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# THE 1976/77 MIGRATION OF HUMPBACK WHALES INTO HAWAIIAN WATERS: COMPOSITE DESCRIPTION

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16. Abstract

The 1976/77 assembly of humpback whales in Hawaiian waters was studied through aircraft surveys, an all-island observer network, sightings from hydrofoil craft, a CB ship reporting network, military air sightings, and a field station. Fifteen days were selected from 7 January through 20 April 1977 to sample population parameters and seasonal trends. The data from these sources and across days indicated (a) the number of sightings increased rapidly to a peak near the third week of February, with an almost equally rapid decline in number of sightings thereafter; (b) the peak calf population also appeared to be reached in February; (c) subregions of relatively highest calf density, identified by aircraft surveys, generally were those where most total whales were observed; (d) fewer whales were seen in areas near dense human habitation or disturbance than in more isolated regions; (e) there was a tendency for the "geographic center" of the population to shift in a northwesterly direction towards Oahu as the season progressed into late March and April; (f) new mother-calf dyads appeared to remain isolated from other whales for an initial period, possibly as a social imprinting mechanism, and then were typically "escorted" by one or more other whales without calves; (g) calves were seen, on the average, in pods of increasingly larger size as the season progressed, so that pod size might serve as a crude index of the age of the calf; and (h) a number of defensive responses of the whales to marine and air traffic were identified. The potential for negative impact on the whales from the ever-increasing marine traffic or whale-watching activities was stressed.

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Preface

The studies reported in the main body of this paper were carried out under contract 03-7-208-35088 with the Marine Mammal Division, National Marine Fisheries Service, N.O.A.A., Seattle, Washington, and were assisted by financial support from the Marine Mammal Commission. The survey of marine and air traffic reported in the Appendix was supported by the Marine Mammal Commission, and the 1978 studies of whale spatial and temporal distribution by Grant BNS 77-16882 from the National Science Foundation to L. M. Herman. This report revises and extends some of the material presented in the October 1977 contracted report to the National Marine Fisheries Service. Revisions were made possible through continued support by the National Science Foundation for our studies of the Hawaiian humpback whale. The present report is Contribution No. 579 from the Hawaii Institute of Marine Biology, University of Hawaii.

We are appreciative of support given by the American Cetacean Society, Maui Chapter. We also thank the U.S. Coast Guard District Office in Honolulu for assistance to our observers during Coast Guard Flights through the Northwest Hawaiian Islands; Capt. Bryson and crew of the N.O.A.A. vessel Townsend Cromwell for their assistance and courtesy to whale observers accompanying their resource surveys of the Northwest Chain; Herbert Bonaventure of the Barking Sands Pacific Missile Range Facility on Kauai for developing and maintaining a whale sighting network among PMRF personnel; Major Goldstein of the Kaena Point Satellite Tracking Station on Oahu for allowing our observers access to this important sighting area; Duane Black of the Lanai Co. for permission to erect our Lanai field station; Paul and Pat Bernick, who ably helped in many aspects of development of the field station; and Howard Brancel who made significant contributions to the data collection phase of the field station.

We also thank Steve Rose and Mary Soares for their help in data processing through to completion; John Reinke, who provided most of the initial computer programs; Larry Kelley of Sea Flite, who arranged for the whale sighting reports from hydrofoil vessels; and Jim Luckey of the Lahaina Restoration Foundation who developed the CB whale sighting network and provided its data to us.

There were many who volunteered their services each week as shore obervers. The data they provided were invaluable. We thank them and the dedicated island co-ordinators: Paul Bernick, Pete Conally, Amy Fujimoto, Pete Hendricks, Michael Holt, Arn Nurock, Coreen Sakamoto and Craig Wolf. The collaboration of Edward Shallenberger in setting up and administering the observer network was important to its success.

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## ABSTRACT

The 1976/77 assembly of humpback whales in Hawaiian waters was studied during the major period of its residency in Island waters. Data were compiled from nine aircraft surveys, an all-island observer network, daily hydrofoil transits between Oahu and Maui, a CB ship network in Maui waters; military aircraft sightings from the Barking Sands, Kauai station; and a field camp for whale observations on the northeast shore of Lanai Island. From the mass of data, 15 days were selected from 7 January through 20 April, 1977 to describe population characteristics and represent seasonal trends. Over these 15 days, there were a total of 928 sightings of single whales or groups of whales from all data sources (many of them were overlapping sightings), for a total of 1,999 whales, including 93 calves. The major findings were (a) the number of sightings increased rapidly to a peak near the third week of February, with an almost equally rapid decline in number of sightings thereafter; (b) the peak calf population also appeared to be reached in February; (c) subregions of relatively highest calf density, identified by aircraft surveys, generally were those where most total whales were observed; (d) fewer whales were seen in areas near dense human habitation or disturbance than more isolated regions; (e) there was a tendency for the "geographic center" of the population to shift in a northwesterly direction towards Oahu as the season progressed into late March and April; (f) new mother-calf dyads appeared to remain isolated from other whales for an initial period, possibly as a social imprinting mechanism, and then were typically "escorted" by one or more other whales without calves; (g) calves were seen, on the average, in pods of increasingly larger size as the season progressed, so that pod size might serve as a crude index of the age of the calf; and (h) a number of defensive responses of the whales to marine and air traffic were identified. The potential for negative impact on the whales from the ever-increasing marine traffic or whale-watching activities was stressed, and some recommendations for methods to protect the Hawaiian population were given.

## Scope of Report

Study of the Hawaiian population of humpback whales, Megaptera novaeangliae, was carried out during their 1976/77 migration into Hawaiian waters. The study continued earlier work on the 1975/76 migration (Herman, 1977; Herman & Antinoja, 1977). The current studies were broader in scope and effort than previously, and were carried out over the major portion of residency of the whales in Hawaiian waters. The principal goals included an assessment of the distribution and relative abundance of whales seasonally; investigation of possible migratory routes and of local movements; identification of important regions for mating and calf-rearing; study of mother-calf pairs; and the evaluation of actual and potential sources of harassment or disturbance to the whales.

Not all of these goals were realized fully, but some data were obtained on each. The overall amount of data obtained was considerable. Sources of data included (a) aircraft surveys over regions of aggregation of the whales throughout the main Hawaiian Islands; (b) sightings from a network of shore observers on each island; (c) reports from a field station on the northeast coast of Lanai Island established for study of the whales; (d) sightings from Sea Flite hydrofoils transiting island waters; (e) reports from a CB-radio ship network developed by the Lahaina Restoration Foundation; and (f) sightings by aircraft and ship personnel of the Barking Sands Pacific Missile Range Facility on Kauai, during their operations off-shore of Kauai and Niihau. Additional information was obtained from a shipboard survey of North Oahu conducted toward the end of the season, and from U.S. Coast Guard flights and N.O.A.A. ship transits we accompanied through portions of the Northwest Hawaiian Islands.

## Material and Methods

Some data were available for almost every day of the period of residency of the whales in Hawaiian waters, from early November 1976 through to late May 1977. For the bulk of this report, a subset of 15 days from early January through to end of April was selected for intensive analysis. The trends across the 15 days were considered representative of seasonal parameters for the population. Multiple criteria were used in selection of the 15 days, with a major consideration being a substantial amount of data for that date. If there were aircraft surveys on a given day, that date was selected unless the sighting conditions were poor. This criterion accounted for selection of nine days: 7 and 19 January; 2 and 18 February; 10, 23 and 30 March; and 6 and 20 April, 1977. On most of these days there were significant contributions to the aircraft data from other sources. The remaining six days were chosen to fill the intervals between 7 January and 20 April and were 14 and 30 January; 1 and 26 February; and 1 and 16 March. To choose these six days the number of sightings for each day of the week separating flights was examined and the day of the week yielding the largest number of cumulative sightings from all remaining sources was selected. The set of 15 days was then referred to as "maximum (max) data days." In addition to the "max" data days, data from the shore observer network on selected Sundays of the season from January 16th through April 24th were included in some analyses, where noted.

Figure 1 shows the main Hawaiian Islands with area and place names important to this study identified. The 100-fathom contour, within which

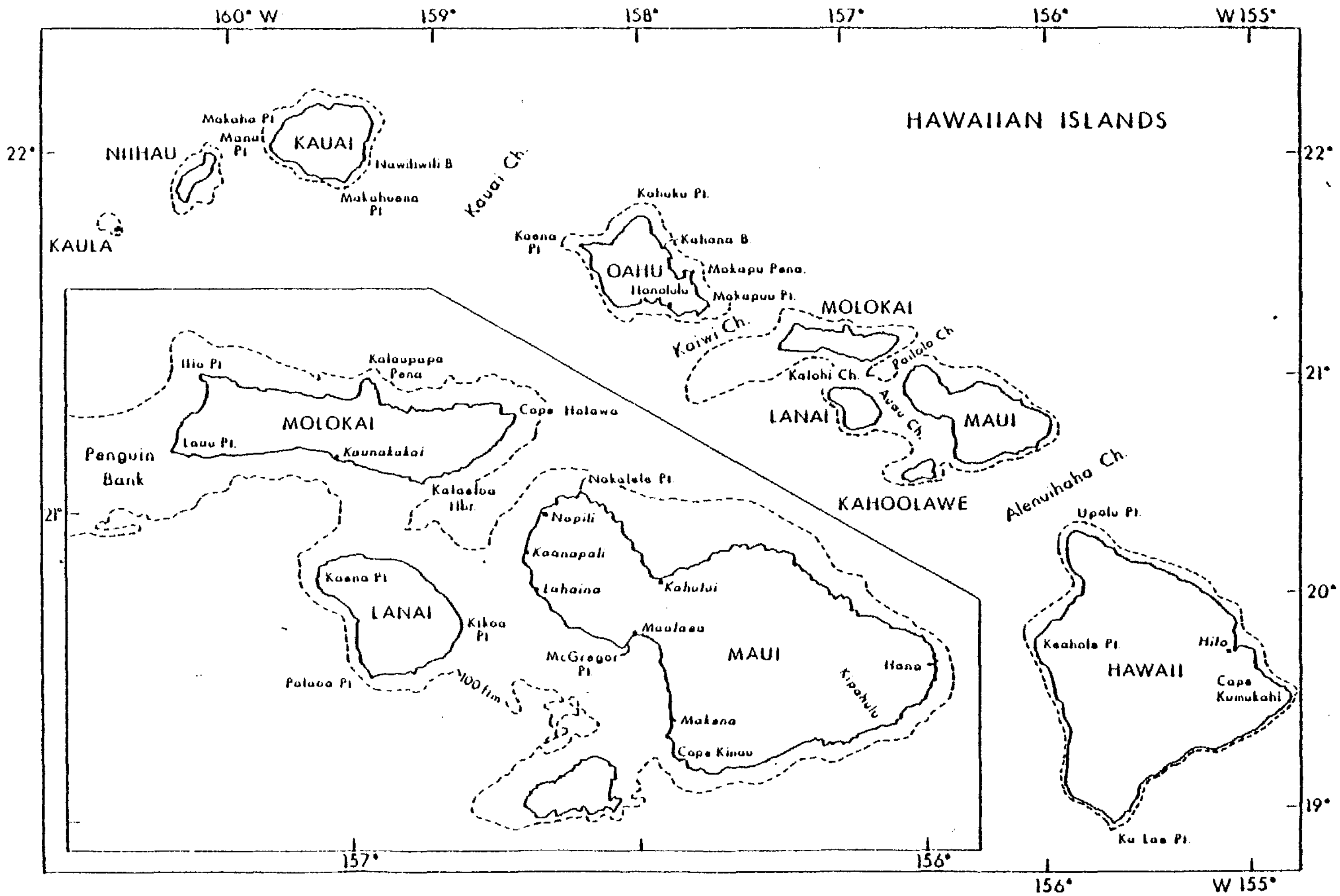


Fig. 1. The main Hawaiian Islands. The inset expands the four-island region, an area of heavy usage by the whales.

almost all whales are found, is indicated. The inset expands the four-island region of Molokai, Lanai, Kahoolawe, and Maui, which contains a shallow water area of high whale density. Other reports (Herman, 1980; Herman & Antinoja, 1977) have described some of the ecological characteristics of the Hawaiian marine habitat.

### Aircraft Surveys

Figure 2 shows the paths of aircraft during the aerial surveys conducted throughout the 1977 season. The flights were principally within regions of 100-fathom water around or between islands. Exceptions were the northerly offshore runs between Oahu and east Maui, which were attempts to intercept migrating whales. Table 1 lists dates of aircraft flights and regions surveyed.

Aircraft were single engine Cessna 172's, Grumman Commanders, or Piper Cherokees, chartered on an hourly basis. On board were the pilot, a photographer, and two observers. The flight log and all observations were recorded on audio tape in real time. We flew at 700 to 800 feet while searching for whales, and descended to 500 feet for closer inspection of a sighting. When possible, sightings were orbited for several minutes to fix the location of the group and determine their heading and to obtain detailed information on pod composition and behavioral and morphological characteristics of individuals.

The most complete data, from all dimensions of interest, was that from aircraft. Position data could be estimated accurately by reference to Vortac Omni stations located on the various islands, or to visual landmarks; the number of whales in a group could be determined reliably; and finally, behaviors and physical characteristics of the whales were readily observable. Disadvantages of the aircraft platform were its short observation time over each pod orbited, its relatively low sampling ratio of the population, and its dependence on good weather conditions.

### Observer Network

The observer network was developed in early January, 1977. Between January 6th and 14th, "Whale Watchers' Workshops" were held on Oahu, Hawaii, Kauai, Lanai, Maui, and Molokai. Volunteers attending each workshop were given a 3 to 4 hour lecture and slide presentation on the Hawaiian humpback whales, including what was known of their history, distribution, abundance, appearance, and behavioral characteristics. The type of information to be collected by the volunteers was discussed and reporting forms (Figure 3) were distributed and explained. A local co-ordinator was selected for each island to assist in the distribution and receipt of completed forms and to enlist new volunteers. Observers were asked to be at designated shore stations each Wednesday and/or Sunday of the week, either from 0800 to 1200 hours, or from 1200 to 1600. Co-ordinators returned all completed forms to the University of Hawaii for processing.

Figure 4 shows the location of the shore stations used by the volunteer observers throughout the season. Not all stations operated on a regular basis, and a few were staffed only on rare occasions. Open circles identify locations from which data were obtained during the max data days studied. Closed circles

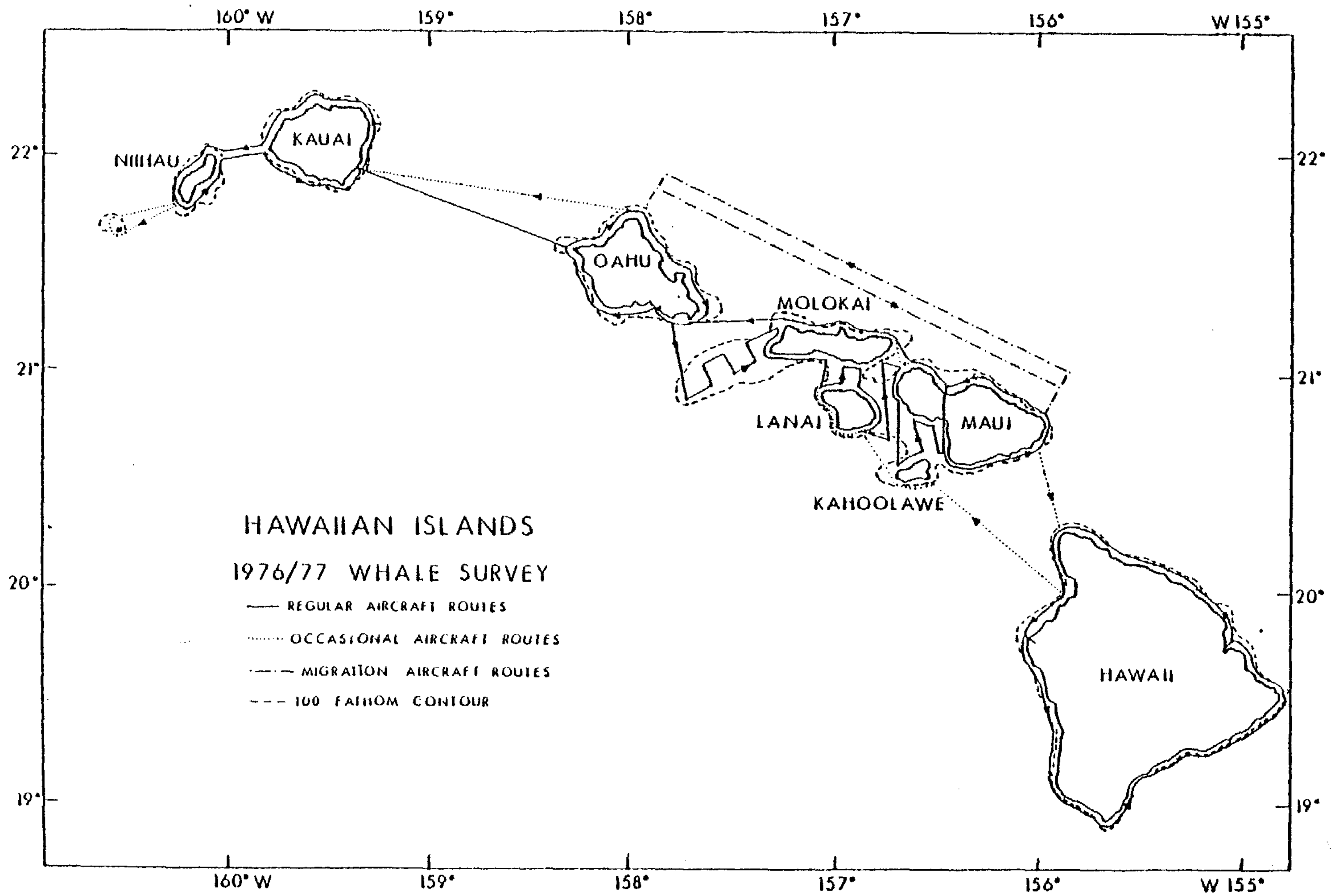


Fig. 2. Routes taken by aircraft during surveys of the islands. Independent aircraft surveyed (a) Oahu and the Niihau-Kauai area, (b) Penguin Bank and the four-island region, (c) Hawaii and (d) the outlying northerly "migration" area.

Table 1

Summary of Aircraft Survey Dates and Regions Surveyed

| Date | | Oahu-Kauai-Niihau-Oahu | Honolulu-Maui-Honolulu | Hawaii: Hilo to Hilo counter-clockwise | Migration: N. Oahu-N. Maui |
|---|---|---|---|---|---|
| January | 7 (Fri) | X | X | | |
| | 19 (Wed) | | X[d] | | |
| February | 2 (Wed) | X | X | X | X |
| | 18 (Fri) | X | X | X | |
| March | 10 (Thu) | X[a] | X | X[b] | X |
| | 23 (Wed) | X | X | X[c] | |
| | 30 (Wed) | | X | | |
| | 6 (Wed) | X | X | | |
| | 20 (Wed) | | X | | |

[a] Actually flown on March 13th but data included with March 10th.

