

Humpback whale (Megaptera novaeangliae) distribution and abundance in the Gulf of the Farallones National Marine Sanctuary

1986 Annual Report for Contract # CX 8000-6-0003

To

Pt. Reyes National Seashore
National Park Service

and

Gulf of the Farallones National Marine Sanctuary
National Oceanic and Atmospheric Administration

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ABSTRACT

This report summarizes the first year of a three-year study on humpback whales in the Gulf of the Farallones National Marine Sanctuary, Cordell Bank, and vicinity. Three vessels conducted 513 hours of surveys for humpback whales in the Sanctuary area between 17 July and 15 September 1986. Over 5,000 black and white photographs were taken of whales to photo-identify individual whales. Additional sightings were made during 37 hours of aerial surveys and by Farallon Research Associates (under a sub-contract from Cascadia) during 34 Oceanic Society nature trips between 7 June and 26 October.

Only a few humpback whale sightings were made in the early part of the study period until 14 August when close to a 100 humpback whales were first seen in the study area. Whales were present in the study area through the end of October, though the main concentrations of whales apparently shifted to outside the study area on several occasions during this period. Highest sighting rates occurred in water depths of 250 to 350 feet. Fluke markings from 88 different humpback whales were photographically identified and incorporated into a catalogue. Individual whales were resighted an average of 5.2 times (n=88, range 1-20, s.d.=3.9) on an average of 3.1 days (range 1-9, s.d.=1.8). Nine whales, including Humphrey, the whale that swam up the Sacramento River in 1985 were matched with photographs of whales taken on breeding grounds near Isla Isabel, Mexico. Given that less than 100 whales were identified from each area, these nine matches represent an extremely high resighting frequency and indicate a close affiliation between whales in these two locations. No matches were found between Hawaii and the Sanctuary and only such match has been reported previously. However, a complete search for matches has not been completed.

Mark-recapture estimates using three different techniques and two data sets (based on all photographs or those meeting strict quality criteria) yielded population estimates of 82 to 103 animals. This number is similar to an adjusted estimate of 90 whales made on a strip-transect aerial survey on 16 September. These numbers verify that most of the whales in the study area were photographically identified and are part of our catalogue of 88 whales. The high number of sightings reported by Oceanic Society nature trips in October and November may indicate either an influx of new animals or movement of the feeding aggregation to the Farallon Islands area, the destination of the nature trips.

A variety of other marine mammal species were also seen during the study including blue, sei, minke, and killer whales; Dall's and harbor porpoise; Pacific white-sided and Risso's dolphins; and several pinniped species. Blue whales were sighted over 100 times and were photographically identified. Results of the blue whale research are covered in more detail in a separate report.

INTRODUCTION

This report summarizes results of research in the first year of a three-year study of humpback whales in the Gulf of the Farallones National Marine Sanctuary. The creation in 1981 of the Gulf of the Farallones National Marine Sanctuary coupled with the apparent return of the humpback whale to the Farallones area provided the impetus and direction for research on humpback whales in the area. The methodology of the research reported here primarily relies on the ability to individually identify humpback whales through natural markings. Aerial and vessel-based survey methods provided data on distribution, abundance and movements of humpback whales in the Sanctuary region. While focussing research on humpback whales, other marine mammals were opportunistically studied. This research was contracted by National Oceanic and Atmospheric Administration Sanctuaries Program through the National Park Service to Cascadia Research.

The primary objectives of the proposed three-year study include: 1) develop a photographic catalogue of individual humpback whales based on fluke photographs, 2) determine the abundance and distribution of humpback whales in the study area, and 3) identify seasonal movements of humpback whales and their interchange with wintering grounds and other summer feeding areas. Other research components included: incidental observations of other marine mammals and aerial photogrammetry to discern age classes. Results of supplemental research conducted on other marine mammals are included here, however, results of research on blue whales performed concurrently with this study are included in a separate report.

BACKGROUND

Historical Sightings

Before the advent of whaling, humpback whales were numerous along the central California coast for much of the year. Beginning in the middle 1800s, a few humpbacks were taken in the North Pacific by whalers, but for the most part this species was ignored until the advent of modern whaling around 1900. Those few humpback whales taken along the coast of central California prior to 1900 were caught from April to December, with the best season reported to be October and November (Scammon 1874). From accounts in Scammon (1874), the majority of humpback whales observed worked their way northward along the coast until about September, whereupon they reversed direction and worked their way southward in search of food. The old methods of rowing out and hand-harpooning whales were only marginally successful on humpbacks, and the whalers probably had little effect on the central California population.

