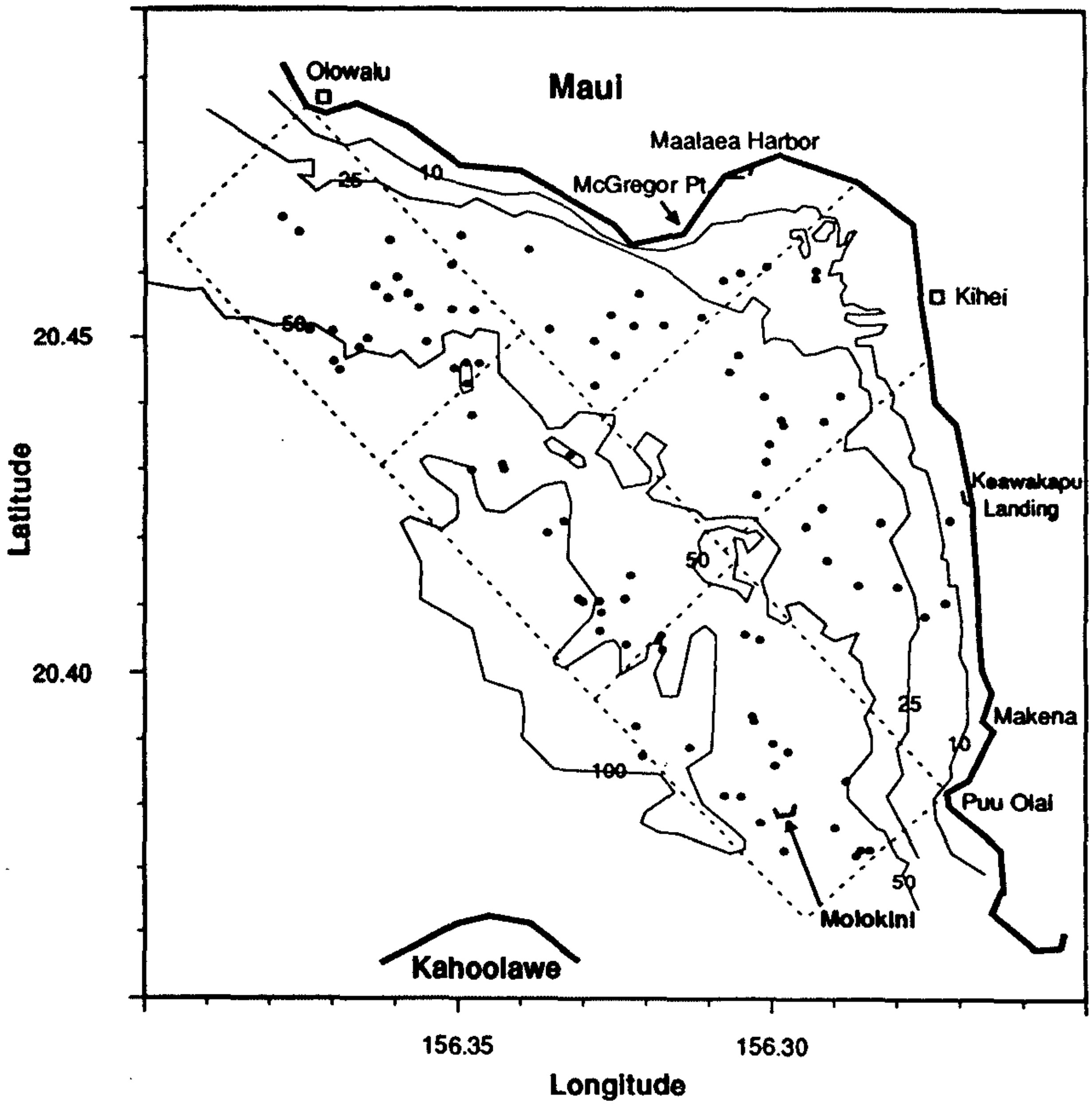

Figure 14: Location of adults not accompanying a calf observed during small boat surveys in 1991 from 9:00-11:00 (n=101).

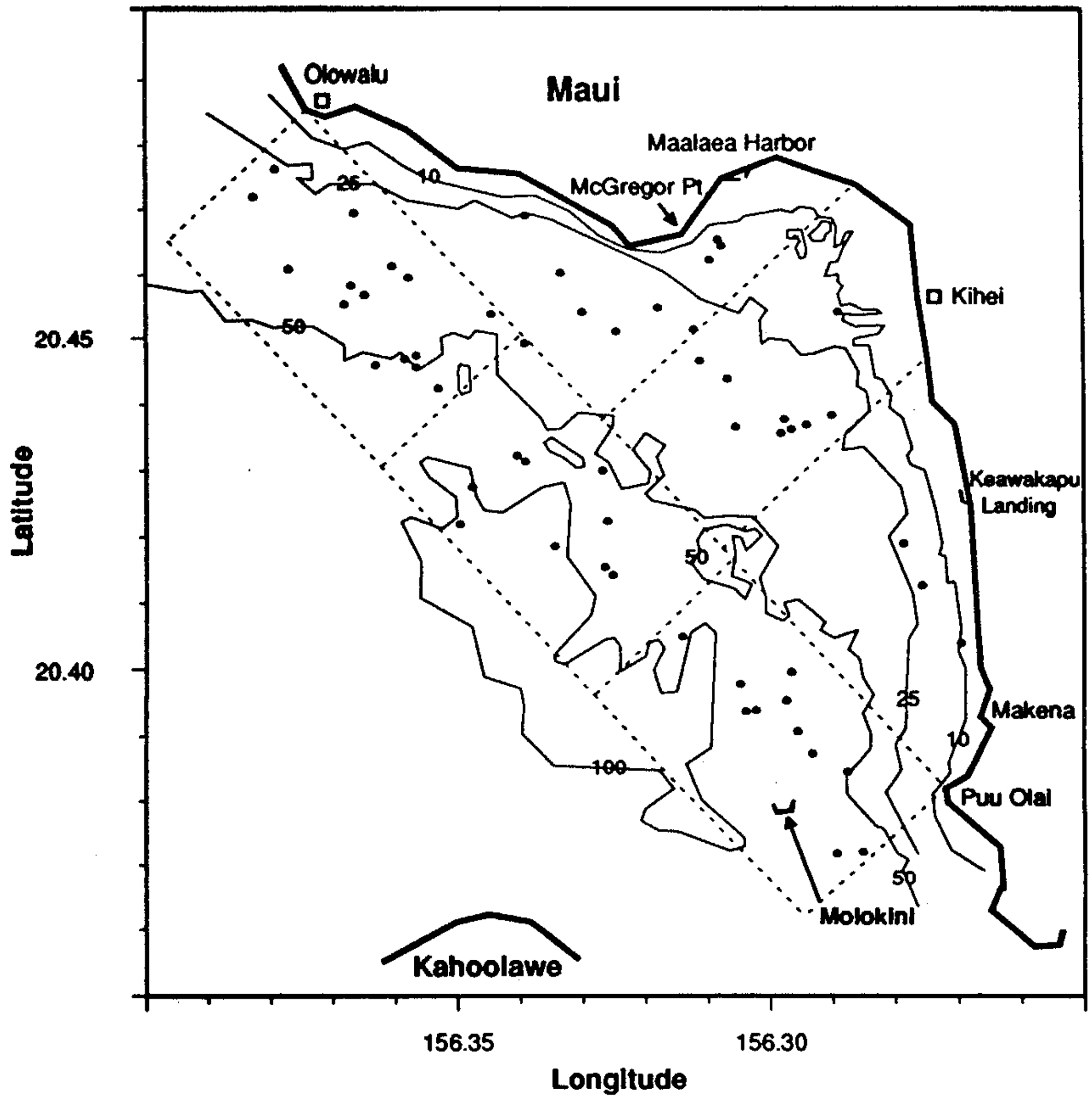

Figure 15: Location of adults not accompanying a calf observed during small boat surveys in 1991 from 11:00-13:00 (n=59).