[b] Actually flown on March 11th but data included with March 10th.

[c] Actually flown on March 22nd but data included with March 23rd.

[d] Includes brief survey of Upolu Point region of Hawaii.

HUMPBACK WHALE SHORE SPOTTING LOG
[return to area coordinator or to 1129 Ala Moana, Kewalo Basin, Honolulu, 96814]

I

Station ____________ Observer ____________ Date ________
Starting time on station ________ Finish time ________ Sheet No. ___ of ___
Spot No. ____ No. of whales ___ ± ___ Calf present? ____ Shape of pod [sketch on back]
Compass or clock heading to whales ______ Distance to shore (miles) ____________
Movement direction of whales ____________

II

Major activity: resting ___ milling ___ swimming slowly ____ swimming rapidly ____
Detailed behaviors (see key): inverted breech ___ tail wave ___ head slap ___
pectoral (fin) wave ___ lobtailing (tail slap) ___ sounding (flukes up) ___
inverted swimming ___ rolling side to side ___ bobbing ___ rubbing other whales ___
other (describe) ____________

Behavioral narrative: in your own words, describe the behaviors of the animals, how long they were occurring, and the sequence in which they occurred. Identify behaviors with individual animals, if possible. If calf present, describe its behaviors. Use back of sheeet 1 (and 2 if necessary).

III

Diving characterisitics:

| Dive No. | Dive Time (min.) | Dive No. | Dive Time (min) | Dive No. | Dive Time (min) |
|---|---|---|---|---|---|
| 1 | ___ | 5 | ___ | 9 | ___ |
| 2 | ___ | 6 | ___ | 10 | ___ |
| 3 | ___ | 7 | ___ | 11 | ___ |
| 4 | ___ | 8 | ___ | 12 | ___ |

IV

Physical description of whales:
Large (no.) ____ Medium (no.) ____
Dorsal fin shapes (Sketch different shapes seen): ____________

Coloration of top side of pectoral fins (indicate no. of animals in each category)
Extensive white ___ moderate white ___ slight white ___ all black ___
Undetermined ___

V

Other Information:
Dolphins nearby? (describe) ____________
Flocks of birds near whales? ____________
Boats or ships nearby? (how far away and do they approach whales?) ____________

VI

Spotting Conditons:
Spotting aids (binoculars, etc.) (describe) ____________
Weather: clear ___ hazy ___ cloudy ___ rain ___
Seas: flat ___ small waves only ___ some whitecapping ___ heavy seas ___

Fig. 3. The form provided volunteer observers in the all-island observer network (shore net). One form was completed for each sighting of a new whale or group of whales.

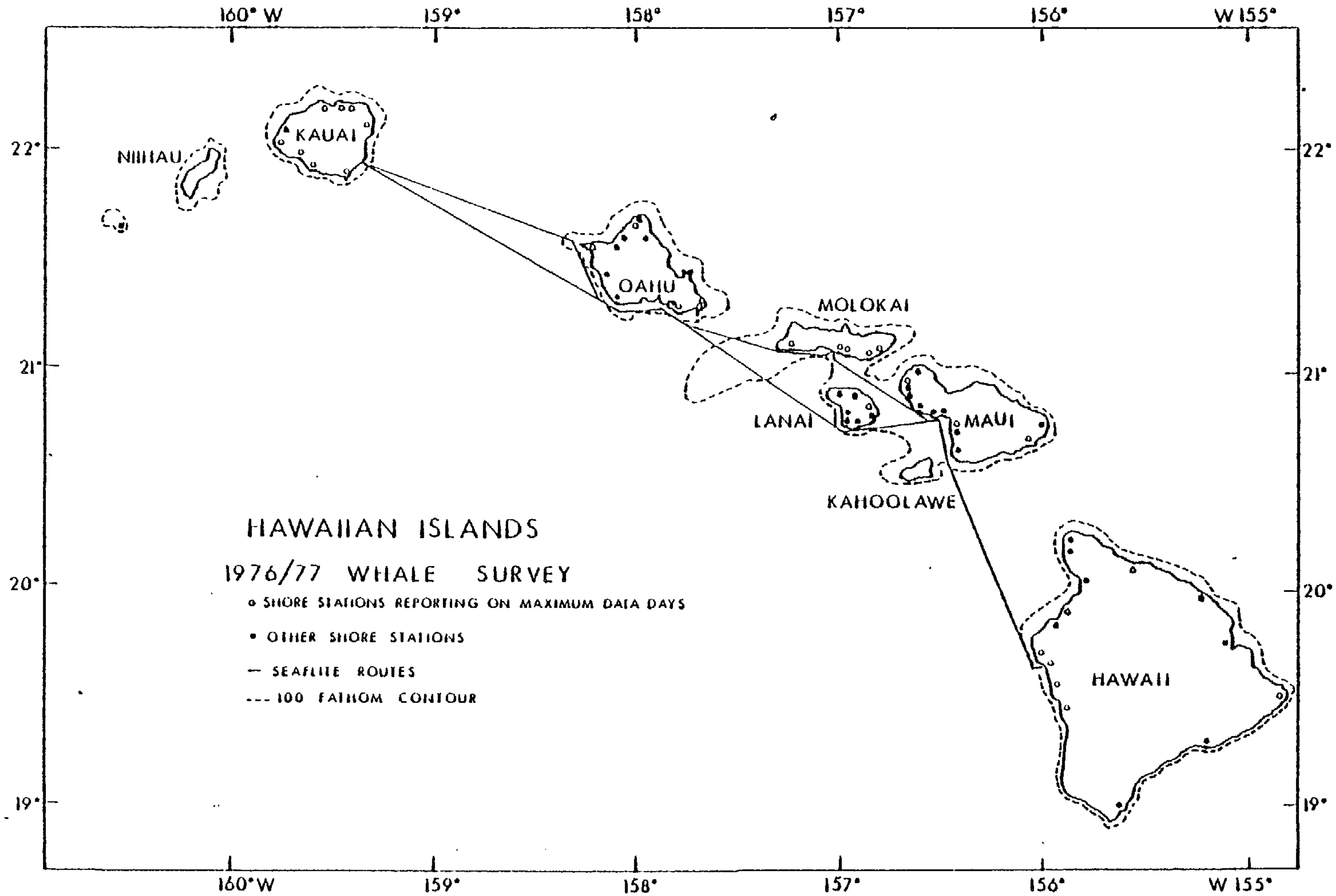


Fig. 4. Routes taken by Seaflite during their interisland transits are shown by the heavy lines. Circles on land indicate locations of shore posts for the observer network. Open circles indicate those stations that contributed data on any of the 15 selected "maximum data days."

show other stations. The shore net data varied in quality, reflecting the differing levels of skill of observers. In some cases, reports included drawings of pod configurations, sketches of the paths of the whales, and detailed text on behaviors. Some obervers who were on station regularly were able to synthesize their observations into valuable conclusions about movement trends and other characteristics of the whales. In other cases, the report was limited to the number of whales seen and their location. Not all observers attended the initial training sessions, and it is likely that some of the reporting differences reflected differences in training. Time and budgetary constraints did not permit the full co-ordination and follow-up necessary to assure appropriate skill levels in all observers, and maintain the network fully. Nevertheless, many of the observers turned out regularly each Wednesday and Sunday, so that a good number of the stations were operational each week. Much useful data was obtained. The potential of a good shore network is sizeable, and with full implementation it can be a highly reliable, valuable adjunct to the study of the whales. Other than aircraft, the shore network is the only source for all-island data.

## Field Station

A field station was developed at Halepalaoa Landing, on the northeast coast of Lanai (Fig.1). This site is close to regions of especially high whale density in Kalohi and Auau Channels. Observers were camped at the station, which is accessible only by jeep trail from Lanai City, from early February through to the middle of April 1977. Whales passing nearby could be studied from shore, using variable-power telescopes and binoculars, or directly from the sea through the launching of inflatable rubber craft. The main function of the station was to carry out detailed, protracted observations of the whales in order to document behaviors and movements, to identify and describe individuals, and to obtain detailed data on calves. Shore observations from the field station were restricted by the limited elevation (approximately 4m), though good lateral viewing was available. Whales observed were usually easily reached by surface vessel, however, providing for important supplementary observations on pod composition and behaviors. Though well situated for whales observations, the camp was difficult to supply logistically, and was susceptible to washouts from heavy rains in the Lanai mountains. Its potential could increase considerably with better logistical support.

## Hydrofoil Observations

During 1977, Sea Flite hydrofoils made multiple daily transits between Honolulu and Maalaea Bay, Maui, and between Honolulu and Nawiliwili, Kauai. They also made less than daily trips between Maalaea Bay and Kailua-Kona on the Big Island as well as occasional trips to Kaunakakai, Molokai on the way between Oahu and Maui. Table 2 presents Sea Flite schedules, and Figure 4 shows the routes followed by the craft. The greatest number of transits was between Honolulu and Maalaea Bay. The path around the south side of Lanai was used from approximately 15 December 1976 through to 15 April 1977. According to Larry Kelley, operations manager of Sea Flite, approximately six trips were made through Kalohi Channel to Kaunakakai during this period.

The Sea Flite data were highly reliable within the limits of the areas covered and the restrictions placed on sighting probability and viewing duration because of the high speed of the craft (approximately 80 km/hr).

Table 2

Interisland Schedule of Sea Flite Hydrofoils

1. Honolulu to Maalaea, Maui

| LV HNL | ARR MAUI | LV MAUI | ARR HNL | FREQUENCY |
|---|---|---|---|---|
| 0730 | 1010 | 1020 | 1245 | Daily |
| 0800 | 1030 | 1055 | 1320 | Daily |
| 1340 | 1630 | 1640 | 1900 | Daily |

2. Maui to Hawaii (Kailua-Kona on W. Hawaii)

| LV MAUI | ARR HAW | LV HAW | ARR MAUI | FREQUENCY |
|---|---|---|---|---|
| 1115 | 1330 | 1410 | 1610 | 3-4 times per week |

3. Honolulu to Kauai (Nawiliwili)

| LV HNL | ARR KAUAI | LV KAUAI | ARR HNL | FREQUENCY |
|---|---|---|---|---|
| 1310 | 1550 | 1610 | 1850 | Daily |
| 0715 | 0955 | 1015 | 1255 | Twice/week |

4. Honolulu to Molokai and Maui

Any trip in Block 1 above could stop at Molokai on request. One example:

| LV MAUI | ARR MLK | LV MLK | ARR HNL | FREQUENCY |
|---|---|---|---|---|
| 1020 | 1125 | 1140 | 1310 | On occasion |

Since the craft followed the same path regularly, its data contributed importantly to detection of seasonal trends in abundance and distribution. Sea Flite captains were well coached in whale spotting, and completed sighting forms while enroute. The reports, however, were restricted to the time and location of the sighting, an estimate of the number of whales present, and only brief reports of behaviors. Negative reports were also filed.

CB Ship Network

The Citizen Band (CB) ship network was directed by James Luckey of the Lahaina Restoration Foundation. Data collected were made available to us. Skippers of vessels berthed in Lahaina were recruited as volunteer whale spotters and reported on sightings whenever they happened to be cruising in the waters of the four-island region. The vessel skipper was provided with a sighting form (Fig. 5) showing the four-island region and a grid overlaying the waters between the islands. On sighting whales, the skipper communicated the position of the whales via CB radio to the Lahaina Restoration Foundation's shore station at dockside in Lahaina. Positions of the whales were given in reference to the grid network. The number of whales present was estimated and brief statements of behaviors were sometimes provided.

Data from the CB network were voluminous, as there were commonly many ships in the Auau Channel and east Kalohi Channel regions each day. The network provided daily coverage of the important four-island region and its data describe seasonal trends in that area well. However, it is often not possible to determine the degree of overlap among reports from adjacent boats on the same day, and the number of whales reported in a sighting may have questionable reliability, or be only broad estimates attempting to bracket the true number. The potential of the network is considerable, and with more instruction to the skippers and more extensive reporting procedures, its value can increase. The operation, within the limits of its scope, was well executed.

PMRF Observations

The Barking Sands Pacific Missile Range Facility (PMRF) is located at Mana Point on Kauai (Fig. 1). The facility includes an underwater listening range extending northwesterly from Mana Point. Naval exercises are conducted periodically in the area between Mana Point and north Niihau and in the regions extending north and northwesterly from that area. The exercises include low-level aircraft flights and deployment of surface vessels. Personnel on these flights and ships reported the presence of whales to PMRF headquarters under a program of assistance to our project set up and co-ordinated by Mr. Herbert Bonaventure of PMRF. PMRF also assisted throughout the season in obtaining recordings of whales from their listening station.

Substantial data were received from PMRF and it is our best resource on the presence of whales in the Kauai-Niihau area. The data were largely restricted to locations of whales, numbers seen, and on some occasions, brief statements of behavior. The position data are generally highly accurate, as sophisticated navigation aids were available to the observers. Relatively little is contributed by PMRF to the data reported in this paper, because their observation dates tended not to coincide with dates chosen for analysis in this study. Problems with PMRF data are similar to those encountered by our

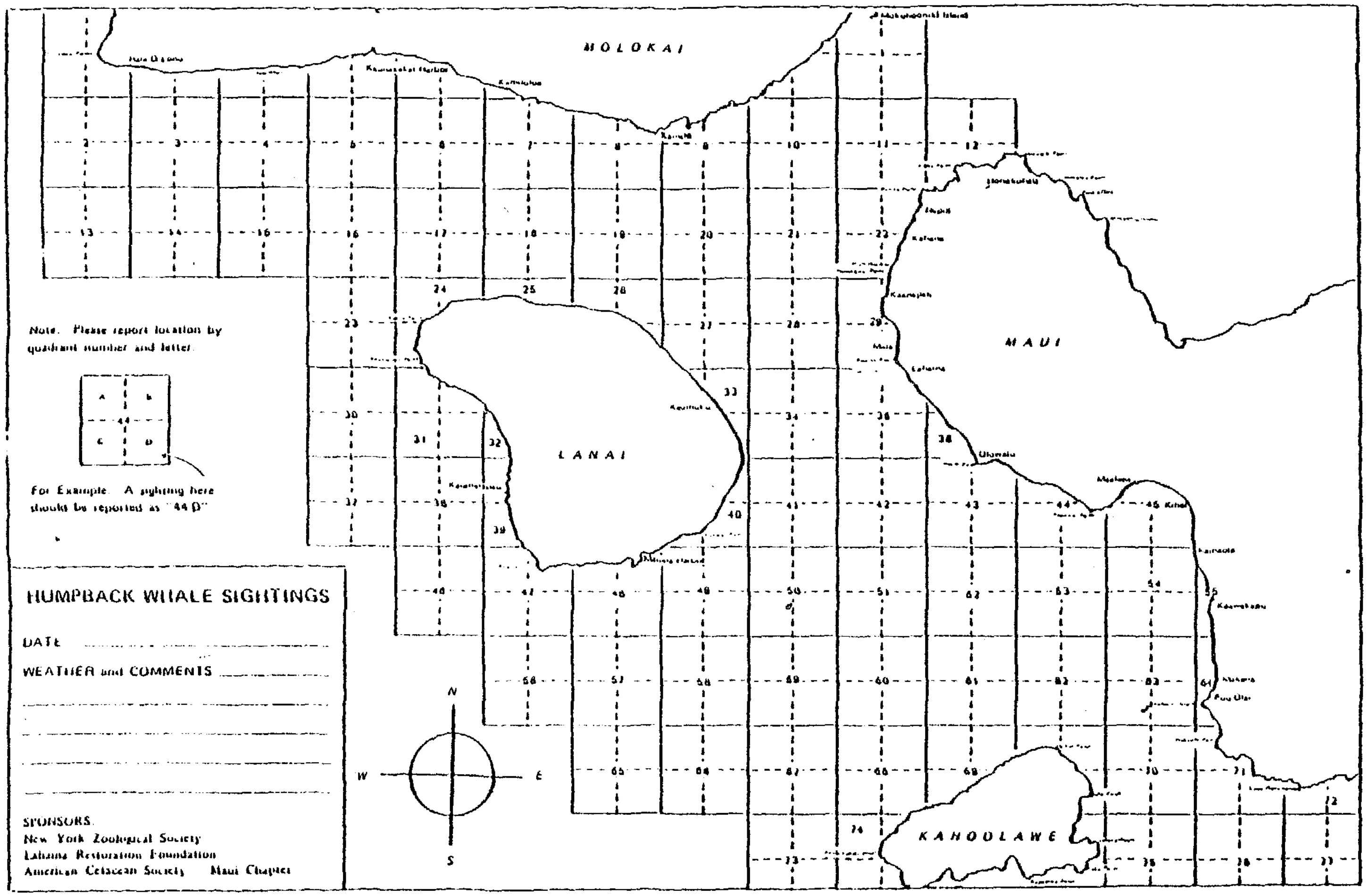


Fig. 5. The form provided to vessels participating in the CB whale spotting network run by the Lahaina Restoration Foundation.

own chartered aircraft, but are compounded by the high speed of PMRF aircraft. To some extent, this is counterbalanced by the greater number of flights taken.

Oahu Migration Survey

Near season's end, attempts were made to study out-migration around northwest and north Oahu. Whales appear to aggregate in this area late in the season. From April 10th through May 18th 1977, observers were stationed on a near-daily basis at the Kaena Point Satellite Tracking Station. From its near-shore approximate 225-m elevation, a commanding view of the adjoining leeward and north coasts of Oahu is obtained. In conjunction with these shore observations, a ship survey was conducted between Waimea Bay and Honolulu on 29 and 30 April, 1977.

Survey of Northwest Hawaiian Islands

Migration possibilities in the Northwest Hawaiian Islands were also studied. We placed two whale observers aboard the N.O.A.A. vessel Townsend Cromwell during its voyage from Midway to Honolulu from 2 to 12 November, 1976, and during its immediately following resources survey of Niihau and Necker Islands from 16 to 24 November. Whale observers were also placed aboard U.S. Coast Guard C130 low-level inspection flights of the Northwest Hawaiian Islands during transits from Oahu to Midway and Kure Islands and return. One to two observers accompanied flights on each of the following outbound dates: November 30th, 1976 and, in 1977, 19 January, 2 and 23 February, 9 and 23 March, and 6 and 20 April. After layover in Midway, aircraft generally returned the day following the outbound date. The inbound flight was usually again at low altitude, and a number of the flights stopped briefly at French Frigate Shoals. In such cases, a somewhat more southerly route was taken than on the outbound flight.