Humpback whales were heavily hunted and severely depleted in the North Pacific during the modern whaling era when whaling ships were equipped with engines and hunting became more efficient. The first modern whaling station opened at Moss Landing in 1918, followed shortly by another at Trinidad in northern California in 1920. As these and other "shore" stations opened and closed along the the California coast during the modern whaling episode, humpback whales were typically among the first species to be exploited and depleted. During this episode 3,377 humpback whales were taken along the California coast alone, before protection was afforded them in 1965 (Rice 1977). Two stations operating from San Francisco Bay caught 755 humpback whales near the Farallon Islands and Point Reyes from 1956 to 1962 (Rice 1963), after which this species was rarely seen in the area. Altogether, at least 23,315 humpback whales were killed during the modern whaling episode in the North Pacific from 1910 to 1965 (Rice 1977), prompting the inclusion of this species on the Endangered Species List.

Recent Observations

Dohl et. al. (1983) summarized recent observations of humpback whales along the central California coast which indicated a steady annual increase of humpback whale occupancy and utilization of the Farallon basin from 1977 to 1983. These investigators extrapolated aerial survey data to estimate 338 ± 199 humpback whales in the California study area (from Pt. Conception to Pt. St. George), and they counted a maximum of 76 whales in the Farallon basin during the month of September. They also commented upon the disparity of observations north and south of this core area, and suggested

it might indicate that the migration of humpback whales on the central California coast is predominantly between Mexican wintering grounds and summer feeding grounds in the Farallon basin. During their three-year study, only 4 juvenile humpbacks were noted.

Researchers in other regions have taken advantage of variation in humpback whale fluke coloration to identify individual whales and have conducted studies of movements and summering site fidelity studies based on photographic identification. Sczepaniak and Webber (1985) reported two humpback whales that were repeatedly identified near the Farallon Islands in 1983 one and six days apart, and another whale seen in the Farallones which was also photographed in the breeding and calving area off Isla Isabel Mexico. Baker et. al. (1986) reported eight individual humpback whales photo-identified from the Farallon Islands, and the Mexico match reported above. These latter authors concluded that humpback whales in the eastern and central Pacific do not form reproductively isolated stocks (Hawaii and Mexico), rather they intermingle to some degree. Analysis of songs (Payne and Guinee 1983) and the discovery of two fluke matches between Hawaii and Mexico (Darling and Jurasz 1983) suggest that the stocks of eastern North Pacific humpbacks may be just one stock. Clearly, individual identification of humpback whales can provide useful data on migration, behavior and stock discreteness.

FIELD METHODS

Vessel Surveys

The major goals of this study were pursued primarily with vessel surveys. The two major types of surveys were those conducted by vessels dedicated to this study and by vessels run by the Oceanic Society for nature cruises out of San Francisco Bay. The dedicated vessels were all chartered and directed by Cascadia Research. Whale watch cruises run by the Oceanic Society to the Farallon Islands were crewed by observers from Farallon Research Associates on contract to Cascadia Research to conduct marine mammal searches and observations.

Dedicated vessels

The three primary vessels used by Cascadia were: 1) Noctilio, a 44' motor sailer, 2) Shachi, a 19' Boston Whaler, and 3) a 14' Zodiac inflatable. Both the Shachi and Noctilio were based out of Bodega Bay and were equipped with LORAN, radar, depth sounder, and VHF radio. Effort of these three vessels is summarized in Table 1. All three boats had at least one researcher/photographer on board at all times, and during some photographic forays, as many as 6 researcher/photographers were operating on three vessels. Radio contact was maintained between the vessels when more than one operated at the same time. Tracks of all dedicated surveys are shown in Figure 1. In the beginning of the season vessels were far-ranging in search of whales but later in the season, vessel survey effort was concentrated at locations where humpbacks were found because the primary objective for the vessels was to develop a photographic catalogue of whales.

The Noctilio was the primary observation vessel and it logged 330 hours of survey effort on 32 days between 23 July and 15 September 1986. The Noctilio generally traveled at 6 kts. Most trips out from Bodega Bay lasted 2-4 days with overnights in either Drake's Bay or off Southeast Farallon Island. The number of observers aboard varied with generally a minimum of two observers.