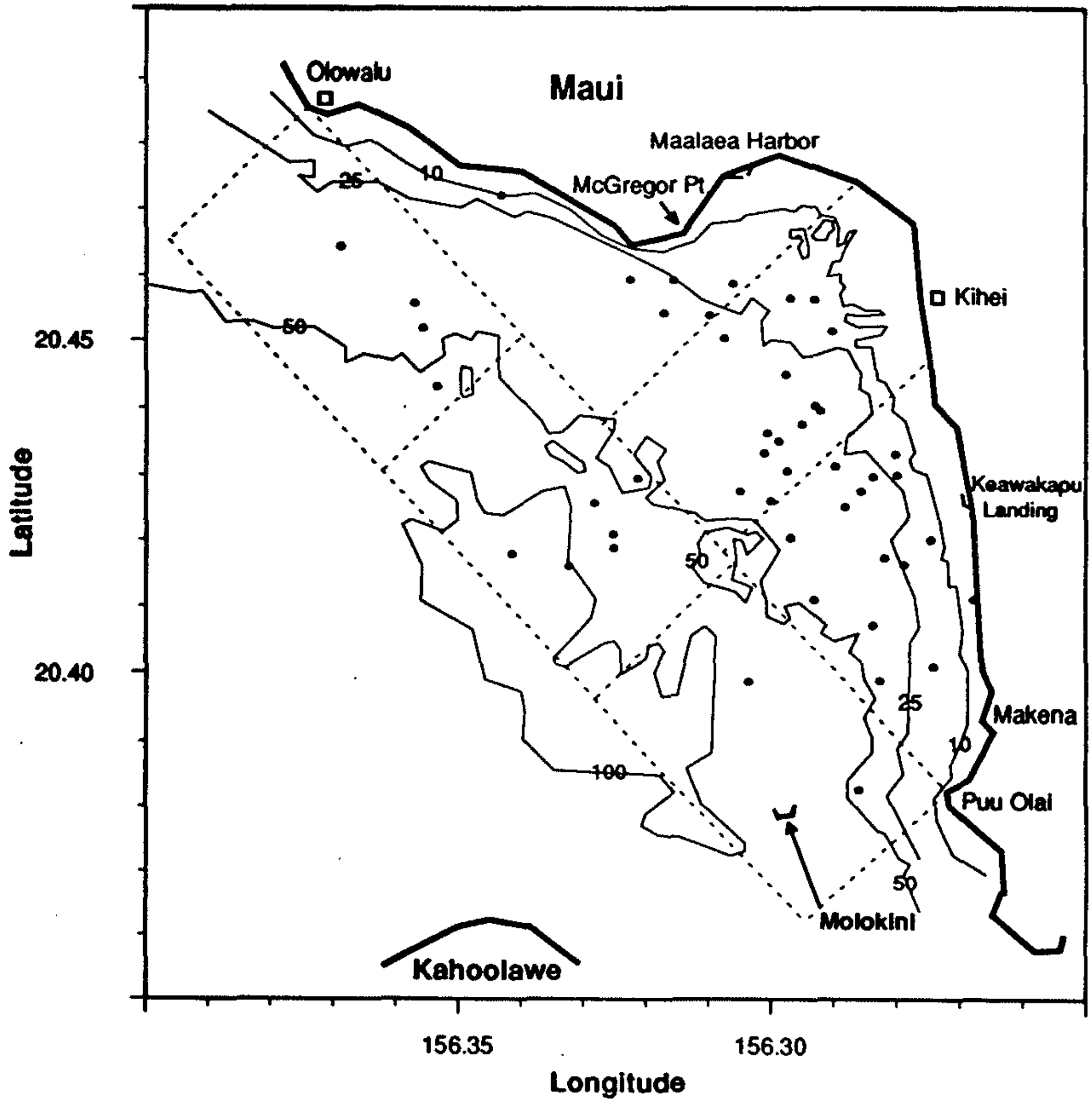

Figure 16: Location of adults not accompanying a calf observed during small boat surveys in 1991 from 13:00-15:00 (n=47).