## Results and Discussion

Data records were prepared for each sighting on a maximum data day from each of the various observational sources. Each data record included the date and time of the sighting, sighting conditions (weather and sea state), total number of whales, presence or absence of a calf, the position of the whales in latitude and longitude and their direction of movement, presence or absence of boats within a quarter-mile radius and whether any approached the whales, the major activity of the whales, and a listing of occurrence of various types of behaviors. The data records were cross-tabulated by computer in a variety of ways to obtain statistics, and to reveal trends and interactions of variables. The overall data base consisted of 928 sightings of one or more whales. The total number of whales sighted over all max data dates was 1,999, including 93 calves. These numbers greatly exceed population estimates (e.g., Herman & Antinoja, 1977), and hence many of the whales and calves were obviously the same animals seen more than once over the season, as well as on the same day by multiple observers. In most cases, only partial data were available from a sighting, and the various analyses reported herein showing lesser numbers of sightings or of whales than the base numbers given indicate that data were missing in some categories.

Seasonal Trends in Relative Numbers

Table 3 summarizes the number of sightings, whales, and calves reported on each max data day by each source of data. The totals for each source indicate that the relative contributions to number of sightings was greatest for the CB-net, followed by Sea Flite, aircraft, shorenet, field station, and Barking Sands. However, these sources varied in the average number of whales counted or estimated per sighting (Table 4), so that there is some rearrangement of their relative contribution to total whales sighted. The aircraft, while orbiting pods, obtained the best viewing angle for counting whales and is regarded as the best estimator of number of whales per pod for the overall population. The favorable viewing angle of the aircraft also allows for the ready detection of calves. Of the total number of whales sighted by aircraft, 9.2% were calves. The lower calf ratios reported by the CB-net (2.7%), Sea Flite (1.1%), and the shorenet (4.7%) reflect their less favorable sighting conditions, or the brevity of their contact with a pod. The high calf ratio reported by the field station (13.4%) is accounted for by the concentration of its efforts in a region having many calves, as is discussed more fully in a following section, and by its protracted detailed observations of pods. The high ratio from the Barking Sands source (14.3%) was based only six total sightings and hence cannot be regarded as a reliable estimator of relative calf abundance.

The trends across the set of maximum data days listed in Table 3 reveal an orderly increase in numbers of sightings and numbers of whales as the season progressed, through to a peak number of 143 sightings and 297 whales on February 18th, based on all reporting data sources. Seasonal trends are somewhat obscured by the differences in numbers of sources reporting on each max data day, and/or the degree to which a given source was operative on the date. Variability in the shorenet data, for example, occurred because observers were at their stations mainly on Wednesdays and Sundays. Four max data days, February 18 and 26, and March 1 and 10, were neither Wednesdays nor Sundays (the shorenet began operation only after January 14th).

Seasonal trends are revealed more clearly by Figure 6 in which the number of whales sighted by aircraft, Sea Flite, and CB network on each max data day are plotted as the percentage of total whales sighted by that source. For example, the 20 whales sighted by aircraft on January 7, 1977 are normalized to 4.9% of the total when divided by the 412 whales sighted by aircraft over all max data days.

Additionally, Figure 6 provides data from the shorenet source on every other Sunday of the season from January 16th through to April 24th. Also included are Sunday, January 23rd, to show the early trends more clearly, and Sunday, February 20th, to help identify when peak numbers of whales were present. Table 5 summarizes the data from the shorenet on the indicated Sundays which form the basis for the shorenet graph in Figure 6.

Figure 6 shows that the peak numbers occurred on February 18th for both the aircraft and Sea Flite sources of data, and on February 20th for the shore network. For aircraft and shorenet the peak is very steep and for Sea Flite, moderately steep. Sea Flite also shows a somewhat lower secondary peak on January 30th. In some contrast, the data for the CB network, which derived almost entirely from the four-island region, show more constant numbers during

Table 3

Number of Sightings, Number of Whales (Including Calves) and Number of Calves for Each of the Maximum Data Dates of the Season

| DATE | SOURCE | TOTAL SPOTS | TOTAL WHALES | TOTAL CALVES | CALVES (%) |
|---|---|---|---|---|---|
| Jan 7 (Fri) | | 28 | 68 | 2 | 2.9 |
| | Aircraft | 9 | 20 | 2 | 10.0 |
| | CB Net | 13 | 33 | 0 | 0.0 |
| | Seaflite | 4 | 12 | 0 | 0.0 |
| | Barksand | 2 | 3 | 0 | 0.0 |
| Jan 14 (Fri) | | 46 | 100 | 3 | 3.0 |
| | CB Net | 29 | 64 | 1 | 1.6 |
| | Seaflite | 14 | 27 | 0 | 0.0 |
| | Barksand | 3 | 9 | 2 | 22.2 |
| Jan 19 (Wed) | | 58 | 127 | 3 | 2.6 |
| | Aircraft | 16 | 32 | 2 | 6.3 |
| | CB Net | 20 | 39 | 1 | 2.6 |
| | Seaflite | 17 | 29 | 0 | 0.0 |
| | Barksand | 1 | 2 | 0 | 0.0 |
| | Shorenet | 4 | 15 | 0 | 0.0 |
| Jan 30 (Sun) | | 84 | 198 | 5 | 2.5 |
| | CB Net | 25 | 76 | 2 | 2.6 |
| | Seaflite | 28 | 56 | 1 | 1.8 |
| | Shorenet | 31 | 66 | 2 | 3.0 |
| Feb 2 (Wed) | | 109 | 239 | 12 | 5.0 |
| | Aircraft | 39 | 76 | 6 | 7.9 |
| | CB Net | 32 | 92 | 3 | 3.3 |
| | Seaflite | 11 | 19 | 0 | 0.0 |
| | Shorenet | 27 | 52 | 3 | 5.8 |
| Feb 13 (Sun) | | 122 | 267 | 11 | 4.1 |
| | CB Net | 34 | 83 | 1 | 1.2 |
| | Seaflite | 21 | 37 | 1 | 2.7 |
| | Shorenet | 55 | 123 | 4 | 3.3 |
| | Fieldsta | 12 | 24 | 5 | 20.8 |
| Feb 18 (Fri) | | 143 | 297 | 15 | 5.1 |
| | Aircraft | 66 | 134 | 9 | 6.7 |
| | CB Net | 33 | 83 | 3 | 3.6 |
| | Seaflite | 36 | 63 | 0 | 0.0 |
| | Shorenet | 3 | 5 | 1 | 20.0 |
| | Fieldsta | 5 | 12 | 2 | 16.7 |
| Feb 26 (Sat) | | 48 | 112 | 2 | 1.8 |
| | CB Net | 27 | 75 | 1 | 1.3 |
| | Seaflite | 18 | 30 | 0 | 0.0 |
| | Shorenet | 2 | 6 | 1 | 16.7 |
| | Fieldsta | 1 | 1 | 0 | 0.0 |
| Mar 1 (Tue) | | 38 | 78 | 3 | 3.8 |
| | CB Net | 28 | 65 | 3 | 4.6 |
| | Seaflite | 10 | 13 | 0 | 0.0 |
| Mar 10 (Thu) | | 56 | 121 | 11 | 9.1 |
| | Aircraft | 23 | 61 | 5 | 8.2 |
| | CB Net | 16 | 42 | 4 | 9.5 |
| | Seaflite | 10 | 11 | 1 | 9.1 |
| | Fieldsta | 2 | 7 | 1 | 14.3 |
| Mar 16 (Wed) | | 43 | 84 | 1 | 1.2 |
| | CB Net | 25 | 53 | 0 | 0.0 |
| | Seaflite | 6 | 6 | 0 | 0.0 |
| | Shorenet | 9 | 20 | 0 | 0.0 |
| | Fieldsta | 3 | 5 | 1 | 20.0 |
| Mar 23 (Wed) | | 51 | 116 | 11 | 9.5 |
| | Aircraft | 14 | 31 | 8 | 25.8 |
| | CB Net | 14 | 52 | 1 | 1.9 |
| | Seaflite | 17 | 19 | 0 | 0.0 |
| | Shorenet | 4 | 9 | 1 | 11.1 |
| | Fieldsta | 2 | 5 | 1 | 20.0 |
| Mar 30 (Wed) | | 56 | 109 | 7 | 6.4 |
| | Aircraft | 12 | 26 | 3 | 11.5 |
| | CB Net | 4 | 10 | 0 | 0.0 |
| | Seaflite | 16 | 24 | 0 | 0.0 |
| | Shorenet | 19 | 38 | 4 | 10.5 |
| | Fieldsta | 5 | 11 | 0 | 0.0 |
| Apr 6 (Wed) | | 16 | 30 | 2 | 6.7 |
| | Aircraft | 4 | 7 | 0 | 0.0 |
| | CB Net | 3 | 7 | 1 | 14.3 |
| | Seaflite | 6 | 10 | 1 | 10.0 |
| | Shorenet | 1 | 3 | 0 | 0.0 |
| | Fieldsta | 2 | 3 | 0 | 0.0 |
| Apr 20 (Wed) | | 23 | 51 | 5 | 9.8 |
| | Aircraft | 11 | 28 | 3 | 10.7 |
| | CB Net | 4 | 6 | 0 | 0.0 |
| | Shorenet | 5 | 7 | 0 | 0.0 |
| | Fieldsta | 3 | 10 | 2 | 20.0 |
| Total | | 921 | 1987 | 93 | 4.7 |
| | Aircraft | 139 | 415 | 38 | 9.2 |
| | CB Net | 307 | 730 | 21 | 2.9 |
| | Seaflite | 214 | 356 | 4 | 1.1 |
| | Shorenet | 160 | 344 | 16 | 4.7 |
| | Fieldsta | 35 | 78 | 12 | 15.4 |
| | Barksand | 6 | 14 | 2 | 14.3 |

Table 4

Number of Sightings of Each Pod Size, as a Function of Observation Method (Source)

| SOURCE | | POD SIZE 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | Total Spots | Total Whales | Avg. No. per Pod |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aircraft | N | 75 | 63 | 43 | 12 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 200 | 416 | 2.07 |
| | % | 37.5 | 31.5 | 21.5 | 6.0 | 3.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | | | |
| CB Net | N | 73 | 120 | 59 | 31 | 9 | 8 | 3 | 2 | 0 | 2 | 1 | 308 | 782 | 2.54 |
| | % | 23.7 | 39.0 | 19.2 | 10.1 | 2.9 | 2.6 | 1.0 | 0.6 | 0.0 | 0.6 | 0.3 | | | |
| Seaflite | N | 114 | 74 | 18 | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 215 | 357 | 1.66 |
| | % | 53.0 | 34.4 | 8.4 | 1.9 | 2.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | |
| Shorenet | N | 50 | 65 | 30 | 10 | 5 | 1 | 0 | 0 | 1 | 0 | 0 | 162 | 351 | 2.17 |
| | % | 30.9 | 40.1 | 18.5 | 6.2 | 3.1 | 0.6 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | | | |
| Fieldata | N | 17 | 6 | 5 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 35 | 78 | 2.23 |
| | % | 48.6 | 17.1 | 14.3 | 8.6 | 5.7 | 5.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | |
| Barksand | N | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 14 | 2.33 |
| | % | 16.7 | 33.3 | 50.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | |
| TOTAL | N | 330 | 330 | 158 | 60 | 27 | 11 | 3 | 3 | 1 | 2 | 1 | 926 | 1998 | 2.15 |
| | % | 35.6 | 35.6 | 17.1 | 6.5 | 2.9 | 1.2 | 0.3 | 0.3 | 0.1 | 0.2 | 0.1 | | | |

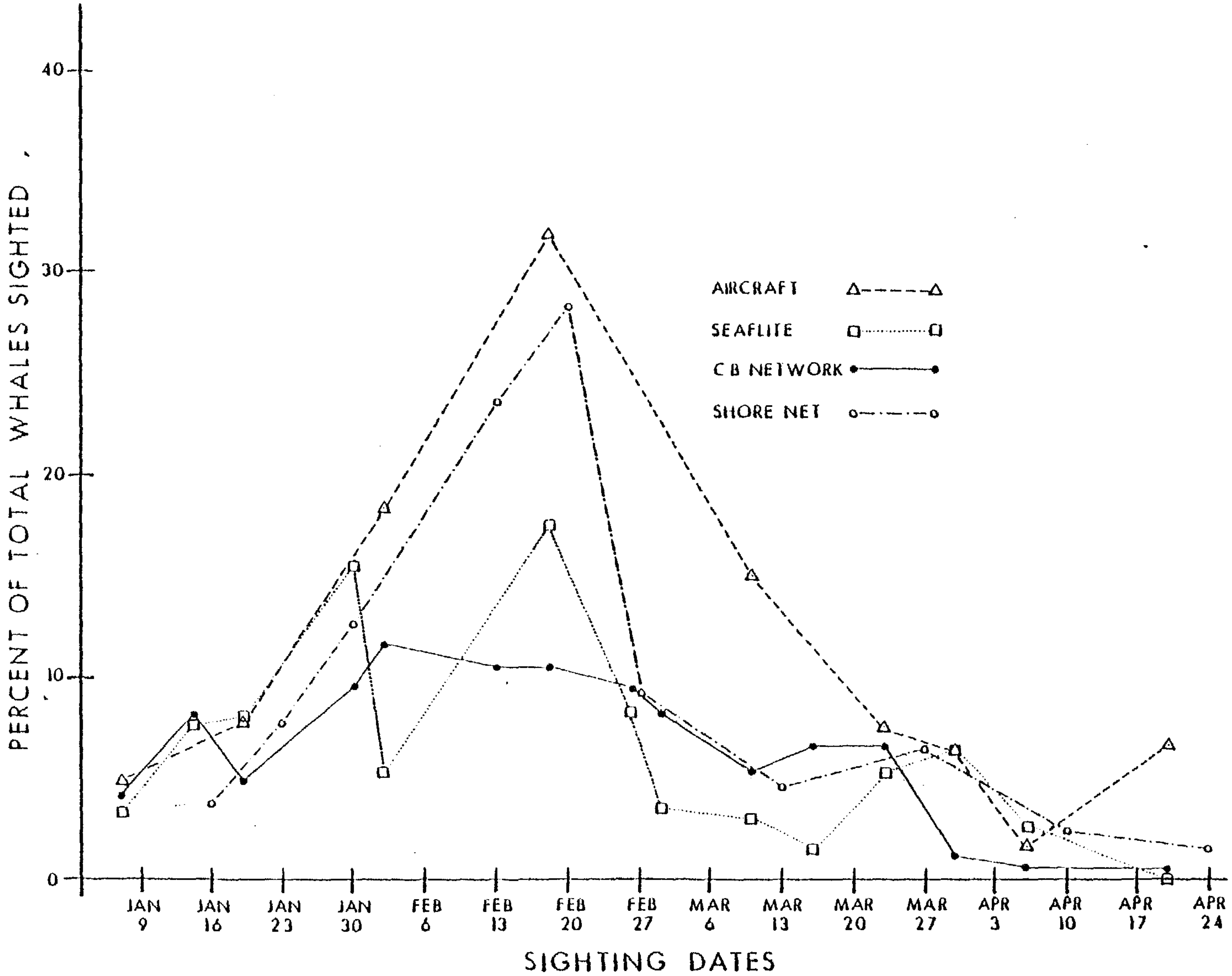


Fig. 6. The percentage of total whales sighted by a source of data on each max data day. Additionally shown are the percentage of total whales sighted during selected Sundays of the season by the network of shore observers.

Table 5

Summary of Sightings by Shore Network on Indicated Sundays

| Date | Sightings | Whales | Calves |
|---|---|---|---|
| Jan 16 | 9 | 20 | 1 |
| 23 | 12 | 41 | 1 |
| 30 | 31 | 66 | 2 |
| Feb 13 | 55 | 123 | 4 |
| 20 | 75 | 148 | 4 |
| 27 | 23 | 48 | 1 |
| Mar 13 | 15 | 24 | 1 |
| 27 | 15 | 34 | 1 |
| Apr 10 | 8 | 12 | 1 |
| 24 | 5 | 8 | 1 |
| Totals | 248 | 524 | 17 |

the entire month of February, with the relative maximum occurring on February 2nd. They also show a relative rise on January 14th. From these data, it appears as if whales may appear in sizeable number relatively early in the four-island region and somewhat later in regions to the northwest. The migration section of this report will discuss seasonal distribution trends more fully.

The aircraft and shorenet data, which cover the entire island chain, are remarkably similar in trends and are thus mutually supportive of each other. In Figure 6, both aircraft and shorenet data show a steep decline in relative numbers after the peak date. For the shorenet, the decline occurs within a period of one week. Because of bad weather, aircraft flights were postponed until March 10th following the peak period of February 18th, but probably would have revealed earlier declines if surveys had been made. This contention is supported not only by the shorenet data, but by the Sea Flite sightings which decreased steeply from February 18th to the 26th. The suddeness of the decline, as well as the suddeness of the earlier appearance of a large number of whales, is somewhat surprising, in view of the protracted period over which at least some whales are present from early November until early June, and in view of descriptions of migrations of Southern Hemisphere humpback whales in which the migration flow appears gradual (Dawbin, 1966). It would be important to determine whether these trends persist over successive seasons.

The data of Figure 6 are influenced by the prevailing sighting conditions. Table 6 summarizes the mean ratings of the sighting conditions on each max data day, as supplied by aircraft and shorenet reports, the only sources regularly providing weather data. Ratings of sighting conditions on the additional shorenet days plotted in Figure 6 are also given. To obtain a sighting rating, the weather and sea-state conditions reported by the observers were combined to yield four qualitative ratings: excellent = weather clear to cloudy-bright, seas calm to slight; good = weather as in excellent, but seas moderate with minor whitecapping; mediocre = weather clear to occasional light rain, seas moderate to rough with whitecaps in abundance; poor = weather clear to cloudy-dull, with very rough seas, high waves, whitecaps and spray. Both mediocre and poor imply windy conditions with moderate to heavy spray obscuring visibility. In general, sea state was considered a more crucial determinant of sighting condition than weather, unless lighting was poor or visibility obscured by haze, rain squalls, or the like.

Table 6 shows that mean sighting conditions over both aircraft and shorenet sources of data remained between excellent and good through to February 20th, with the exception of January 16th. Hence the data on the sudden appearance of large numbers of whales is not biased with respect to sighting conditions.