The Shachi operated on 13 days between 23 July and 2 September and logged 69 hours of survey effort. With the exception of a few overnights in Drake's Bay the Shachi operated on a daily basis out of Bodega Bay. A speed of 20 kts. or more allowed this vessel to travel quickly to almost any part of the study area. The Shachi operated with either one or two researchers aboard.

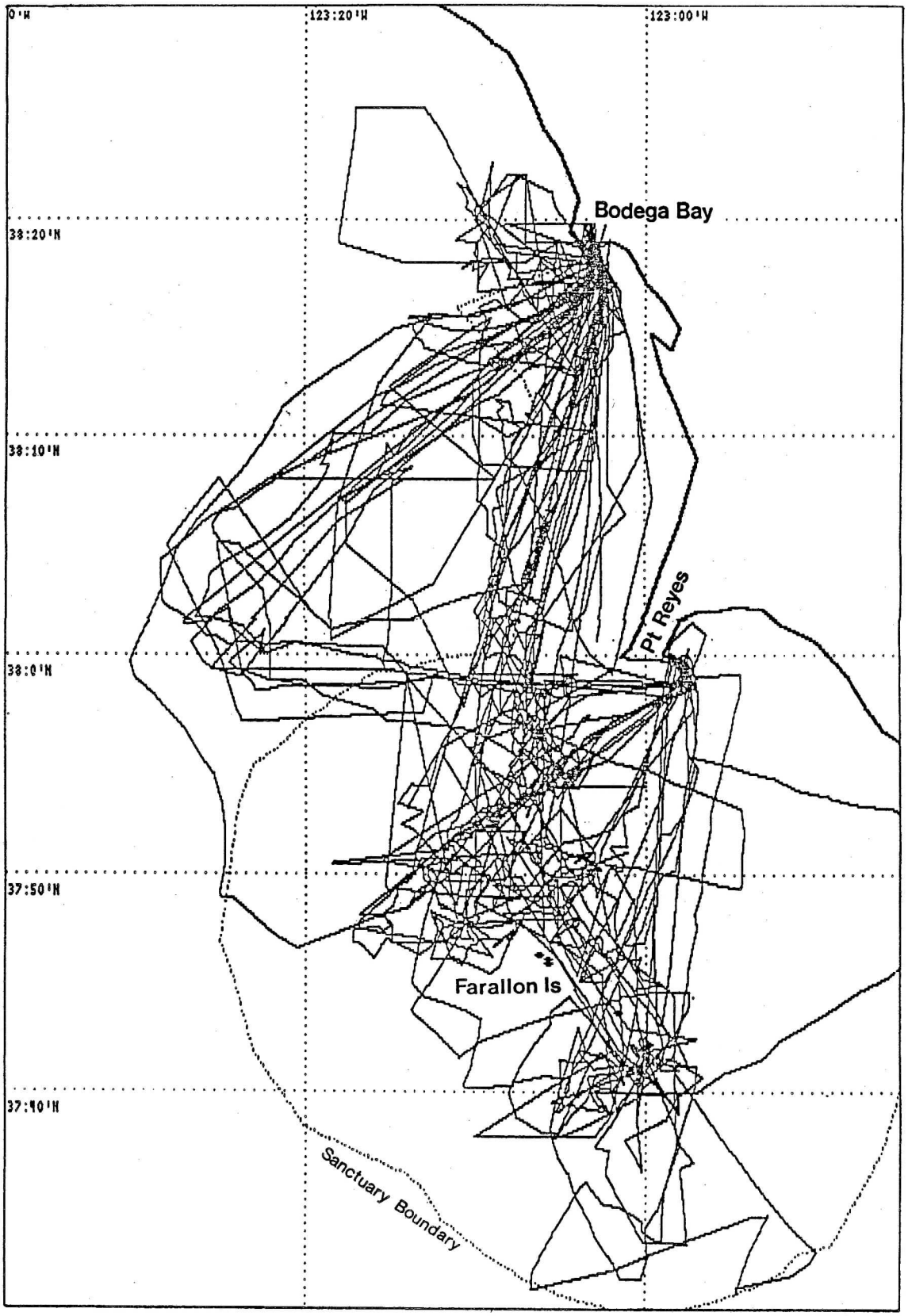


Figure 1. Tracklines of all dedicated vessels (Noctilio, Shachi, and Zodiac) throughout study period. See text for effort summary and vessel description.

The Zodiac operated primarily in conjunction with the Noctilio, usually within 5 nm, though on calmer days it operated independently. The Zodiac was operated for 114 hours on 24 days between 27 July and 15 September 1986. This vessel was used more heavily and independently from the Noctilio in the latter half of the study period. Either one or two researchers were aboard the Zodiac.