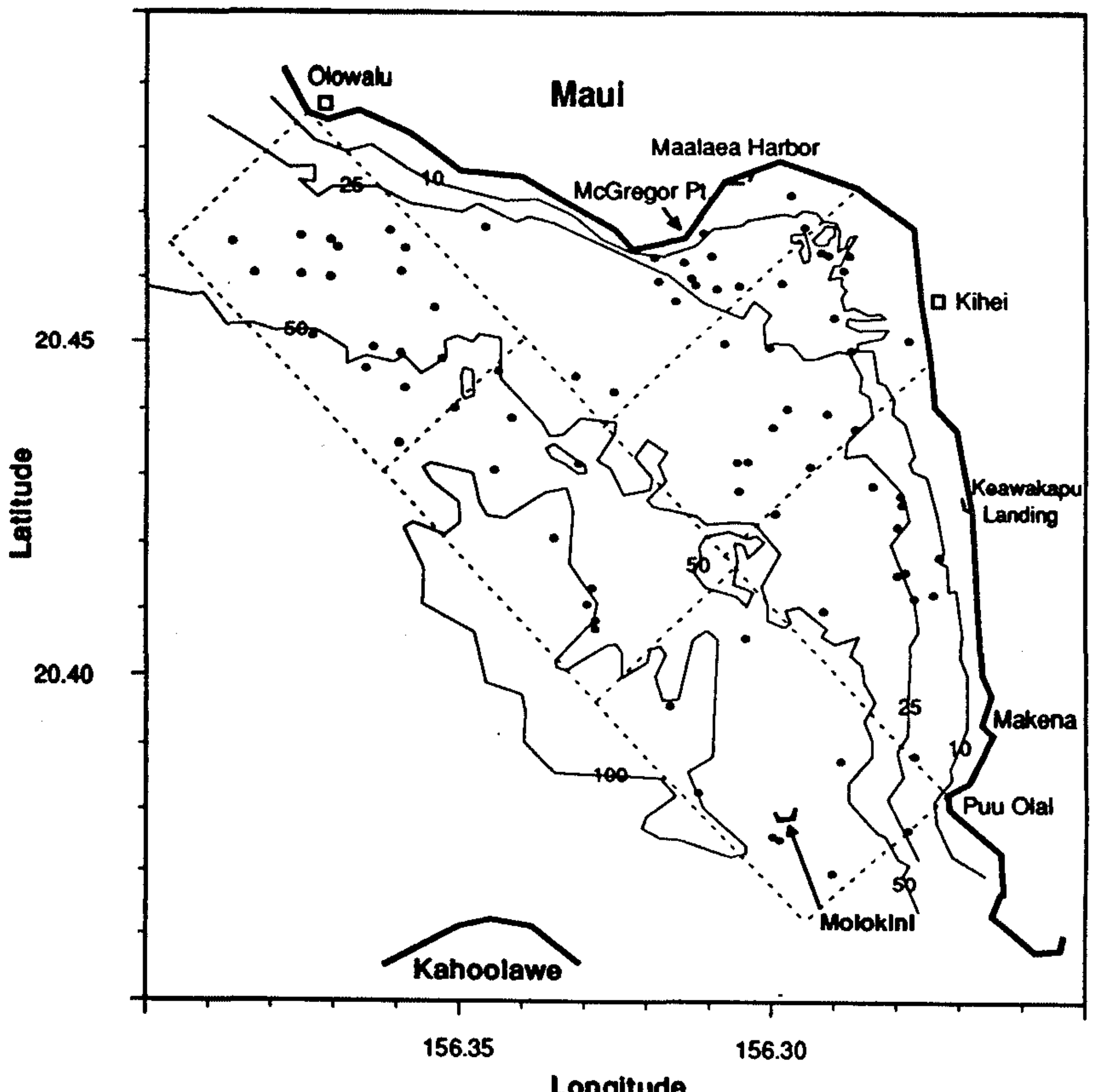

Figure 17: Location of calves observed during small boat surveys in 1991 from 9:00-11:00 (n=82).

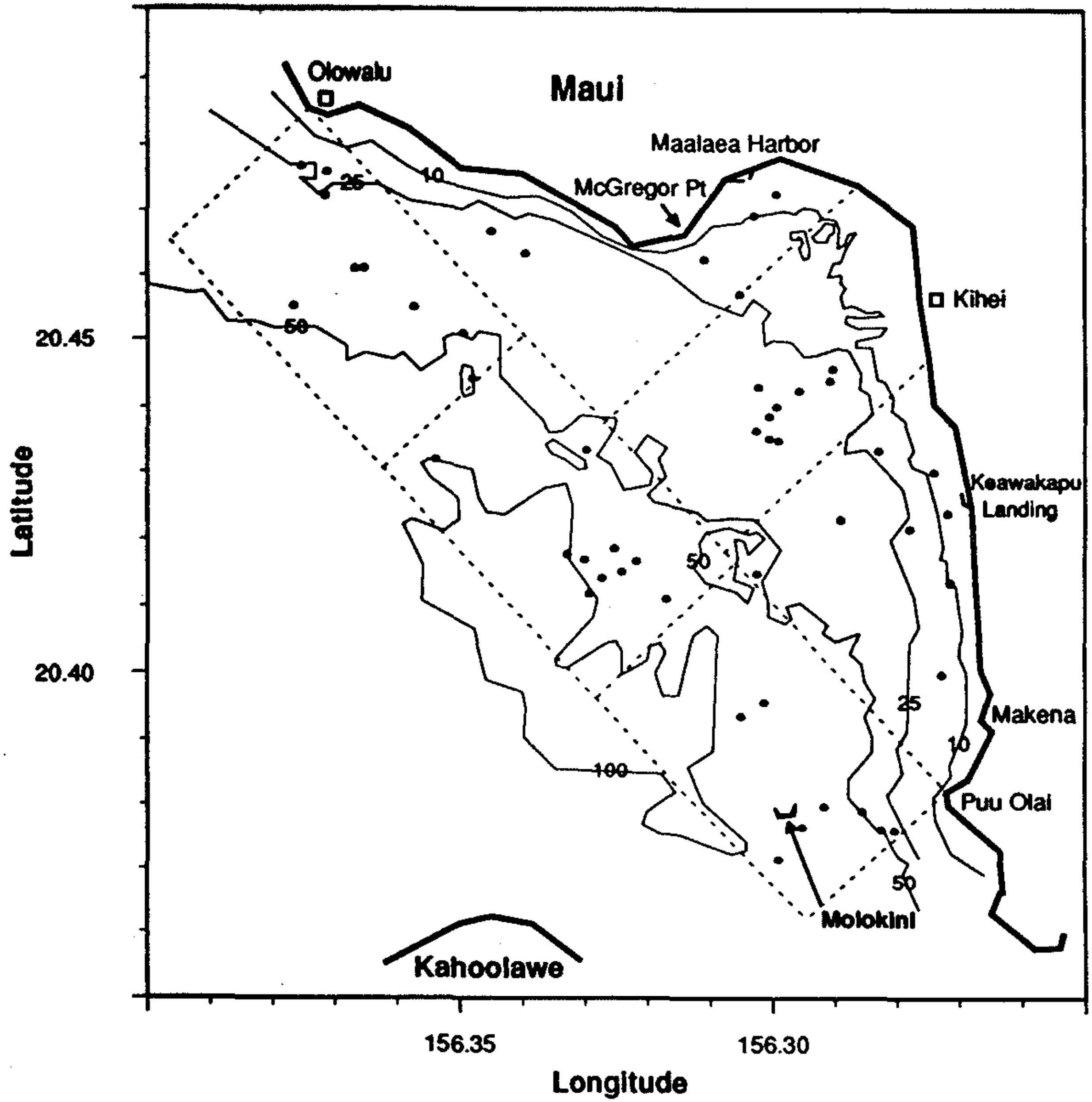

Figure 18: Location of calves observed during small boat surveys in 1991 from 11:00-13:00 (n=50).