From February 26th to April 10th, with the exception of March 10th, the mean sighting ratings moved closer to or even beyond the mediocre category. Thus, a portion of the sudden decline noted in Figure 6 may reflect the poorer sighting conditions present after February 20th. That the majority of the decline is probably real, however, is indicated by several independent sets of data: (a) the cumulative March 10th data, obtained under near-excellent sighting conditions, which evidence the steep decline; (b) the February 27th shorenet data, obtained with sighting conditions not severely reduced, but

Table 6

Sighting Ratings Based on Weather and Sea State

for Maximum Data Days and Additional Shorenet Sighting Days

| | Mean Sighting Condition[a] | | |
|---|---|---|---|
| Date | Aircraft | Shorenet | Both[b] |
| Jan 7 | 1.11 | ---- | 1.11 |
| 16 | ---- | 2.50 | 2.50 |
| 19 | 1.00 | 1.75 | 1.16 |
| 23 | ---- | 1.84 | 1.84 |
| 30 | ---- | 1.71 | 1.71 |
| Feb 2 | 1.67 | 1.41 | 1.56 |
| 13 | ---- | 1.40 | 1.40 |
| 18 | 1.00 | 1.00 | 1.00 |
| 20 | ---- | 2.00 | 2.00 |
| 26 | ---- | 3.00 | 3.00 |
| 27 | ---- | 2.61 | 2.61 |
| Mar 1 | ---- | ---- | ---- |
| 10 | 1.00 | 2.00 | 1.09 |
| 13 | ---- | 3.10 | 3.10 |
| 16 | ---- | 3.11 | 3.11 |
| 23 | 3.07 | 3.50 | 3.17 |
| 27 | ---- | 2.27 | 2.27 |
| 30 | 2.17 | 2.37 | 2.29 |
| Apr 6 | 2.50 | 3.00 | 2.60 |
| 10 | ---- | 3.00 | 3.00 |
| 20 | 1.00 | 2.00 | 1.31 |
| 24 | ---- | 1.00 | 1.00 |

[a]Sighting code: 1= Excellent; 2= Good; 3= Mediocre; 4= Poor

[b]Weighted Mean

which nevertheless show the decline; and (c) by our daily field station observations (not reported in Figure 6) between late February and early March, which showed the decline even though there were a few good sighting days intervening in that period.

The conclusion seems forced that significant numbers of whales departed from the main observational areas in Hawaii during the last week of February or slightly later. It seems likely that the departure was part of an out-migration. Some of the departing whales appear to have relocated to the Kauai and Oahu areas temporarily from areas further east, as will be discussed in more detail in the migration section, while others may have left directly for northern waters.

Relative Usage of Subregions by Whales and Calves

Figures 7, 8 and 9 show the total numbers of whales (adults plus calves) and calves sighted by aircraft over all surveys, on max data days, within each of the indicated subregions of the various islands. Subregions (dotted lines) are areas of relatively constant orientation paralleling straight runs of coastline, or in the case of large open areas such as Penguin Bank, convenient partitions of the space into subspaces. Regions (solid lines), discussed in a following section, consist of two or more subregions, though in a few cases they are the same as a subregion. The subregions reveal the detail of usage and are also important for interpreting movement directions, the subject of a later report. Regions are more functional for interpreting seasonal trends. Being generally larger areas than subregions, they encompass more sightings and provide a more reliable data base. The different subregions are not equivalent in area, nor are the different regions. Relative usage must be interpreted within that context.

The aircraft data in Figures 7, 8 and 9 were considered the most representative, among the various data sources, of the relative usage of subregions. Unlike other data sources, the aircraft devoted approximately equal observational effort to almost all of the subregions within a survey area.

The Maui complex was surveyed more often than were the Oahu-Kauai-Niihau areas, which in turn were surveyed more frequently than was the island of Hawaii (Table 1). Unfortunately, one cannot simply divide the counted whales in each figure by the total number of surveys comprising that figure to obtain comparisons of mean usage, because the number of whales seen in part depended upon the survey date. Within each figure, however the relative usage numbers are unbiased, or nearly so.

Kauai-Niihau-Oahu. The Kauai-Niihau data (Fig. 7) reveal relatively heaviest usage in the southeast portion of Niihau, where 18 whales and 1 calf were sighted. By these data, use of this subregion exceeds that of a number of the coastal subregions of the west Maui area (Fig. 8), which are commonly considered important whale habitats. Niihau, with a total of 30 whales, including 2 calves, seems to be a preferred habitat to Kauai, with a total of ten whales sighted. Although some animals were seen in the 15-NM wide Kaulakahi Channel between Niihau and Kauai, during our surveys, and by Barking Sands personnel during their flights, there does not seem to be a continuity in the distribution of the population from one island to the other. On our

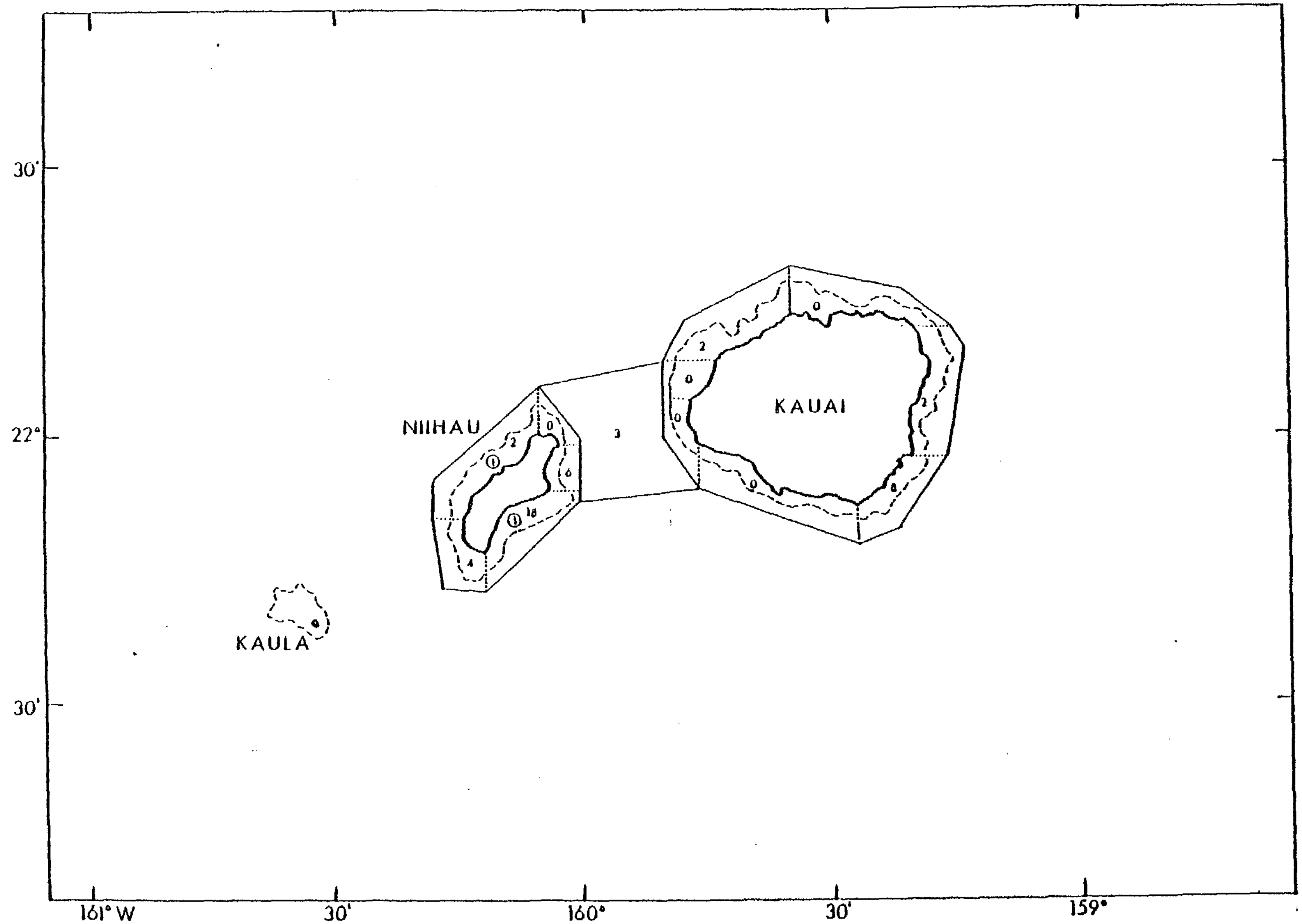


Fig. 7. The total number of whales and calves seen in each indicated subregion of Kauai and Niihau over all chartered aircraft surveys. The total of whales and calves is shown by the uncircled numbers. The subtotal of calves is shown by the circled numbers.

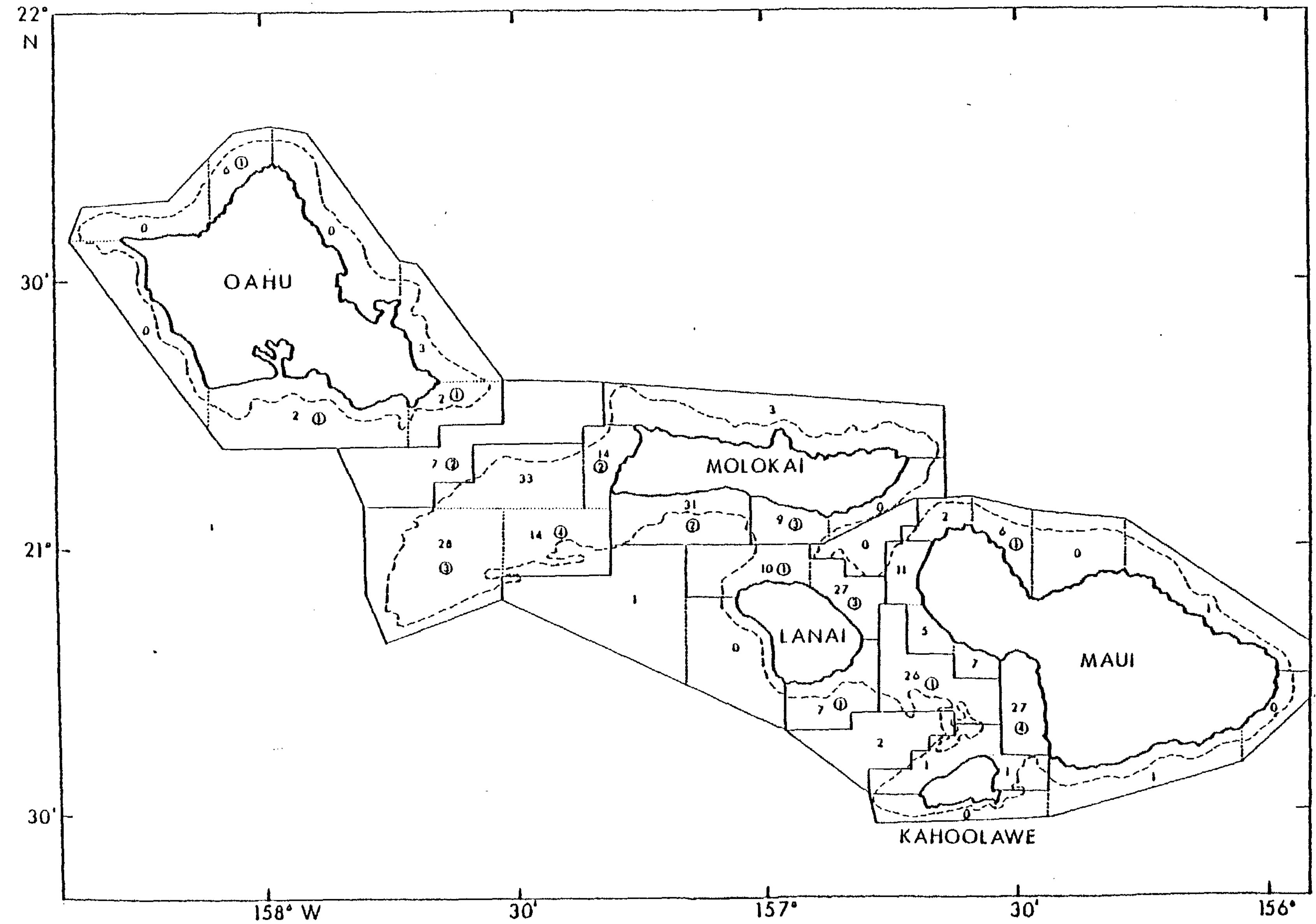


Fig. 8. The total number of whales and calves seen in each indicated subregion of Oahu, Penguin Bank, and the four-island area over all chartered aircraft surveys. The total of whales and calves is shown by the uncircled numbers. The subtotal of calves is shown by the circled numbers.

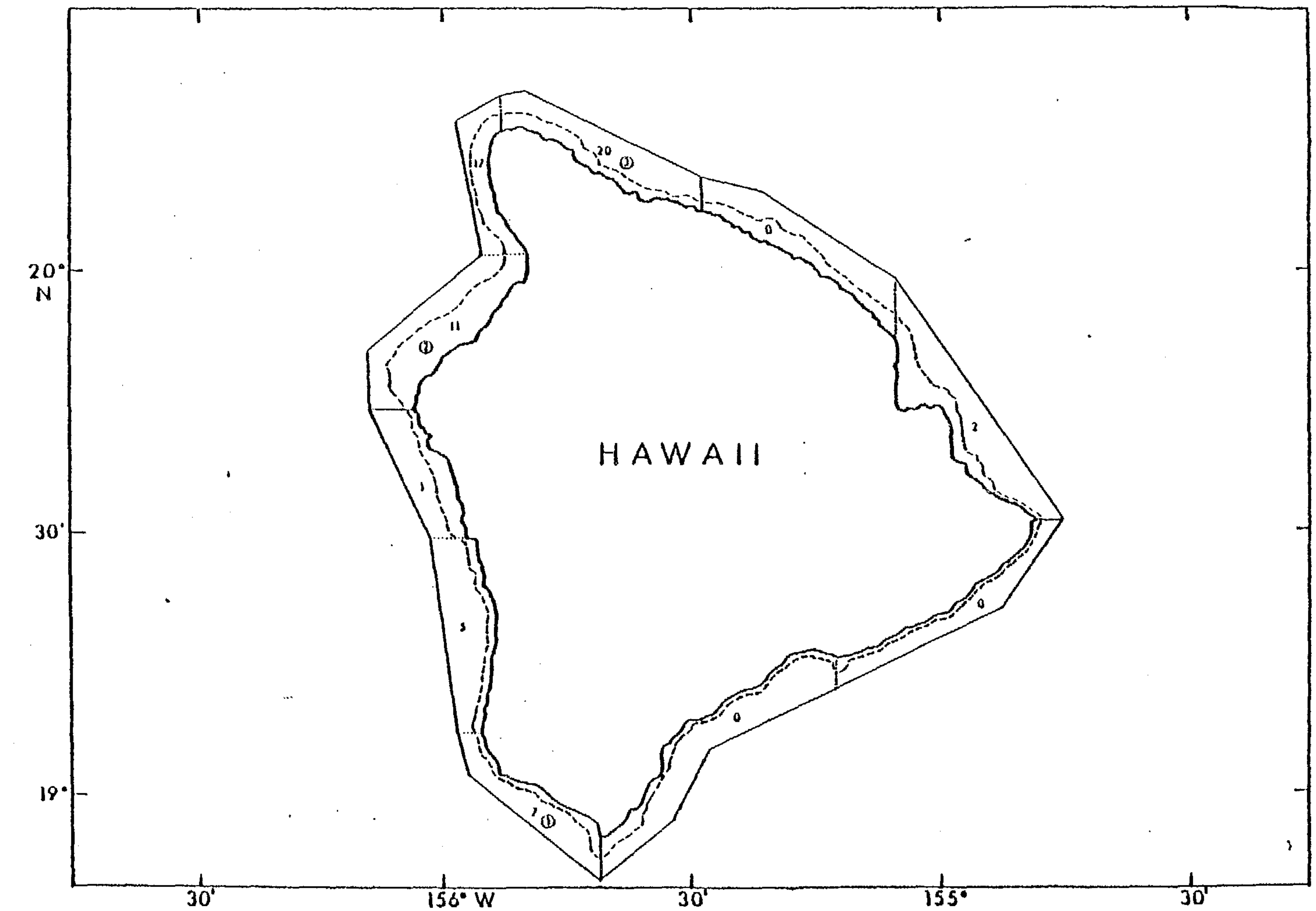


Fig. 9. The total number of whales and calves seen in each indicated subregion of Hawaii over all chartered aircraft surveys The total of whales and calves is shown by the uncircled numbers. The subtotal of calves is shown by the circled numbers.

survey flights, whales were not seen along the coasts of Kauai closest to Niihau. Barking Sands personnel have encountered whales there on occasion, as have some shore observers, but the major concentration on Kauai seems to be on the coast furthest from Niihau.

Two calves were seen on Niihau and none on Kauai. The calf seen on the northwest shore lay next to its mother in the still waters of the bay, and seemed to be nursing. It appeared to be quite small.

Figure 8 reveals the relatively low usage of Oahu as compared with the four-island region. The Oahu data should be compared with the data of Figure 7 because they were largely collected on the same flights that surveyed Niihau and Kauai. On that basis, Oahu usage is considerably less than Niihau but barely less than Kauai. Oahu becomes more important late in the season as a temporary habitat, as does Kauai (see next section). The relatively most important subregion on Oahu is the north sector, with six whales, including one calf, sighted.

Four-Island Region. The remainder of Figure 8 shows the heavy usage of portions of the four-island region, including Penguin Bank. There seems to be little regular movement between Penguin Bank and Oahu, judging by the relatively few whales sighted in Kaiwi (Molokai) Channel. The southwest and northern subregions of Penguin Bank with 28 and 33 whales, respectively, had the relatively greatest usage. Calves were sighted more commonly in the southern half of the Bank (7 calves) than in the northern portion (2 calves).

Many whales (31) were seen along the southwest coast of Molokai and relatively few (9) along the southeast coast, although there were more calves (3) seen in the latter subregion than in the former (2). Possibly, whales of the southwest coast are continuous with the Penguin Bank population. One of our regular shore observers, Joan Aidem, stationed on the southwest coast of Molokai at Kolo Wharf, reported on February 27 her impression from cumulative sightings, that a mass of whales sweeps west down the coast of Molokai early in the morning and returns in the opposite direction in the afternoon, passing Kolo Wharf generally between 1530 to 1800 hours. She noted that on windy, rough days the whales seemed to head eastward much earlier. This description sounds very much like a daily movement between Penguin Bank and the south coast of Molokai.

In the remainder of the four-island region between Molokai, Lanai, Maui, and Kahoolawe, there was a band of most intense relative usage encompassing the subregion on the northeast coast of Lanai (27 whales), the mid-Auau Channel subregion (26 whales), and the Kihei coast of Maui from McGregor Point to Cape Kinau (27 whales). The collective count for the three near-shore regions bordering the coast of west Maui from Napili to McGregor Point was 23 whales. This is surprisingly light considering that shore observers and the CB net regularly report large numbers of whales in these subregions. It may be that the numerous reports principally reflect the large observer effort put into these coastal areas. The bulk of the whales in reality seem to be in subregions further seaward or along less populated coasts.

There is a widespread distribution of calves throughout the various subregions of Figure 8. The northeast coast of Lanai (3 calves), the Kihei region of Maui (4 calves), and the southwest coast of Molokai (3 calves), and the two southerly subregions of Penguin Bank contained the relatively greatest numbers of calves. The presence of many calves along the Lanai northeast coast is confirmed by close-hand observations from the field station. The Kalohi Channel nearshore areas, especially the northeast coast of Lanai, the Kihei region of Maui, and the south coasts of Molokai appear to be the most important calf-rearing areas in the four-island complex. Penguin Bank, outside of the four-island area is also important.

Hawaii. Finally, Figure 9, for Hawaii, shows highest usage in the subregions surrounding and near Upolu Point. Twenty whales, including three calves, were sighted in the subregion adjoining the north coast of Upolu Point, 17 along its west coast, and 11 further south to Keahole Point. Subregions of lesser importance, but still significant usage, occur at the southeast portion of the island. We again find calves most common where whales are most common.

Usage Patterns. From Figures 7 to 9, a striking usage pattern emerges, of importance in assessing habitat preferences of whales. By and large, whales tend to be found in relatively greatest numbers in subregions that are most remote from areas of dense human population or human use. Thus, Niihau is preferred to Kauai. Oahu is little used, with the exception of the rural coastline of the north shore. The south coast, encompassing the Honolulu and Pearl Harbor areas, is little used. Penguin Bank has many whales, as does the remote southwest coast of Molokai. Fewer whales are seen near Kaunakakai. The uninhabited northeast coast of Lanai is highly preferred as is mid-Auau Channel and the rural area of the Kihei coast. Along the heavily populated southeast coast of west Maui, there is relatively lesser usage. On Hawaii, the areas along Upolu Point are nearly uninhabited by humans, while the lesser used central western coast (Kona coast) is heavily populated. This is not to say that human population is the only factor determining habitat preference. Deep water areas, such as Pailolo channel between Molokai and Maui, are little used except probably for ingress or egress. Also, there are some subregions with little human habitation that are little used by the whales, e.g., west Lanai. The windward areas of some of the islands are not used much, but this may reflect the limited extent of shallow water available. The high usage of the northeast coast of Hawaii shows that prevailing wind conditions may not be a major factor in determining usage. Also, Penguin Bank is regularly exposed to strong, gusty trades, but is highly preferred. North Kahoolawe is little used and has no human habitation, but is regularly bombed by low-flying military aircraft. The simplest generalization is that the whales tend to avoid areas of dense human habitation or use, selecting instead from among the remaining subregions of lesser habitation. In such selection, multiple criteria are undoubtedly used.

## Seasonal Trends in Usage of Regions

Table 7 summarizes seasonal trends on relative usage of regions by whales, based on all sources of data. For some regions, observations were not made on all max data dates. Nevertheless, marked differences in usage of different regions are apparent and some interesting seasonal trends occur. The underlining in Table 7 indicates the date on which peak usage of a region occurred. For almost all regions this was sometime in February, consistent with the overall data on peak periods in Figure 6. Somewhat earlier peak usage occurred in mid-Auau Channel (January 30th); in the Ka Lae to Cape Kumakahi

Table 7

Total Numbers of Whales Sighted in Each Region

By Date for All Data Sources Combined

| REGION | JANUARY 7 | 14 | 19 | 30 | FEBRUARY 2 | 13 | 18 | 26 | MARCH 1 | 10 | 16 | 23 | 30 | APRIL 6 | 20 | ALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIIHAU: | | | | | | | | | | | | | | | | |
| All Coasts | 7 | | | | 11 | | 7 | | | | | | | | | 25 |
| KAULAKAHI CHN: | | | | | | | | | | | | | | | | |
| Niihau-Kauai | 3 | | 2 | | 1 | | | | | | | | | 2 | | 8 |
| KAUAI: | | | | | | | | | | | | | | | | |
| All Coasts | | 9 | 3 | 18 | 15 | 24 | 14 | | | | 14 | 1 | 31 | 3 | 6 | 138 |
| OAHU: | | | | | | | | | | | | | | | | |
| All Coasts | | | 2 | 2 | 8 | 17 | 1 | 3 | 3 | 6 | 1 | 12 | 3 | 8 | 3 | 69 |
| KAIWI CHN: | | | | | | | | | | | | | | | | |
| H'lulu-Penguin Bank | | | 4 | 2 | 4 | 11 | 1 | | | 3 | | 1 | 4 | | | 30 |
| PENGUIN BANK: | | | | | | | | | | | | | | | | |
| Entire Area | | 1 | 15 | 25 | 19 | 8 | 60 | 13 | 2 | 22 | 4 | 13 | 5 | 1 | 7 | 198 |
| MOLOKAI: | | | | | | | | | | | | | | | | |
| Ilio-Halawa | | | 1 | 2 | | | | | | | | 3 | 2 | | | 8 |
| Laau-Kaunakakai | 2 | 2 | 2 | | 2 | 1 | 11 | | | 3 | | 4 | 5 | | 8 | 40 |
| Kaunakakai-Halawa | 4 | 3 | | 3 | 2 | 6 | 2 | | 1 | | | 1 | 6 | | | 29 |
| LANAI: | | | | | | | | | | | | | | | | |
| Kaena-Palaoa | | | | | 1 | 6 | 2 | 3 | 3 | | | 1 | | | | 16 |
| Palaoa-Kikoa | 3 | 2 | 1 | | 16 | 8 | | 2 | 4 | 1 | 2 | 3 | | | | 42 |
| Kikoa-Kaena | 11 | 9 | 15 | 20 | 20 | 21 | 47 | 22 | 3 | 9 | 11 | 8 | 31 | 3 | 11 | 241 |
| PAILOLO CHN: | | | | | | | | | | | | | | | | |
| Deep Water | 7 | 16 | 9 | 6 | 1 | 10 | 13 | 7 | 1 | | | | 1 | | 1 | 72 |
| MAUI: | | | | | | | | | | | | | | | | |
| Hana-Napili | | 3 | 1 | 2 | 3 | | 1 | 6 | 2 | | | 5 | 5 | | 2 | 30 |
| Napili-McGregor | 21 | 43 | 7 | 27 | 24 | 71 | 52 | 35 | 17 | 34 | 44 | 42 | 2 | 10 | 5 | 434 |
| McGregor-Kinau | 7 | 8 | 15 | 38 | 35 | 48 | 14 | 10 | 25 | 14 | 5 | 1 | 7 | | | 227 |
| Kinau-Hana | | | | 4 | 2 | | | | | | | | | | 1 | 7 |
| MID-AUAU: | | | | | | | | | | | | | | | | |
| Lanai-Maui-Kahoolawe | 3 | 4 | 19 | 32 | 23 | 25 | 28 | 7 | 11 | 9 | 3 | 13 | 6 | 3 | | 186 |
| KAHOOLAWE: | | | | | | | | | | | | | | | | |
| NW and E Coast | | | | 5 | | 3 | 1 | 2 | 6 | 1 | | 5 | | | | 23 |
| KEALAIKAHIKI CHN: | | | | | | | | | | | | | | | | |
| Lanai-Kahoolawe | | | 2 | | 6 | 1 | | | | | | | | | | 9 |
| HAWAII: | | | | | | | | | | | | | | | | |
| Upolu-Keahole | | | 5 | | 11 | 1 | 11 | | | 3 | | 2 | | | | 33 |
| Keahole-Ka Lae | | | | 2 | 8 | 3 | 7 | | | 1 | | | | | | 21 |
| Ka Lae-C Kumukahi | | | 10 | | 1 | 3 | | | | | | | | | | 14 |
| C Kumukahi-Upolu | | | | 8 | 2 | | 22 | | | | | | | | | 32 |
| TOTALS: | 68 | 100 | 117 | 196 | 215 | 267 | 294 | 110 | 78 | 135 | 84 | 116 | 108 | 30 | 44 | 1932 |

region of Hawaii (January 19th), though coverage of this area by observers was spotty; and in the Pailolo Channel region (January 14th). The data are suggestive that the earliest arrivals at the island of Hawaii are at its southeast side, though the regions of most intense seasonal use are on the northwest and northeast sides. Possibly, these early arrivals have come from a northeasterly direction, and slightly missing the northeast point, Cape Kumakahi, strike the coast at southeast Hawaii first.

An interesting early usage of the four-island region is indicated by an observation of 16 whales in the Pailolo Channel area on January 19th. Additionally, there was a report on January 18th from the vessel Viva of the CB-net of 12 to 15 whales near the southeast portion of Pailolo Channel. On January 17th, there was a report from another vessel of "too many whales to count" off north Lanai, not far from where the tongue of Pailolo extends into Kalohi Channel (Fig. 1). On January 14th, a vessel reported a "whole bunch" of whales near the Seven Sacred Pools area just south of Hana, Maui. These data hint at an arrival from the north or northeast of Maui with animals proceeding down the Pailolo Channel to the main Auau and Kalohi Channel assembly areas, or else proceeding clockwise around east Maui from Hana and entering the four-island water via the channel between Maui and Kahoolawe. Very early arrivals appearing in the four-island region seem to be lone animals or, at times, pairs. The first whale report in the 1976/77 season was from Sea Flite on November 3, 1976 of an animal 6 nm west of McGregor Point, Maui. The next sighting by Sea Flite was on November 22 of a whale near Koko Head, Oahu and then from the 22nd to the 30th of November, a total of 14 whales, all singletons or groups of two, were seen in the four-island region. There was also an early report on November 30 from N.O.A.A. research vessel Townsend Cromwell of three whales on the southwest tip of Penguin Bank. In contrast, at Kauai, the earliest report, based on hearing of whale songs, was on December 30, 1976.

The data in Table 7 on late usage reveal an extraordinary number of whales at Kauai on the 30th of March, and also relatively large numbers, though not a maximum, around Oahu on the 23rd of March. Our observations (not cited in Table 7) of significant numbers of whales around north Oahu in late April and May support the Oahu late-season trend in Table 7. A relatively high proportion of the sightings were of calves. The combined data from Kauai and Oahu may indicate a massing of animals prior to late out-migration around these two islands. Paradoxically, though the earliest arrivals seem to approach from the north or northeast, the latest departures appear to leave from the northwest sector of the main Hawaiian Island chain.

Over the entire season, the regions of heaviest usage (100 or more animals) based on all reporting sources were, in order, the Napili to McGregor coast of Maui (431 whales); the north and northeast coasts of Lanai from Kaena Point to Kikoa Point (241); the Kihei coast of Maui from McGregor Point to Kinau (227); Penguin Bank (198); the mid-Auau Channel (186); and all coasts of Kauai (138). We noted previously that there are biases inherent in the combined data from all sources, reflecting uneven observer effort across regions. The unbiased aircraft data give much lesser density estimates for the Napili to McGregor regions of Maui than do the combined sources, a number of which were concentrated in that region. Penguin Bank and Niihau would undoubtedly stand relatively higher than indicated were they sampled by more data sources. Only the chartered aircraft and the Sea Flite cruises reported on Penguin Bank, and the chartered aircraft and Barking Sands flights were the only sources of data for Niihau.

Migration

Attempts to determine the migratory routes of the whales into and out of the Hawaiian Islands included surveys of the Northwest Hawaiian Islands by aircraft and surface vessel, flights along the northern perimeter of the main islands from Oahu to Maui at distances of from 10 to 15 nm from coastal areas (Fig. 2), and study of the aggregations appearing late in the season around the north coast of Oahu.

Northwest Hawaiian Islands. No whales were seen during any of our inspections of the Northwest Hawaiian Islands. The earlier inspections, from 2 November, 1976 through to 2 February, 1977, would be expected to have uncovered in-migrants, if significant numbers were following the chain of islands southwesterly to the main islands. The later inspections, from 23 February through 20 April 1977, ought to have revealed out-migrants, if significant numbers were following the chain northwesterly. We did receive notice of a sighting by Karl Kenyon on French Frigate shoals of a humpback whale mother and calf sighted on February 17th off-shore of the shoals in "green water." The calf was reported to be less than one third the length of the mother. This sighting, and one or two others at widely separated times by the surface vessel Easy Rider, can be considered "stragglers."

We also inquired of residents of Midway Island whether any whales had been sighted there at any time in the past. With the exception of a mother and a calf, species undetermined, swimming between Midway Island and Kure Atoll about six years ago, reports were uniformly negative. Also, NAVFAC personnel on Midway reported detecting no whale songs on their monitoring gear (which gives a visual analog of acoustic energy). It seems then that Nishiwaki's (1972) statement that humpback whales are commonly seen around Midway Island in winter is mistaken. In summary, the evidence gathered for this report strongly indicates that the main humpback whale population wintering in Hawaiian waters does not pass through the Northwest Hawaiian Islands during migration.

Waters Immediately North of Oahu and Maui. Aircraft surveys flown north of Oahu and Maui (Fig.2) on 2 February and 10 march 1977 also yielded no sightings. The first flight was approximately two weeks prior to the peak period of residency of the whales in Hawaiian waters and the second one to two weeks after the period of rapid decline in population (Fig. 6). One might have expected the interception of some whales if large numbers were migrating southward or southwesterly toward Maui at the first flight or northwesterly away from it during the second flight. However, the timing of the flights may have been sufficiently displaced from the peak migration interval to have made sighting probabilities low. These probabilities are further reduced by the wide expanse of ocean to be covered, the fairly short sampling period of the aircraft, and the fact that the whales may migrate at any hour including at night. It is also possible that the aircraft failed to pass over the main migration routes. The data discussed in the previous section on seasonal trends indicated some tendency for early arrivals to appear at the northeast portions of Maui and Hawaii. If so, we would have failed to cross most of that path, except for the final in-bound leg near Maui.

Late-Season Aggregations. Table 8, derived from the data in Table 7, shows the percentage of the total sightings for all regions that were at Kauai and at Oahu during the months of January, February, March, and April of 1977. For both islands, the percentage tends to rise as the season progresses. The steepest rise occurred during March and April at Kauai and during April at Oahu. This may indicate that many whales move towards these two islands late in the season before departing to their summer feeding areas. This may be especially true for mothers with calf, which seem to be among the last classes of whales to out-migrate. Other classes of whales may tend to use other departure routes. During our nearly daily observations at Kaena Point, on Oahu's northwest corner, a total of 71 whales were seen between 10 April and 2 June 1977. Of these, 15 were mother-calf pairs, comprising 30 of the 71 sightings. During the cruise of the University of Hawaii vessel Noi'i on 30 April, 1977 from Waimea Bay on North Oahu to Kaena Point, then to Honolulu, a total of 27 whales were counted in nine groups. The 27 included four calves.

Overview. In summary, the composite migration picture suggests that the earliest arrivals tend to be single animals or pairs. Later arrivals may appear in relatively large groups. Some of these groups may enter the four-island region via the Pailolo Channel, perhaps intercepting Maui at points to the northeast. Other groups seem to arrive early at Hawaii from a northeast direction. It may be that those whales seen at northeast Maui have crossed the channel from Hawaii. In any event, from the four-island region some of the population may disperse westward to Kauai, Niihau, and perhaps Oahu. The first arrivals in Kauai that we were aware of were more than a month after the earliest reported arrivals in the four-island region.

The out-migrants in the earliest stages of the return migration e.g., in early March, may leave directly northward through the Pailolo and Alenuihaha channels. We have little data to confirm this, however, During the later portion of the out-migration, many whales seem to move towards Oahu and Kauai, remain there for a while, and then depart. The direction of the final seaward move from these areas is still unknown. Neither in-migration nor out-migration occurs to any significant degree through the Northwest Hawaiian Islands.

## Calves and Calf Pods

Composition and Size of the Pod With Calf. There were 93 sightings of calves over the 15 max data days, based on all sources of data (Table 3). As with our previous observations of the Hawaiian population (Herman & Antinoja, 1977), pods with more than one calf were never seen, suggesting that mothers with calf avoid other mother-calf pairs. Herman and Antinoja reported that the most common calf-pod consisted of the mother, calf, and a single adult "escort" whale. This arrangement characterized 48% of the calf-pods reported by them during their Winter/Spring 1976 sightings. During the Winter/Spring 1977 sightings summarized in this paper, the trio arrangement characterized 45% of the calf-pod sightings (Table 9), a remarkably close correspondence.

For the Winter/Spring '77 sightings, there was an increase in the percentage of sightings of unescorted mother-calf pairs over that seen during the Winter/Spring '76 season--29% of all calf-pod sightings were of unescorted pairs in 1977 as compared with 17% in 1976. However, the 1976 data were based on sightings from the end of February onward, while the 1977 data included

Table 8

Percentage of Total Whales Counted that Were at Kauai and Oahu During Months of the 1977 Season: All Data Sources Combined

| Island | January | February | March | April |
|---|---|---|---|---|
| Kauai | 6.2 | 6.0 | 7.4 | 12.2 |
| Oahu | 0.8 | 3.3 | 5.1 | 14.7 |

Table 9

Frequency of Occurrence of Different

Size Pods With Calf on Each Max Data Day

| DATE | | Pod Size (incl. calf) 2 | 3 | 4 | 5 | 6+ | Total Calves |
|---|---|---|---|---|---|---|---|
| Jan | 7 | 0 | 2 | 0 | 0 | 0 | 2 |
| | 14 | 1 | 2 | 0 | 0 | 0 | 3 |
| | 19 | 0 | 3 | 0 | 0 | 0 | 3 |
| | 30 | 3 | 2 | 0 | 0 | 0 | 5 |
| Feb | 2 | 6 | 2 | 3 | 0 | 1 | 12 |
| | 13 | 4 | 6 | 1 | 0 | 0 | 11 |
| | 18 | 5 | 4 | 4 | 2 | 0 | 15 |
| | 26 | 0 | 2 | 0 | 0 | 0 | 2 |
| Mar | 1 | 2 | 1 | 0 | 0 | 0 | 3 |
| | 10 | 3 | 5 | 2 | 0 | 1 | 11 |
| | 16 | 0 | 1 | 0 | 0 | 0 | 1 |
| | 23 | 1 | 8 | 0 | 1 | 1 | 11 |
| | 30 | 1 | 3 | 1 | 2 | 0 | 7 |
| Apr | 6 | 1 | 1 | 0 | 0 | 0 | 2 |
| | 20 | 0 | 0 | 3 | 2 | 0 | 5 |
| Total | | 27 | 42 | 14 | 7 | 3 | 93 |
| | % | 29.0 | 45.2 | 15.1 | 7.5 | 3.2 | |

observations during January and early February. Table 9 shows that in January and early February, there was a large percentage of unescorted mother-calf pairs. Figure 10 reinforces this observation, demonstrating that there is a sizeable increase in the mean size of the pod with calf (i.e. in the number of whales accompanying the mother-calf pair) as the season progresses. The mean size of all-adult pods (pods without calf) did not change correspondingly. The increase in the size of the calf-pod was therefore not an artifact reflecting general increases in size of whale groups as the season unfolded.