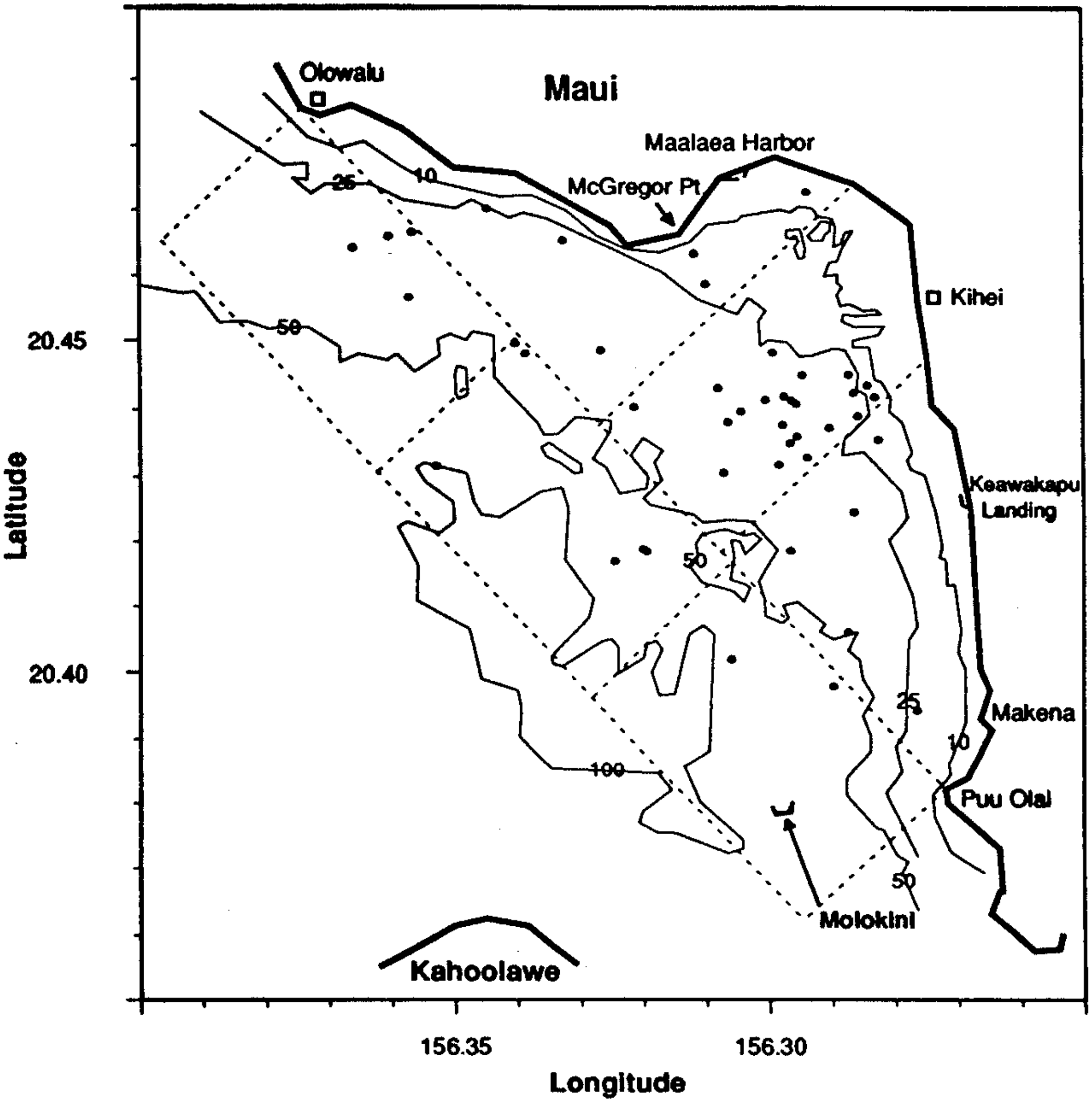

Figure 19: Location of calves observed during small boat surveys in 1991 from 13:00-15:00 (n=46).

TABLE 3: AVERAGE HOURLY RATE AT WHICH ADULTS NOT ACCOMPANYING CALVES, CALVES, AND BOATS WERE OBSERVED IN EACH SUB-REGION DURING EACH TWO-HOUR INTERVAL BETWEEN 0900 AND 1500 HRS IN 1989 AND 1991.

TIME START	SUB-REGION	SURVEY HOURS	ADULTS PER HR*	CALVES PER HR	BOATS PER HR
0900	1	26.1	2.18	1.05	2.11
	2	32.8	1.98	1.47	1.61
	3	26.8	1.00	1.00	5.92
	4	27.0	2.74	1.00	1.05
	5	30.0	2.73	.53	1.40
	6	27.0	2.41	.47	6.41
1100	1	12.2	2.00	1.00	7.57
	2	15.3	3.57	1.29	6.43
	3	13.0	.44	.89	6.89
	4	16.5	3.00	1.29	2.29
	5	14.2	3.13	1.25	1.50
	6	22.2	2.27	.64	4.73
1300	1	11.0	.67	1.33	6.67
	2	13.0	3.42	1.92	4.50
	3	16.0	3.46	.56	3.46
	4	6.0	3.50	2.00	1.00
	5	12.5	1.45	.73	.91
	6	6.0	.50	.50	2.00

* INCLUDES ONLY WHALES OBSERVED IN PODS THAT DID NOT CONTAIN A CALF.

These patterns show evidence that as the focal areas of boat traffic changes through the day, the distribution of whales also changes. This can be better assessed by looking at a Pearson Correlation Matrix of observation rates. The correlation between boats and calves, based on 18 paired observations (6 sub-regions during 3 time blocks) is a negative .08, suggesting that calf distribution is quite independent of boat distribution. However, the correlation between boats and whales not with calves is a negative .28, a moderate but important indication that movement of whales not in calf pods is influenced by boats.

Boat-Whale Interactions: The locations of all observations of whales with boats within .4 km are shown in Figure 20. of the 73 pods observed with boats nearby, 33 (45.2%) were calf pods. Of the 405 pods observed during 1991, 186 (45.9%) were calf pods, therefore it appears that calf pods are no more likely to be approached by boats than non-calf pods. The present data do not allow a determination of whether boats may behave differently around calf pods, or stay longer, or get closer.

The rate of boat-whale encounters is at least 50% greater inside the Bay (.46 encounters per hour of survey) than outside (.30 encounters per hour). The highest encounter rates overall were found in sub-regions 4 (.24/hr), 1 (.22/hr), and 2 (.21/hr). The observations rates in sub-regions 5 (.10/hr), 3 (.13/hr), and 6(.15/hr) were considerably lower.

AERIAL SURVEY DATA

Changes in Frequency of Observations: Figure 21 shows the location of all pods of whales observed during flights conducted in 1978, 1979, 1985, 1986, 1989, 1990, and 1991. The data from 1978 and 1979 are from Forestell et al. (1985), using procedures described in Herman et al., 1980. The remaining data are from Forestell (1989, 1991) using procedures described in Forestell (1989). Survey effort across all years is essentially equivalent, providing a reasonable index of abundance changes during the period 1978 - 1991. The data were grouped in blocks of two years each, from 1978 - 1990. The locations of whales observed in each two-year interval is shown in Figures 22 - 24. Figure 25 shows the results for 1991 alone.

A Chi-square test was conducted on the frequency of sightings for the three two-year periods: 1978-1979, 1985-1986, and 1989-1990. There was a significantly greater than chance increase in frequency of sightings ($X^2 = 14.03$, $df = 2$, $p<.001$) indicating that the use of Maalaea Bay and the adjoining waters by whales has increased during that period. The observation of 71 pods in 1991 indicates the trend continues. The number of calves observed in each two-year period, however, has not shown a significant change, either up or down. There were 10 calf pods observed in 1978-1979; 9 in 1985-1986; 19 in 1989 - 1990; and 11 in 1991 alone. Although the numbers do show an upward trend, the increase is not yet statistically significant. Continuation of surveys should help establish whether calf observations are increasing.

Comparison of Boat and Aerial Observations: A comparison of the boat survey data and the aerial survey data provides an opportunity to look at the correspondence between patterns observed from the water with patterns observed from the air.

The degree of correspondence can be seen by comparing Figure 6, showing the locations of all pods of whales observed during boat surveys in 1989 and 1991, with Figure 21, showing the locations of all pods of whales observed during aerial surveys

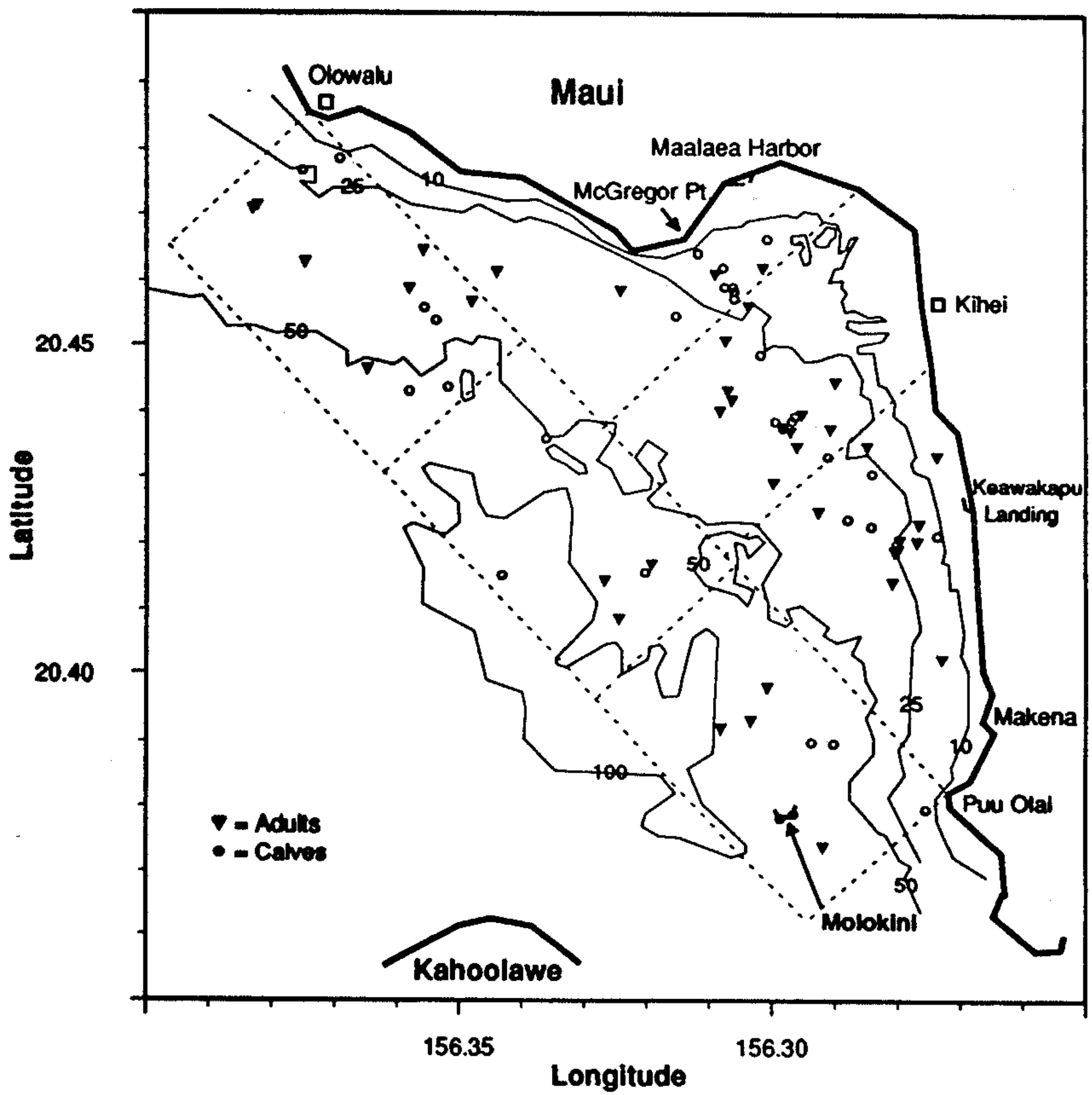

Figure 20: Location at which boats were observed within .25 miles of adult and calf pods during small boat surveys in 1991 (n=73).

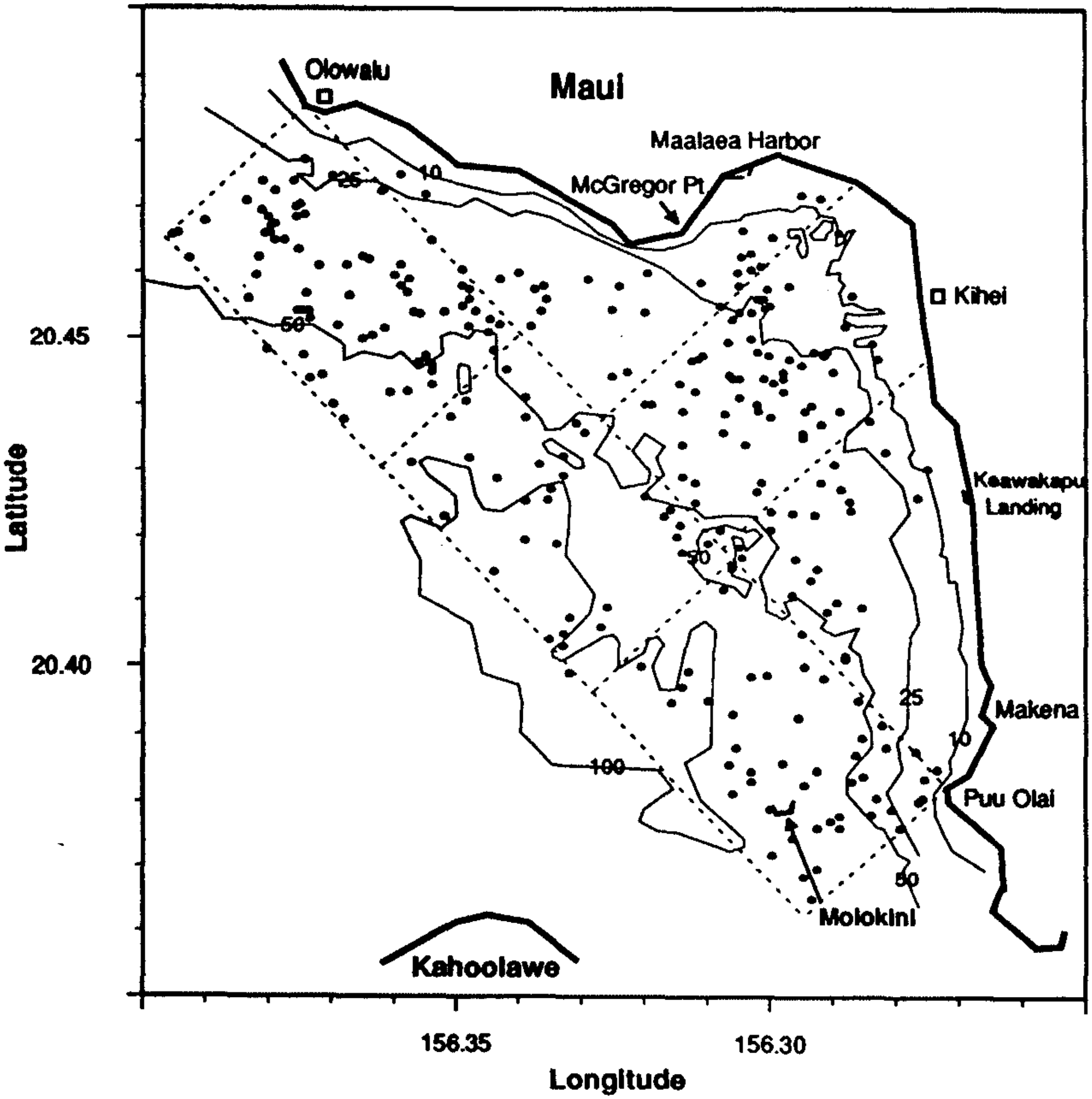

Figure 21: Location of all pods observed during aerial surveys from 1978 to 1991 (n=272).