From the data of Table 9 and Figure 10, a pattern emerges suggesting that young calves may often be accompanied only by the mother. Herman and Antinoja (1977) have suggested that an early period of isolation with the mother may allow for the formation of a strong mutual social attachment. Following the initial period of isolation, the mother-calf pair may then be joined by an escort (or escorts) which we hypothesize serve, in part, a protective function. Whether the mother-calf pair seeks out other whales, or other whales are attracted to the pair, and join them, is unknown. Perhaps, once the mother has recovered enough from the parturition experience to travel about, and/or the calf strengthens sufficiently, the pair simply enters areas of denser habitation by whales (e.g., see Figures 7, 8 and 9), and a reciprocal attraction between the pair and other whales occurs.

To some degree, then, the number of whales accompanying the mother-calf pair may reflect how long the pair has been in contact with other whales. This raises the interesting possibility of broadly estimating the calf's maturity according to the size of the pod in which it is found. The larger the size of the pod, the older the calf may be, at least within the limits of the months from January through April.

<u>Temporal Distribution of Calves</u>. Table 9 shows that calves were seen from early January through late April, during each of our max data days. Additionally, calves were seen as late as the end of May during our shore observations from Kaena Point, Oahu, as was noted earlier. Figure 11 summarizes the data of Table 9, and shows the mean number of calves sighted during each max data day within each month of the season. The temporal distribution of relative calf abundance in Figure 11 is very similar to that found for all whales, shown earlier in Figure 6. The steep increase in mean calf sightings in February and the decline thereafter indicate that the peak calving period was in February, assuming the majority of the calves are indeed born in Hawaiian waters rather than during the southbound migration. Judging by the presence of some unescorted mother-calf pairs seen in March and April (Table 9), it appears that several calves may have been born during those late months.

Calves, along with their mothers, may remain in Hawaiian waters for relatively protracted periods. This is demonstrated by Figure 12, showing that as the season progressed there was an increase in the percentage of total whales sighted that were calves. Also, Figure 13 shows a nearly linear seasonal increase in the percentage of total pods sighted that contained a calf. Taken together with Figure 11, which revealed a seasonal <u>decrease</u> in the absolute number of calves sighted, the interpretation of Figures 12 and 13 is that there was a selective, continuing out-migration of classes other than mother-calf pairs as the season progressed, increasing the relative proportion of calves and calf-pods. A rough guess from these data is that a mother-calf

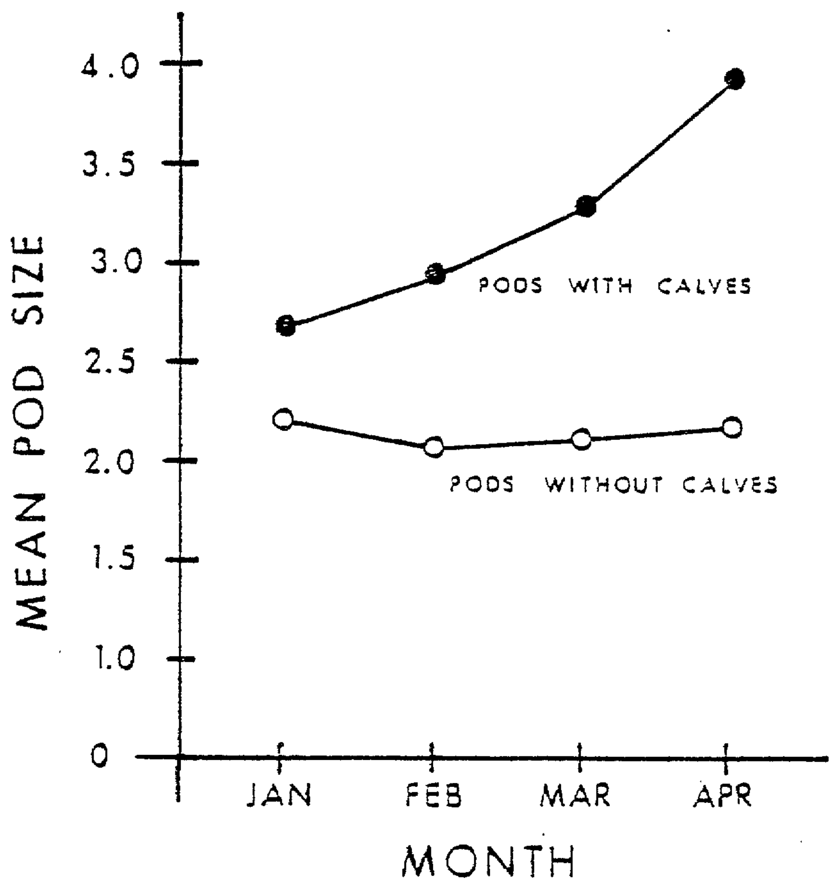


Fig. 10. The mean pod size (number of whales) for pods with calf and without during the maximum data days within each month.

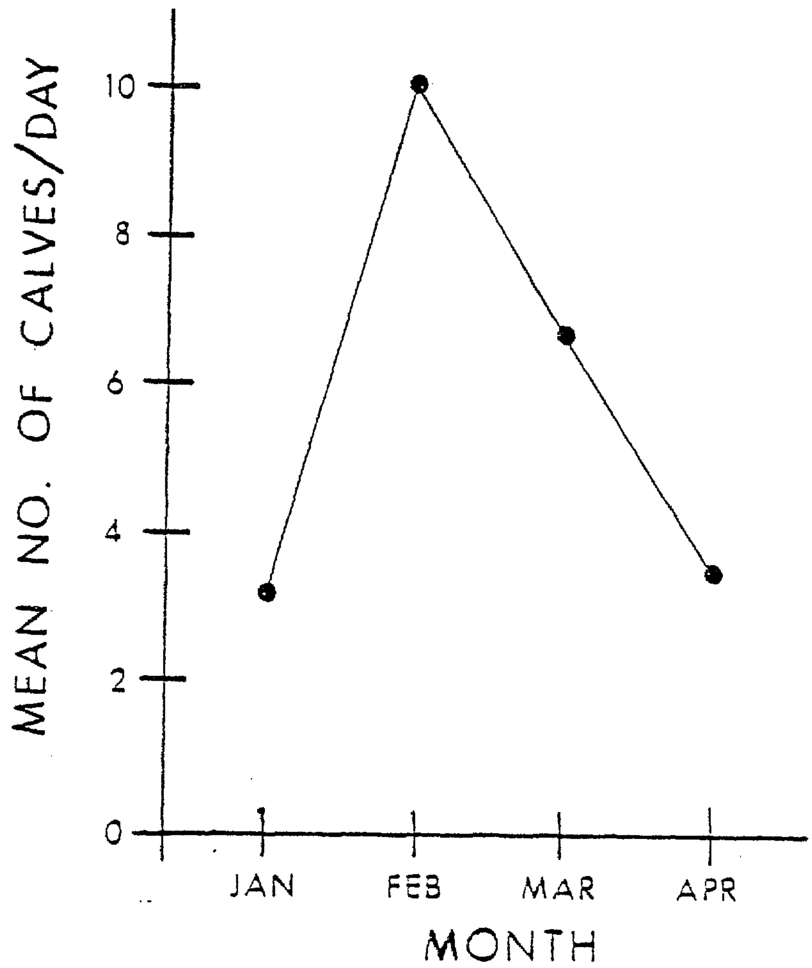


Fig. 11. The mean number of calves seen per maximum data day within each of the four months, based on all sources of data.

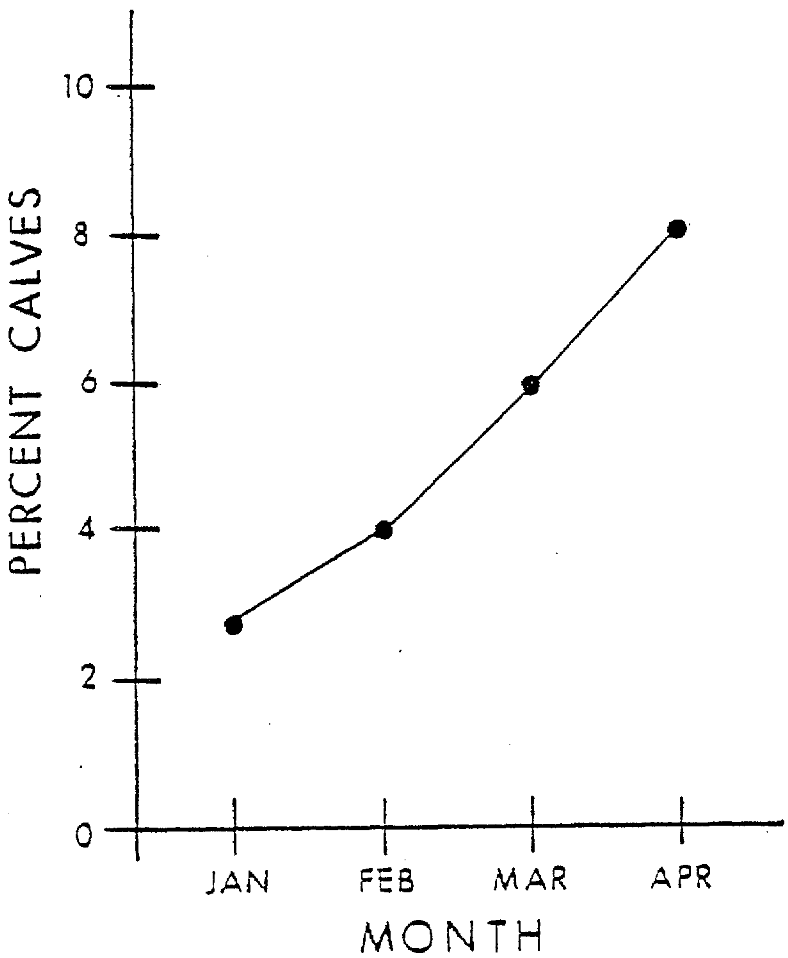


Fig. 12. The percentage of total whales sighted which were calves, during the maximum data days of each month.

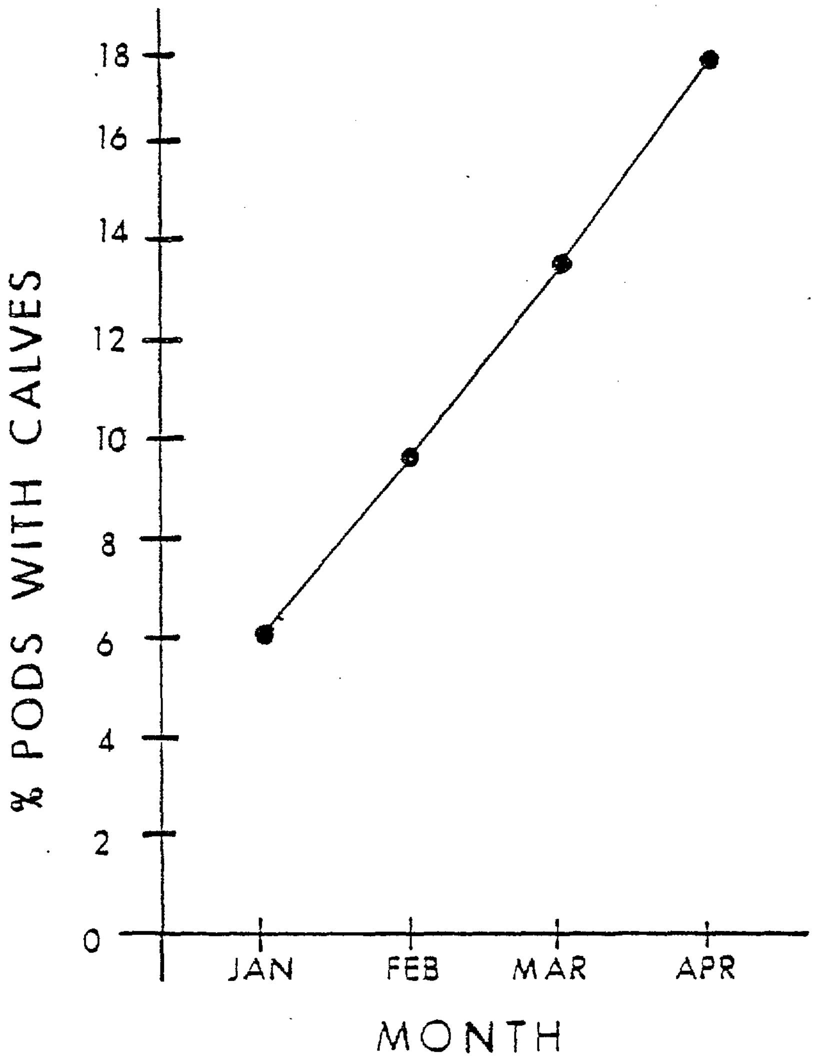


Fig. 13. The percentage of pods sighted that had a calf, during the maximum data days of each month.

pair may remain in Hawaiian waters for between five to eight weeks before finally out-migrating. Other classes of whales may remain for shorter periods.

Spatial Distribution of Calves Seasonally. Figures 7, 8, and 9 give the cumulative spatial distribution of calves over all max data days combined. Many of the subregions favored by mother-calf pairs were those favored by other whales as well. There were some exceptions, such as the Niihau region and the southeast coast of Molokai.

The data on seasonal distribution of calves reveal a westerly and northwesterly shift in concentration of calves as the season progressed, consistent with the general seasonal shift for all whales noted earlier. In Table 10, the number and percentage of calves sighted in various large regions is indicated for the combined January-February period and for the combined March-April period. In the first time period, 84.9% of the calves sighted were in the four-island region or in Hawaii, in what may be called the easterly half of the main island chain. In March and April, this percentage declined to 57.5%, with the largest relative decrease occurring at Hawaii. The largest relative increase in April was at Oahu, and the largest absolute increase at Penguin Bank. The westward spatial shift appeared to continue past April 20th, the last max data day contributing to the data of Table 10. We have previously mentioned our ship survey of the north and west coasts of Oahu on April 30th, 1977, which yielded a count of four calves, and our continued sightings of calves near Kaena Point, Oahu, throughout much of May, 1977. The seasonal shift may be part of a gradual northwesterly out-migration route through the main islands taken by some mothers, but this requires further study.

## Interactions of Whales With Boating Traffic

A boat observed within a one-quarter mile radius of a pod was defined as "in the vicinity" of the whales. Sea Flite and vessels of the CB-net are surface craft, and sightings reported by either source in actuality may be instances of a boat in the vicinity of whales. Reports from these sources did not include the distance of the sighting from the boat, or whether the observer's vessel approached the pod after the initial sighting, and are therefore not included in our data on boat-whale interactions. The voluminous data collected from these sources leave little doubt, however, that in in the four-island region, boats may frequently be within the vicinity of whales (c.f. Appendix to this report).

During aircraft surveys of the whales, information was collected on boat activity near whales. The information was also requested from shore observers (Fig. 3), though individual observers varied greatly in their attention to this category of information. We therefore limited our data to the aircraft reports and to the shore forms for which a positive notation on boat activity was made. Of a total of 62 reports of boats in the vicinity of whales, subsequent closer approaches by the boats were reported in 14 cases (22.6%). The 62 pods with boats nearby represent 117 whales, and the 14 pods approached contained 29 whales, or 24.8% of the total. If we can generalize from this sample result, it would appear that 20 to 25% of boats in the vicinity of whales may attempt to approach closer.

Our observations of responses of the whales to aircraft and surface vessels confirmed earlier descriptions of responses of whales in the 1976

Table 10

Number and Percentage of Total Calves Sighted Seasonally in Each Indicated Area.

| AREA | January-February N | % | March - April N | % |
|---|---|---|---|---|
| Kauai - Niihau | 5 | 9.4 | 4 | 10.0 |
| Oahu | 1 | 1.9 | 5 | 12.5 |
| Penguin Bank | 2 | 3.8 | 8 | 20.0 |
| 4 Island Region | 39 | 73.6 | 21 | 52.5 |
| Hawaii | 6 | 11.3 | 2 | 5.0 |
| TOTALS | 53 | 100.0 | 40 | 100.0 |

assembly (Herman, 1977; Herman & Antinoja, 1977). Though there were many cases in which whales showed no apparent response to the presence of an aircraft or surface vessel, in other cases defensive responses such as pod dispersal, sounding, evasive underwater swimming, and maintaining distance occurred. For pods with calf, the sheltering of the calf between mother and escorts was seen again, as was an adult (presumably the mother) moving the calf away from the source of disturbance.

As in our 1976 observations, the probability of a defensive response appeared to be inversely related to pod size. Singletons and pairs seemed wary and difficult to approach by surface vessel. With increased numbers of animals in the group, there appeared to be fewer defensive responses and in cases of very large groups, the animals appeared undisturbed by the presence of aircraft, boat, or diver. On March 25th, 1977, for example, two of our observers (P. Forestell and H. Brancel) were able to remain in the vicinity of a pod of 15 whales for almost three hours while the pod drifted slowly along next to the observers' rubber inflatable craft. The group included 11 adults, three subadults (judging by their smaller size), and one calf. The pod was undisturbed when the observers entered the water to document the pod's membership and activities on 16-mm film. Whales passed on all sides of the photographer and one whale, drifting slowly by, carefully raised its pectoral fin over the head of the diver to avoid brushing him.

Mother-calf pairs unaccompanied by other whales were often difficult to approach and defensive. For example, the approach of our large 65-ft surface vessel, Noi'i, towards a mother-calf pair swimming off leeward Oahu on 30 April 1977 was met with a series of highly evasive underwater maneuvers including frequent changes of direction. On another occasion on this same cruise, a calf was observed lying on its back waving its pectoral fins in the air. The boat hove to and the calf, on seeing the boat, turned and swam rapidly to meet it. At that moment, a large whale, presumably the mother, appeared in front of the calf and quickly turned it away from the boat. The pair swam off rapidly.

A type of defensive response not identified by us in earlier reports was "tail swishing." This was a sideways back and forth movement of the tail flukes in the near-horizontal plane. Generally, the movement occurred just beneath the surface. It may be a threat display and on one occasion was encountered by one of us (LMH) during an underwater approach toward a juvenile and adult. The juvenile lay obliquely at the surface nearly touching the larger whale. On being approached, it began to swish its tail laterally with increasing velocity. The diver retreated. Long ago, Scammon (1874) described "sweeping" as "the action of a whale when wielding its flukes in an offensive or defensive manner, causing a great commotion in the water" (p. 312). In Southern Hemisphere waters humpbacks have been observed using their tails to beat off attacking killer whales (Chittleborough, 1953).

Surface vessels probably commonly encounter one or more of these various types of defensive responses when approaching whales. If harassment is defined as the elicitation of a defensive response by the whale, there may be numbers of instances of harrassment in Hawaiian waters. How harassment affects the whales on a long-term basis is not well understood, though a review of the history of the Hawaiian humpback whale (Herman, 1980), notes that a habitat shift may occur as a response to chronic or severe disturbance. The data presented earlier in this report, showing apparent preferences of whales for subregions removed from areas of dense human habitation or activity, are further indicants of the possibilities of local habitat shift by whales in response to the presence of humans.

## Summary

The 1976/77 assembly of humpback whales in Hawaiian waters was studied during the major period of its residency in Island waters. Observations were compiled from six data sources, including surveys by chartered aircraft throughout the eight main Hawaiian Islands, reports from Sea Flite interisland hydrofoil transits, reports from civilian and commercial surface vessels contributing sighting information via a CB radio link to a shore station, observations of a network of volunteer shore observers, reports from Navy vessels and aircraft operating in the Kauai-Niihau area, and observations from a field station in daily operation on the island of Lanai. Additional data were contributed by observers placed aboard U.S. Coast Guard flights through the Northwest Hawaiian Islands, and aboard N.O.A.A. ship surveys in that region.

From the mass of data, 15 days were selected from 7 January through 20 April 1977 to represent seasonal trends and the data from those days were analyzed intensively. Over these 15 days, there were a total of 928 sightings of single whales or groups of whales, for a total of 1,999 whales, including 93 calves.

The data revealed a steep rise in total whales sighted through to a peak near the third week of February. A rapid decline in number of whales sighted occurred thereafter. The peak number of calves also appeared in February. Study of seasonal changes in distributions suggested that early aggregations occur in the four-island region between the islands of Lanai, Molokai, Maui and Kahoolawe. The whales appear to arrive from a northeast or northerly direction. Early arrivals were also noted in Hawaii, along its southeast coast. The topography of the coast of Hawaii is such that the approach of whales might also have been from a north or northeasterly direction. From these areas in the four-island region and Hawaii, the whales may distribute themselves westerly and northwesterly in increasing proportions as the season progresses. Toward the end of the season, significant numbers of whales are seen at Kauai and along the north shores of Oahu. A number of these sightings are of mother-calf pairs who may linger in these areas for many days and finally are not seen again. Oahu and Kauai may serve as temporary staging areas for the return migration, for those departing late, but are not heavily used at other times.

Subregions of relatively highest whale usage were identified through results of the all-island aircraft surveys. The important subregions on Hawaii are at or near Upolu Point, and through to Keahole Point on Hawaii's west coast. In the four-island area, a band of subregions stretching from the northeast coast of Lanai through mid-Auau Channel to the Kihei coast of east Maui was the most heavily used. There was also heavy usage of Penguin Bank, especially its westerly and northerly areas, and the adjoining southwest coast of Molokai. The southeast coast of Niihau was also an area of relatively heavy usage.

The subregions in which most calves were found generally corresponded closely to those where most total whales were observed. These included the Upolu Point regions of Hawaii, the Kihei subregion of Maui, the northeast coast of Lanai, the southeast coast of Molokai, and the southerly half of Penguin Bank. There were relatively fewer calves seen off Niihau, despite the high total count of whales.

Examination of regions that were little used by the whales revealed a tendency by the animals to avoid areas near dense human habitation or disturbance, in preference to more isolated regions. Populated areas near Maui show less usage than more rural zones. The same is true for Hawaii, Molokai, and Oahu. Niihau, heavily used, is almost entirely rural. Kahoolawe, subject to heavy bombing by military aircraft, is little used, though unpopulated.

As the season progressed, calves were seen, on the average, in pods of increasingly larger size. It was suggested that newborn calves may remain isolated with their mothers during the early post-parturition period, perhaps as a social attachment (imprinting) mechanism, and that associations with other whales may be delayed until later. As the season progresses, an increasing percentage of the total sightings are of pods with calf, suggesting that mother-calf pairs may remain in Hawaiian waters the longest of any class of whales. The overall birth rate may be modest. The ratio of calves to total whales sighted from aircraft averaged less than 10% (Table 3), which compares closely with data for the Winter/Spring 1976 season reported by Herman and Antinoja (1977).

Data from aircraft and the oberver shorenet revealed that of 62 groups of whales observed with boats within roughly a quarter-mile radius, the whales were approached even closer by the boats in 14 cases (23%). In view of the attraction of whales for humans, this is not a surprising figure, and is suggestive of a significant potential for harassment. Some of the species-typical defensive responses of the whales to surface vessels and aircraft were noted (cf. Herman & Antinoja, 1977) and their occurrence might be used as an indicant of whether given actions by humans are disturbing to the whales.

No evidence was found of any significant migration of humpback whales through the Northwest Hawaiian Islands. Further efforts at study of out-migration might more profitably be directed toward late-season surveys by boats of waters adjoining Oahu and Kauai. Early-season studies of in-migration should focus on areas north and northeasterly of Maui and Hawaii.

# APPENDIX

## POTENTIAL IMPACT OF MARINE AND AIR TRAFFIC ON HAWAIIAN HUMPBACK WHALES

Louis M. Herman and Paul H. Forestell

During 1977, the waters within the four-island region of Maui, Molokai, Lanai, and Kahoolawe were identified as a major winter assembly area for the Hawaiian population of humpback whales. During 1978, aerial surveys around all the islands of Hawaii indicated that the waters within the four-island region accounted for a full 47% of all whales sighted. The four-island region is also important as a maritime recreation and tourist area, and is both a fishing ground and an access route to outlying fishing areas. It additionally serves as a passageway for marine traffic to and from Oahu. Commuter airlines fly over the waters regularly, at times at low altitude, during scheduled flights between the islands of Maui, Lanai, Molokai, and Oahu. The extensive marine and air traffic within this important whale habitat poses a significant harassment threat. Though there are other off-shore areas in the Hawaiian Islands where humpback whales may be found in considerable numbers--e.g., within Penguin Bank, and to a lesser extent, along the Northwest coast of Hawaii--it is within the four-island region that the combined usage by whales and humans is at its maximum.

In order to assess the magnitude of the harassment potential within the four-island region, the following material was gathered:

a. The number and types of vessels berthed or moored at harbors or roadsteads on the islands of Maui, Lanai, and Molokai were counted and cataloged (the island of Kahoolawe is used exclusively for military operations and is without commercial or recreational harbors).
b. Those commercial vessels specifically advertising whale watching cruises were identified.
c. Interisland commercial marine traffic and transient marine traffic were described.
d. The number of commuter airline flights to Maui, Lanai, and Molokai were noted for the two principal commuter airlines.
e. Three charter aircraft companies specifically advertising whale-watching flights were identified.
f. The spatial and temporal distribution of whales in the four-island region for the winter 1976/77 and 1977/78 seasons were determined. These data provide the context within which the harassment potential of marine and air activities can be evaluated.

### Maritime Traffic

The main harbors and anchorages in the four-island region are shown in Figure A-1. They include Lahaina Harbor and Anchorage (or Roadstead), Maalaea Bay Small Boat Harbor, Malo Pier, and Kihei Beach, all on Maui; Manele Bay Small Boat Harbor and Kaumalapau Harbor, both on Lanai; and Kaunakakai Harbor on Molokai. There are additional bays on the island of Maui at which a few small boats are moored (e.g., at Kaanapali, just northwest of Lahaina), and there is a small harbor, Kamalo, near the southeast corner of Molokai which serves principally for the launching of small boats from trailers. Facilities for launching of trailered vessels also exist at all of the harbors in Figure A-1. The number of trailered vessels launched daily was not formally assessed, but informal observations from the past four years suggest that such craft may be as numerous as berthed or moored vessels.

Table A-1 presents the number of vessels berthed or moored at the main harbors and anchorages of Figure A-1 on January 20, 1979. "Hauled out" indicates that a vessel was in drydock for repair or repainting. All vessels are classified as either (a) private pleasure craft (used for private fishing or general recreation); (b) charter fishing, diving, or sight-seeing boats; or (c) commercial fishing boats. Vessels were further designated as either sail or power craft. Malo Pier and Kihei Beach are not included in the data of Table A-1, but there were 15 sailboats moored at Malo Pier and five at Kihei on January 20th. The Lahaina Roadstead data are accounted for by the moorage figures presented for Lahaina Harbor. The number of vessels moored at Lahaina Roadstead would normally be expected to increase markedly by the end of February, as additional transient craft arrived for the winter tourist season.

It can be seen in Table A-1 that the potential traffic from Maui greatly exceeds that from either Molokai or Lanai. On Maui, private sailing vessels, especially those in the mid-range size (25 to 45 feet), constitute the major source of marine traffic. Power charter vessels, again in the mid-range size, are an additional major source of traffic.

Not all of the boats counted venture out with equal frequency, and some may never leave their berths for weeks at a time. Real use is not easily determined, as owners are not available in many cases, or may be unwilling to say how often they use their boat. Technically, berths are for the use of operational craft. Commercial boat charters for fishing, sightseeing, diving, or interisland recreational excursions constitute a major portion of the marine traffic in and out of Lahaina Harbor, as these, unlike the private vessels, may make one or more daily excursions into the adjoining waters. Thirty-seven brochures advertising commercial charters were collected on Maui, eight of these specifically advertising whale-watching cruises (see Table A-2). Seven of the whale-watching boats depart from Lahaina Harbor, while the eighth departs from an anchorage at Kaanapali.

In addition to the more or less permanent sources of marine traffic listed in Table A-1, there is additional transient private and commercial movement between the four-island area and Oahu and Hawaii. Private vessels from Honolulu, where there are great numbers of boats, may travel interisland for recreation, and anchor at Maui for varying lengths of time. The same is true for Big Island (Hawaii) boats, although there are fewer of these. We did not attempt to estimate the amount of such traffic. Private vessels from the west coast of the mainland appear in increased numbers at Lahaina during the winter season. Our informal observations from the 1978 season indicated that perhaps a dozen or more large sailing vessels from the mainland United States or Canada were moored at Lahaina Roadstead.

Finally, an interisland tug and barge service, operated by Young Brothers of Honolulu, runs daily between Honolulu and Molokai/Maui, except on Saturday. On its eastward travel, the barge may pass through the Kalohi Channel between Molokai and Lanai, stopping at Kaunakakai, Molokai and then proceeding to

Table A-1

Types of Vessels in Major Harbors or Anchorages of the Four-Island Region on February 1, 1979

| | MAUI | | | | | | LANAI | | | | | | MOLOKAI | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lahaina Hbr | | | Maalaea Bay | | | Manele Bay | | | Kaumalapau H | | | Kauanakakai H | | |
| Vessel Type: | B | M | H | B | M | H | B | M | H | B | M | H | B | M | H |
| Private Sail | | | | | | | | | | | | | | | |
| <25' | 11 | 8 | - | 7 | - | - | 2 | - | - | - | - | - | - | - | 1 |
| 25-45' | 30 | 11 | - | 10 | - | 4 | 5 | - | - | - | - | - | 4 | 6 | - |
| >45' | 11 | 4 | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Power | | | | | | | | | | | | | | | |
| <25' | 8 | 2 | - | 6 | - | 3 | 7 | - | - | - | - | 4 | 4 | 18 | 2 |
| 25-45' | 3 | - | - | 4 | - | - | - | - | - | - | - | - | 12 | 2 | - |
| >45' | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Charter Sail | | | | | | | | | | | | | | | |
| <25' | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25-45' | 4 | - | - | 1 | - | - | 4 | - | - | - | - | - | 1 | - | - |
| >45' | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Power | | | | | | | | | | | | | | | |
| <25' | 4 | 2 | - | 1 | - | - | - | - | - | - | - | - | - | - | - |
| 25-45' | 17 | - | - | 13 | - | 1 | - | - | - | - | - | - | - | - | - |
| >45' | 12 | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - |
| Commercial Fishing | | | | | | | | | | | | | | | |
| Power (only) | | | | | | | | | | | | | | | |
| <25' | 2 | - | - | 8 | - | 1 | 3 | - | - | - | 9 | 2 | 1 | 8 | - |
| 25-45' | 4 | - | - | 9 | - | 2 | 1 | - | - | - | 2 | - | - | - | - |
| >45' | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - |
| Subtotals: | 110 | 29 | 0 | 65 | 0 | 11 | 22 | 0 | 0 | 0 | 11 | 6 | 22 | 34 | 3 |
| Island Totals: | --------- 215 --------- | | | | | | --------- 39 --------- | | | | | | ----59 --- | | |

Note: B = Berthed; M = Moored; H = Hauled out for maintenance
Charter vessels include sport-fishing, diving, and tourist cruises.

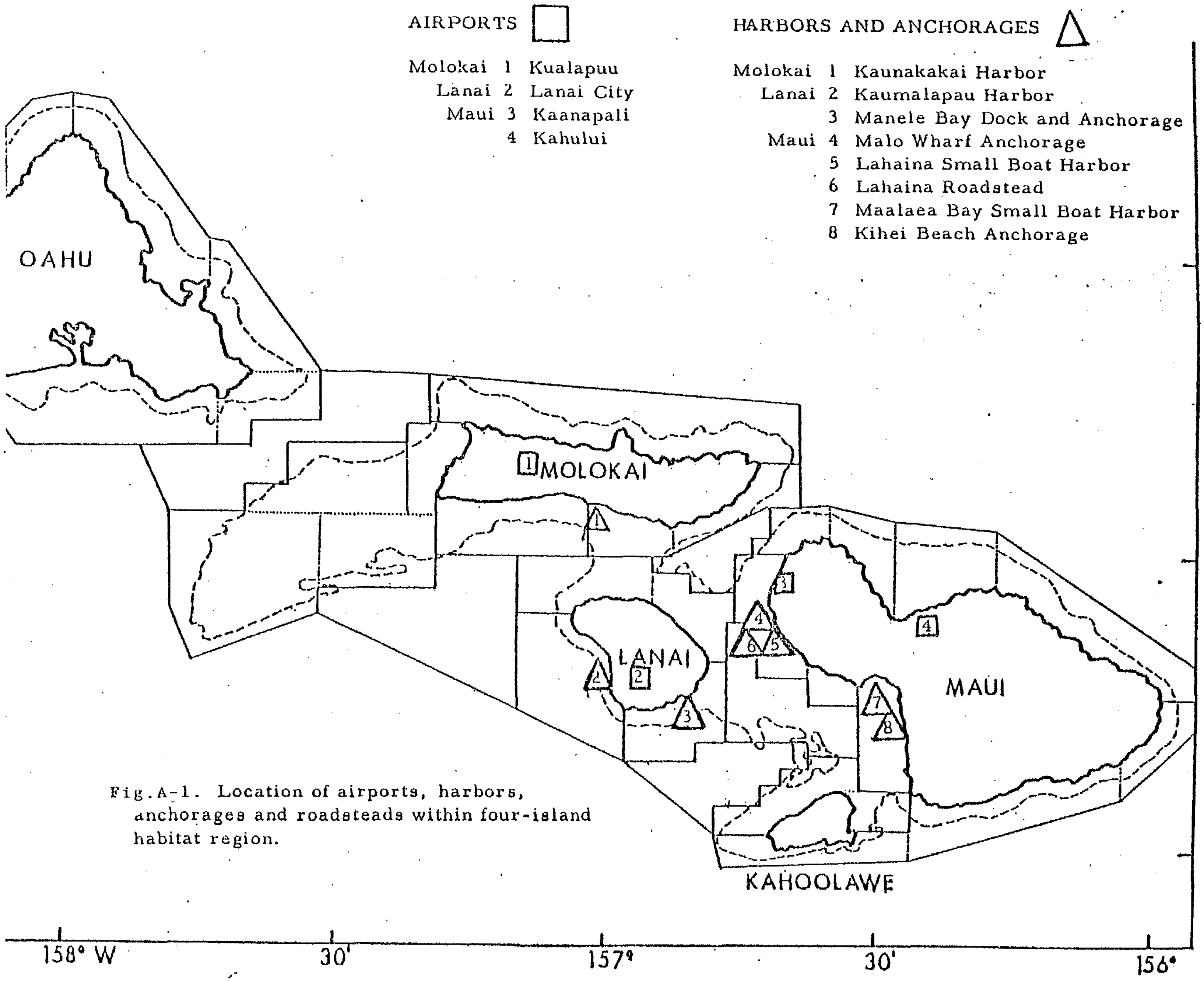


Fig. A-1. Location of airports, harbors, anchorages and roadsteads within four-island habitat region.

Kahului Harbor on Maui via the Pailolo Channel separating Molokai and Maui. The westward trip may follow the reverse route. During our aircraft surveys and our observations from boats, we have seen tugs with one or two barges in tow, within a quarter-mile radius or less of pods of whales.

## Aircraft Traffic

Two commuter airlines, Air Hawaii and Royal Hawaiian Airlines, fly regularly between the islands of Maui, Lanai, Molokai, and Oahu, often traversing the Auau and Kalohi Channels. During whale season, many of the flights between Honolulu and Maui may intentionally pass south of Maui and Molokai rather than than to the north of those islands, in order to view the whales. The flights may pass directly over areas of greatest whale aggregation. Pilots watch for whales and show them to their passengers. Flights may be made at altitudes of 1,000 feet, sometimes lower. The final approach to Kaanapali Airport in normal trade winds is from the southeast, taking the aircraft very low over waters near Kaanapali, where whales are commonly seen. As a passenger, one may occasionally overhear exchanges of information between pilots or between pilot and control tower at Kaanapali, reporting locations of whales. Pilots may divert their aircraft to view the whales reported and may orbit a group of whales one or more times as passengers watch or photograph. However, activities such as these appear to be decreasing in frequency in response to an increased awareness by the pilots of the potential for disturbing the whales.

Table A-3 gives the operating schedule for Royal Hawaiian Airlines and Air Hawaii. Royal Hawaiian flies 33 times daily to Kaanapali airport, and 19 times daily to Kahului Airport. The trip to Kahului may be made along the southern coast of west Maui, at the pilot's discretion, and then into Kahului across the "neck" separating west and east Maui. Air Hawaii does not fly to Kaanapali Airport, but like Royal Hawaiian may fly south of Maui rather than along its northern shoreline during some of its 20 daily trips to Kahului. At present, the airport at Kaanapali is privately owned, and normally available only to Royal Hawaiian aircraft. A new, larger airport open to all airlines, including the Aloha and Hawaiian Air jet fleet, is planned for this area in the near future, and will undoubtedly lead to greatly increased air traffic in the Auau channel area.

Two helicopter companies, Maui Helicopters and Western Helibirds, advertise whale-watching excursions, as does one seaplane company, Seaplane Safari. These companies are listed in Table A-2, and contribute an unmeasured quantity to the total amount of whale-watching activity. The flight patterns and observation techniques of these chartered aircraft have not been observed by us.

Military air traffic occurs around the island of Kahoolawe, which is used regularly as a target island for bombing practice. The flight paths of these aircraft as they make their bombing runs have not been monitored by us, but it can be assumed that a number may fly at low altitude over portions of the Auau Channel. It is not known whether any bombs may inadvertantly fall into waters adjoining the island. The airborne sounds of explosions from air strikes on Kahoolawe can at times be heard on the nearby islands, but it is not known to what degree the noise or vibration may penetrate into adjoining waters.