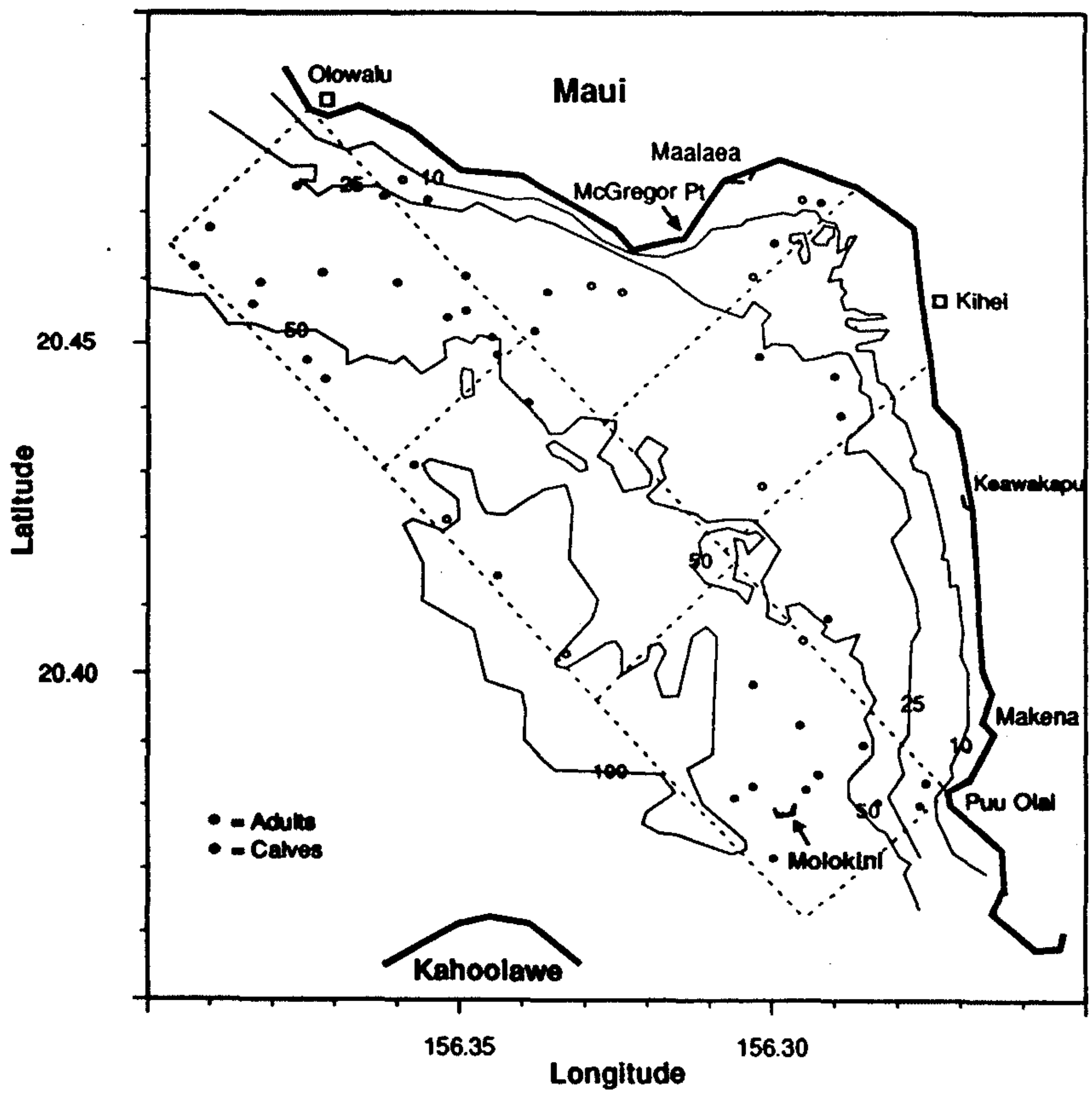

Figure 22: Location of adult and calf pods observed during aerial surveys in 1978 and 1979 (n=47).

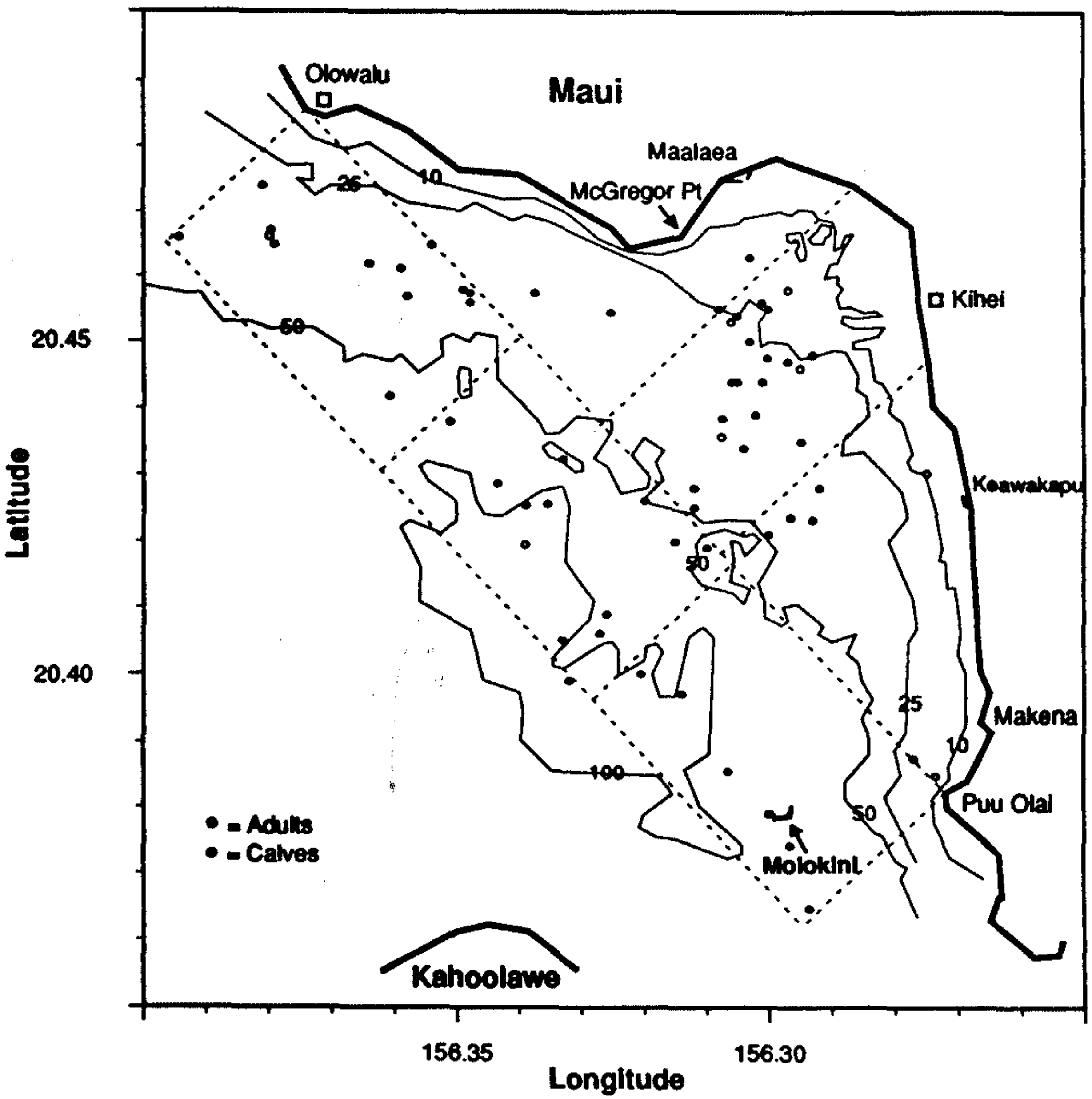

Figure 23: Location of adult and calf pods observed during aerial surveys in 1985 and 1986 (n=64).

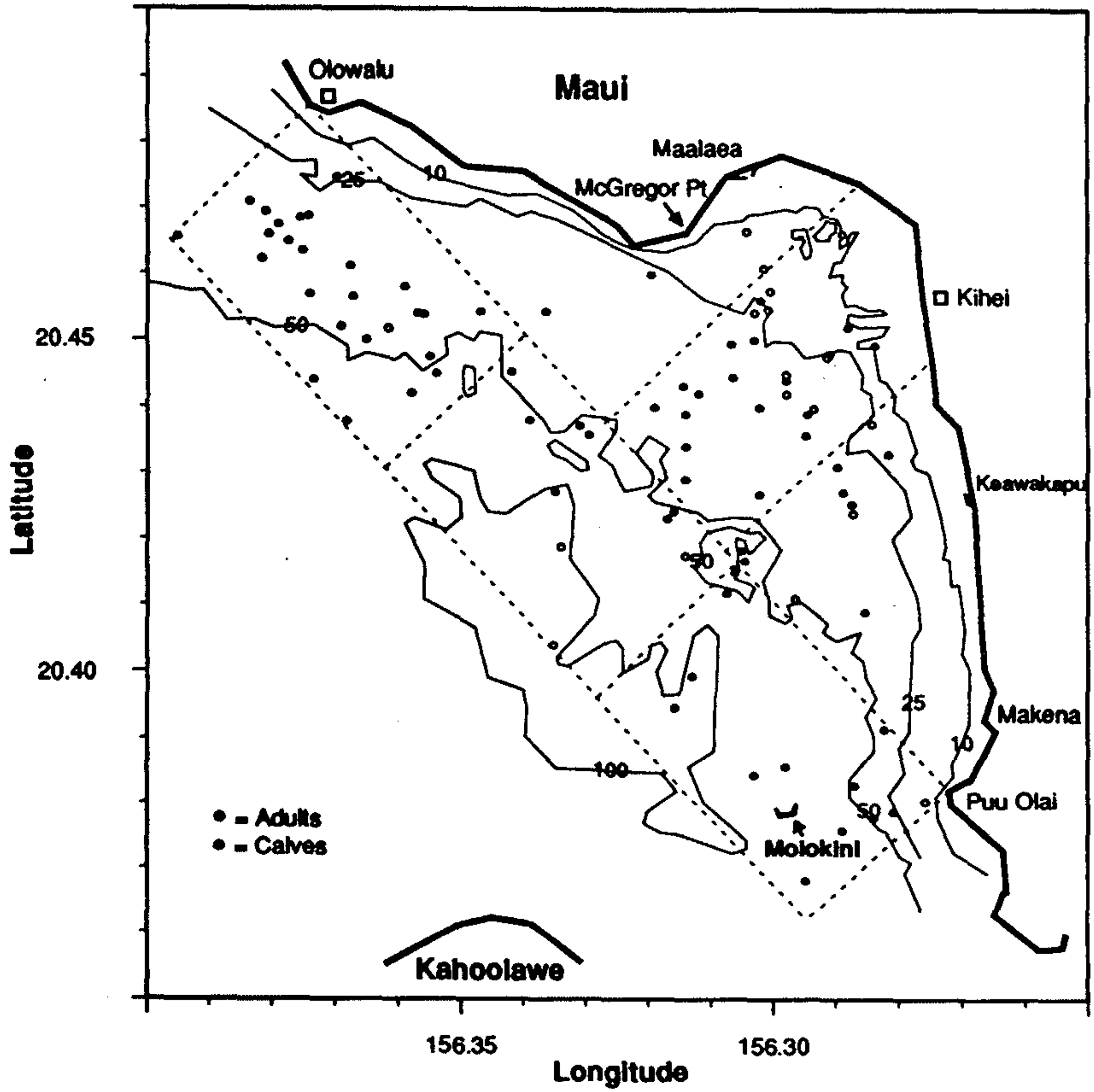

Figure 24: Location of adult and calf pods observed during aerial surveys in 1989 and 1990 (n=90).

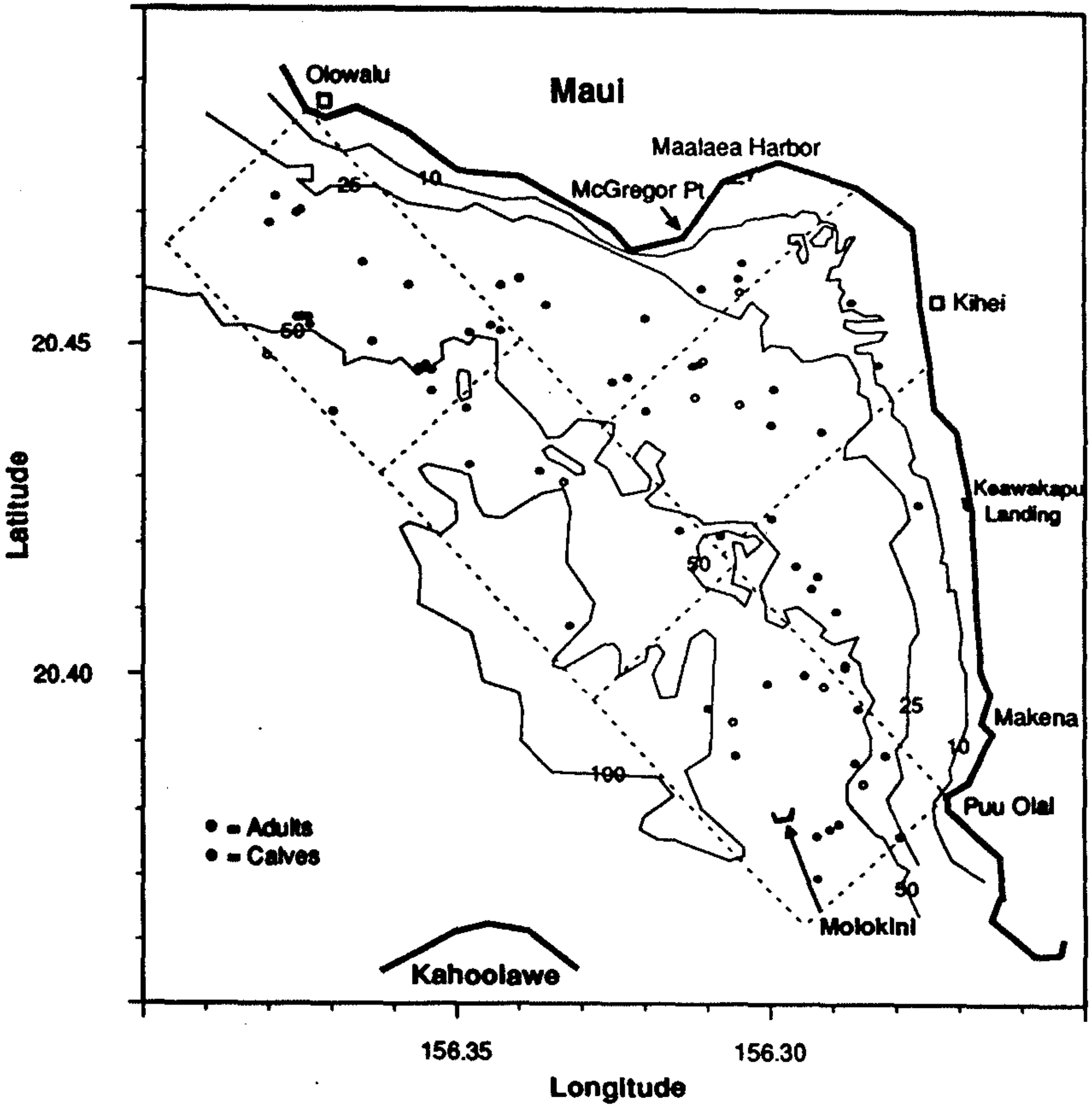

Figure 25: Location of adult and calf pods observed during aerial surveys in 1991 (n=71).