Table A-2

Sightseeing Tours Advertising Whale-watching

| Vessel | Type | Length | Location | Frequency |
|---|---|---|---|---|
| Scuba King | Power | 38' | Lahaina | As chartered |
| Maui Adventures | Power | 30' | Lahaina | As chartered |
| Seahorse | Sail | 52' | Kaanapali | Twice daily |
| Scotch Mist | Sail | 36' | Lahaina | Daily |
| Iconoclast | Sail | 34' | Lahaina | Twice daily |
| Vida Mia | Power | 61' | Lahaina | Twice daily |
| Viajero | Sail | 65' | Lahaina | Twice daily |
| Windjammer | Sail | 70' | Lahaina | Sat. & Sun. |
| Maui Helicopters | Helicopter | -- | Lahaina | As chartered |
| Western Helibirds | Helicopter | -- | Kihei | As chartered |
| Seaplane Safaris | Aircraft | -- | Lahaina | As chartered |

Table A-3

Number of Daily Flights by Commuter Airlines into Airports within Four-Island Region

| Commuter | Molokai | Lanai | Kaanapali | Kahului | Total |
|---|---|---|---|---|---|
| Air Hawaii | 14 | 13 | 0 | 20 | 47 |
| Royal Hawaiian Airlines | 30 | 12 | 33 | 19 | 94 |
| Totals | 44 | 25 | 33 | 39 | |

## Publicity Given Whales

The potential impact of human activities on the whales can be expected to increase with the heightened publicity given the whales. Although some publicity warns against harassment, much of it is geared toward generating interest in whale-watching or related activities, especially from boats. There is no doubt that such publicity has increased greatly over the last three to four years. Films on the Hawaiian humpback whale have been shown on national television, and the whales have been described in a variety of magazines having large circulation. Whale posters can be found throughout the Maui tourist area. There is a continuous showing of a humpback whale film aboard the whaling museum Carthaginian, docked at the entrance to Lahaina Harbor. The vessel is being restored as a whaling ship under the auspices of the Lahaina Restoration Foundation. One can additionally expect a large number of whale talks, slide shows, and films by visiting or local photographers throughout each season.

In general, there appears to be a rapidly growing recognition on Maui that the whales can be important to the tourist industry, providing an additional inducement for visiting Maui in winter. In addition to the direct business generated by whale-watching charter boats or aircraft, many shops sell whale memorabilia, such as whale books, T-shirts with whale slogans, scrimshaw, whale and dolphin figurines, whale jewelry, and even narwhal tusks. The number of shops featuring whale items seems to be increasing rapidly.

Free tourist publications, available throughout Maui, amplify the publicity given the whales. A painting of a humpback whale was featured on the front page of the complimentary publication, "Holiday on Maui," for the week of February 2-8, 1979. Its caption read in part: "Join a whale-watching cruise off Lahaina, or read about Maui's whales in National Geographic . . . ." The January 4-10, 1979 issue of the complimentary "Hawaii Tourist News" also featured a front-page story on the whales titled "Biggest Visitors are Back." The story gives details of whale-watching cruises, including prices. A conservation note is appended to the end of the item. The January 6-10 issue of the free "Guide to Maui" urges all to "Go Watch the Whales." Charter boats are mentioned and recommended.

Realistically, whale publicity can be expected to increase each season. During the winter, Maui hotels are filled to capacity. Many more condominiums and hotels are under construction as Maui explodes into a speculative fever built around the tourist business. The implication seems clear; that without a great deal of education and intelligent guidelines, what is good for Maui may not necessarily be good for the whales.

## Spatial Distribution of Whales

Figures A-2 and A-3 show, respectively, the relative density of all whales (including calves), and of calves alone, within specified subregions of the four-island region. For each subregion, density figures were calculated as the total number of all whales (Figure A-2) or the total number of calves (Figure A-3) counted during nine aerial surveys in 1977 and six aerial surveys in 1978. The surveys were spaced at approximate two-week intervals between January and April. Adjustments were made in the calculations to compensate for differences

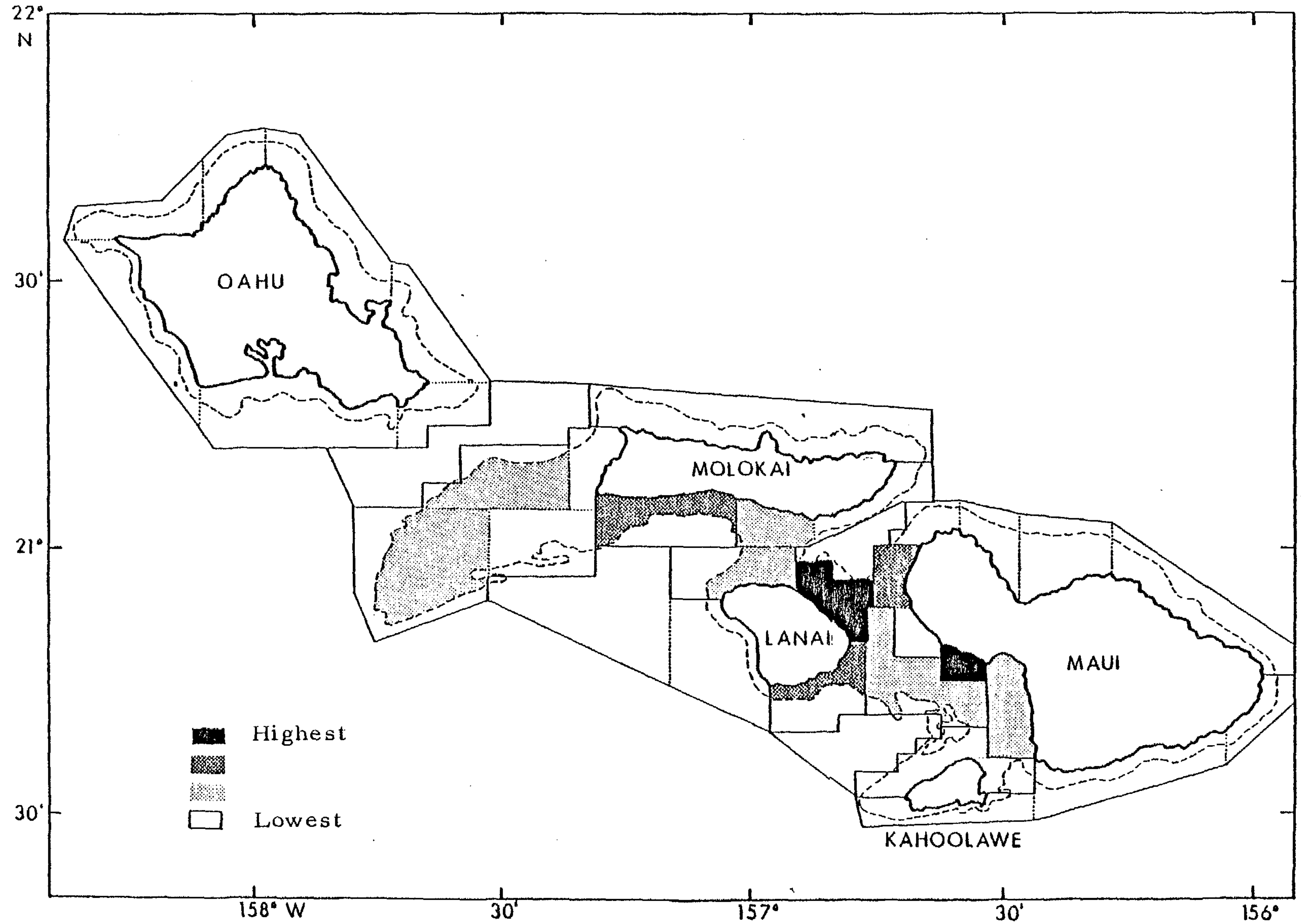


Fig. A-2. Relative Density of All Whales (1977-1978)

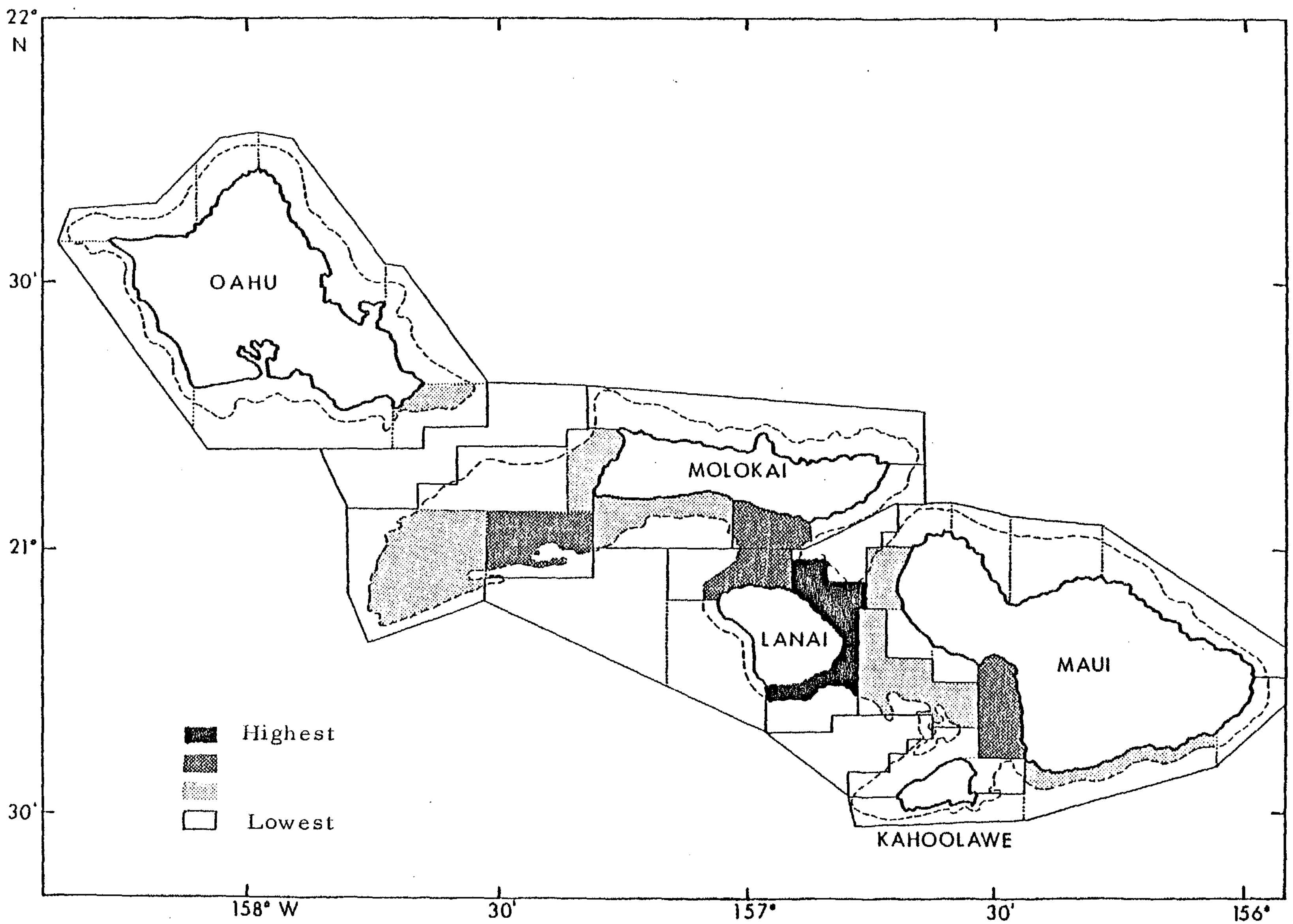


Fig. A-3. Relative Density of Calves (1977-1978) in sizes of the various subregions. The mean and standard deviation (SD) of the distributions were obtained for all whales and for calves alone, for the two years combined. Subregions with densities greater than two SD's above the mean are shown by the darkest shading; those between one and two SD's above the mean are shown in medium shading; those between the mean and one SD are shown with the lightest shading; finally, those below the mean are shown in white. It is apparent that subregions of greatest calf density tend to correspond with those of greatest overall whale density, although there are some exceptions. The area between Olawalu and McGregor Point on Maui, although densely populated by adult whales, shows relatively few calves.

Of particular note is the sector bordering Lahaina Harbor. This is an area of least density of both total whales and calves, although bordered by areas of higher density. Is this a case in which intense maritime activity has produced an avoidance of the area by the whales? In general, there seems to be a negative correlation between areas of heavy whale usage and heavy human usage. For example, the remote, almost uninhabited, north and northeast coasts of Lanai are areas of heavy whale usage. In the main text of this report, further instances are given of the negative correlation between human and whale use of areas.

## Temporal Distribution of Whales

Figure A-4 shows the temporal distribution of whales for the 1977 and 1978 seasons, based on aerial survey data. The data are for all areas of Hawaii combined. Results for the two seasons are remarkably similar. Peak numbers of whales are present in Hawaiian waters during the third and fourth weeks of February. At those times, encounters between whales and human maritime activity may be expected to be at a maximum.

## Summary and Conclusions

The results of the survey of marine and air traffic in the four-island region, together with the distributional pattern of the whales, raises concern for the well-being of the whale population. Specifically:

a) A full 47% of the 1978 sightings of whales by aircraft survey were in the Kalohi and Auau Channels. Air and marine traffic through or over these channels is common (Table A-3).
b) Of the commercial and private boats located in the larger bays and harbors within the four-island region during January of 1979, approximately 69% were berthed in Maui's Lahaina Harbor, or in Maalaea Bay. These areas border subregions in which many whales are found during the winter season.
c) The presence of whales near resort areas has been well advertised and whale-watching is becoming an important commercial venture. The port of Lahaina provides the bulk of the tourist whale-watch charters.

It is clear that there are significant regions of overlap between areas used by marine and air traffic and areas of dense whale concentration within the four-island region. A high potential for harassment exists, and may be

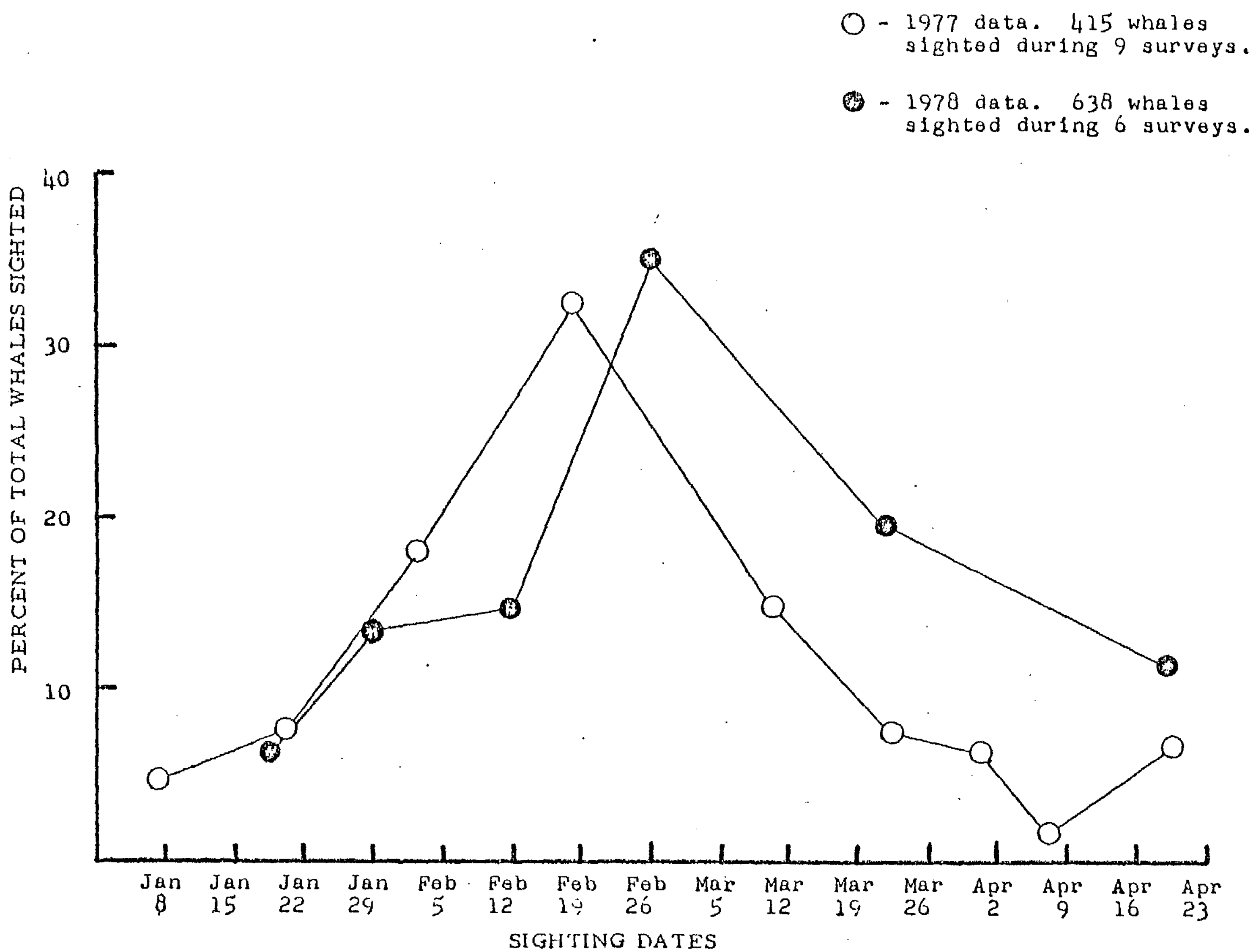


Fig.A-4. Relative abundance of whales, all islands of Hawaii combined, from January through April, during 1977 and 1978. The number of whales counted in each survey date is expressed as a percentage of the total whales counted over all surveys in a season.

expected to increase as interest in the whales increases. Given the small numbers of North-Pacific humpback whales, and the absence of data indicating strong trends towards recovery, it may be wisest to proceed as if conditions for negative impact were present.

A program to prevent harassment will require co-ordinated efforts at local and Federal levels to achieve (a) greater education of the public and private sector with regard to the socio-ecology of the humpback whale and the need to regulate access to whales in Hawaiian waters; (b) effective implementation and enforcement of conservation goals; and (c) additional research efforts to identify habitat usage and requirements of the whales, the functions of their behaviors, the structure of their social organization, and the manner in which the well-being of the whale population may be threatened by marine and aerial traffic.

The most effective co-ordination may be accomplished through an appointed "Recovery Team," a standing committee of specialists whose function is to monitor the status of the whales and their habitat, to evaluate the successes or shortcomings of implemented conservation programs, to identify areas needing further study, and to make recommendations to local, State, and Federal Agencies. The Recovery Team should concern itself with the status of the whales over their summer range, as well as in the winter breeding habitats.

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