between 1978 and 1991. In general, the tendency for whales to be observed along the 25- and 50-fathom contours is apparent in both figures. One striking difference is seen in sub-region 1 in the vicinity of McGregor Point, and sub-region 3, from Keawakapu to Makena. Figure 6 shows a large number of observations of whales from the survey boats in each of those areas. Figure 21 shows few sightings in these areas during aerial surveys. Baker, Herman, Bays, and Bauer (1983) and Bauer and Herman (1986) have shown that one of the most clearly observable responses of whales to intrusive boat activity is increased dive time. Data from the current study indicate that both sub-regions 1 and 3 have the highest densities of boat traffic. It is possible that the impact of the boat activity is not in reducing the numbers of whales in the area, but rather in increasing their average down times, resulting in a smaller probability of being observed during aerial surveys.

Another difference between boat data and aerial data is that a higher proportion of pods observed from boats are calf pods (.42), compared with the proportion of pods observed from aircraft that are calf pods(.18). The proportion of pods observed from boats containing a calf in the present study agrees with the results of a similar boat survey study conducted near Lahaina in 1990. In that study, Forestell, Brown, Herman and Mobley (1991) reported the proportion of observed pods that contained a calf was .41. This is probably an artifact of survey protocol differences between the boat surveys and the aerial surveys. During boat surveys, survey time is suspended while pods are approached closely enough to verify whether or not a calf is present. The aerial surveys (except for those in 1978 and 1979) do not approach pods to verify composition, so it is likely that calf pods are under-represented in the final counts.

SUMMARY AND RECOMMENDATIONS

SUMMARY

The work described in the present report may be summarized as follows:

1. Observations of 1348 whales, including 251 calves, were made during 348 hours of boat survey time in 1989 and 1991. During 1991, 679 boats were observed in 190 hours of survey effort. During aerial surveys between 1978 and 1991, 272 pods, including 49 calves, were observed.

2. Both the vessel and aerial survey data indicate that whales are distributed along the major contours in the study area. Boat distribution patterns lie perpendicular to the whale distribution patterns.

3. There is no significant difference in the rate of observation of either calves or adults on either side of the NMFS-designated 300-yard boundary marker.

4. Throughout the day, adults appear to shift their locus of distribution to avoid areas of greatest boat activity. Calf pods do not.

5. The NMFS-designated 300-yard zone does not appear to result in a lower incidence of whale-boat interactions.

6. Aerial survey data show there has been a significant and steady increase in the number of whales observed in the study area between 1978 and 1991. There has not been a significant increase in calves, although this may be due to an artifact in survey protocol.

7. Whales in areas of high boat density spend less time at the surface.

RECOMMENDATIONS

We believe there is compelling evidence that the current level of boat activity in Maalaea Bay and vicinity already influences humpback whale distribution and behavior. Avoidance of high boat areas by adults, and longer down times by whales in high boat areas are established indices of impact recognized by other researchers (cf. Bauer and Herman, 1986, for an excellent review).

At the same time, we recognize that although there is an observable impact, the long-term significance of that impact must be viewed in the context of the data that suggests a steady increase in the number of whales using the Maalaea Bay area during the past decade. At least with respect to the data on adults, the long-term impact of human activity has not led to a reduction in numbers. The data on calves is not so straightforward. They appear to not show active avoidance of the high boat areas at certain times of the day. This may well be a result of the more topographically-specific needs of a mother with a new-born calf. In other words, adults can move away from high-boat areas, and avoid a long-term reduction in fitness. It is worthy of note that calves do not show a tendency to avoid areas of high boat density, nor have they shown evidence of a significant increase in numbers over the same time period that adult numbers have increased. Does this provide evidence of a long-term reduction in fitness of calves? It is unclear. The calf numbers are relatively small, they tend to be under-represented in aerial survey data, and it seems that it would be difficult for adult numbers to increase if calves weren't surviving.

Most importantly, we urge the responsible agencies to recognize that as the numbers of whales increase, increases in the numbers of boats will almost certainly result in increased occurrences of whale-boat collisions, which have only been reported once to date in the Maui area (Stevens, 1988). The cost of such collisions, both to the endangered humpback whale and to the humans involved, will be a direct function of the frequency with which such incidents happen, and the force vectors of the collision (i.e, size and speed of vessel, size of whale, fullness of contact, etc.)

The findings of the present work lead us to suggest that any changes in boat distribution patterns should be mitigated by a geographical centralization of activity to the greatest degree possible, and a reasonable reduction in any factor that can be viewed to add to the opportunities for negative impact on whales. Consequently, we recommend that any increase in the number of boats operating out of Maalaea Bay be accompanied by an enforced reduction of offshore moorings, in particular those that may be illegal, throughout other areas of the Bay. Every effort should be made to funnel increases in boat activity into more and more highly localized areas, rather than providing the circumstances for more diverse distribution, which will prevent whales from finding areas low in boat density.

We recommend that speed limits be imposed throughout Maalaea Bay in order to reduce the unpredictable nature of boat activity, and to allow whales a greater amount of time to adjust to incidences of close approach by boats. A secondary effect of speed limits will be to provide boat operators a greater ability to respond to the sudden appearance of a whale, and will reduce the probability of death or serious destruction in the ever-increasing likelihood of a collision. Such speed limits might be developed in consideration of the size of the vessel. For example, smaller, more maneuverable vessels (under 25 ft.) could be limited to 15 knots; vessels between 25 and 75 feet could be limited to 10 knots, and vessels over 75 feet limited to five knots. Although the 300-yard zone in Maalaea Bay does not seem to be based on an accurate understanding of whale movement or calf distribution, it is a clearly defined area that would be an appropriate site for implementing speed limits for at least that period of time when whales are present.

The work described in the present report did not address the nature of the acoustic environment, and this is something that almost certainly needs to be considered. In addition, ongoing monitoring of distribution and abundance patterns should be a high priority for both state and federal funding to determine that the baseline conditions described in the present report do not deteriorate.

Overall, we believe that it should be possible for some degree of expansion at Maalaea Small Boat Harbor, but urge that appropriate steps be taken to reduce the breadth of area over which boats may be distributed. In addition, we believe controls over speed and movement should be implemented, and that a cost-efficient long-term monitoring program be initiated to document the ongoing status of the whale population in this important area.

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