Oceanic Society nature cruises

Marine mammal sightings from the Oceanic Society cruises to the Farallon Islands are also included in this study under a subcontract from Cascadia to the Farallon Research Associates. These cruises were conducted on 34 days between 7 June and 26 October 1986 and primarily cover the area around the Farallon Islands and between the islands and San Francisco Bay. The trips began at 0900 and generally ended at 1700. Observations were primarily made from the Nautilus, a 68' charter sport fishing boat operating out of San Francisco. Observations were made from an observation deck approximately 10' above the water level. From one to three researchers from the Farallon Research Associates were aboard the vessels and making and recording observations of marine mammals as well as taking photographs of humpback and blue whales for identification.

Data collection

Aboard the Noctilio, data were collected by a laptop computer cabled to receive navigational data directly from the LORAN and time and date from an internal clock. The computer queried observers for data and wrote all data to memory and a cassette tape in ASCII format. Effort data (time, position, depth and codes for number of ships, boats, birds in the area) were recorded every 15 minutes. Weather data (visibility, cloud cover, Beaufort, swell height, and overall observation quality) were recorded every hour. This effort data allowed us to test trends in depth of sightings, association with birds, and relative density of sightings by area. Sighting data that were recorded included time, date, position (recorded automatically by the computer), count, species, bearing and distance from vessel, behavior, direction of travel, depth of water, and counts of boats, birds and ships in the area.

Aboard the Shachi, throughout surveys, data on vessel position (based on LORAN) and time were recorded in a log. Sighting details (species, count, behavior comments) were also recorded. On the Zodiac, position was determined from dead reckoning and azimuth sightings on landmarks. Vessel position and time were recorded regularly. Sighting data including count, species, location and time were also recorded.

All handwritten data were encoded and entered into a microcomputer in ASCII format. Surveys conducted during Oceanic Society cruises recorded ship position, depth, sighting count and species and weather. Summaries of species encountered, time, date, count, and location were entered into the microcomputer.

Photographic techniques - film and equipment

Identification of humpback whales focussed on photographing the underside of the flukes. We used several motorized advance 35mm cameras with lenses from 180mm f2.8 to 300mm f4.5, and Kodak Tri-X or Ilford HP-5 film. Shutter speeds were 1/1000 or faster to "freeze" action whenever lighting conditions permitted. The black and white film was exposed for ASA rating 1000, and development times were adjusted accordingly using Edwal FG7 1:1 with 9% sodium sulfite. All film was contact printed, and individual selected prints were custom enlarged on RC paper 2 1/4" x 3 1/2" for comparison matching.

Approaching whales for photo-identification

Humpback whales were located visually from the research vessels and approached slowly from behind to within 100 yards whenever possible. They were followed through several dive sequences until flukes were raised and several identifying photographs of the underside pattern of the flukes were taken by one or more of the field personnel. Usually, the whales were feeding and were approachable without disturbing them. Because we used multiple vessels in the field effort and because whales often moved around the feeding area in an unpredictable fashion, they were occasionally approached more than once or by more than one research vessel during the course of a research day. Nonetheless, no obvious disturbance or radical change of behavior was noted for most of the whales photo-identified, though most were apparently aware of the presence of the research vessel(s). Best fluke photography was obtained when the whales were approached to within 100 feet from directly behind.

Aerial Surveys

Aerial surveys were conducted primarily to search large portions of the study area to direct vessels to humpback whale concentrations for subsequent vessel-based photo identification work. Strip transect surveys were conducted on some occasions to provide a census estimate of humpback whales in the study area. In addition, humpback and blue whales were measured with photogrammetry techniques to determine approximate age class of animals found in the Farallones area.

Effort summary

Over 37 hours of flight time were logged on aerial surveys conducted from August through October. Aerial surveys were conducted from Oakland International Airport, Napa County Airport, or Gnoss Field. Surveys were attempted in May and July, but poor weather prevented useful flights. Initially, the first three surveys were flown in a Cessna 337, however, we shifted to a Cessna 172 on later flights because of its greater visibility and practicality. Aerial survey effort is reviewed in Table 2 and survey tracks are shown in Figure 2. Because poor flying conditions were common, we sometimes attempted surveys in marginal conditions that then had to be cancelled.

Survey procedures

A crew of three (1 pilot, 2 observers) flew most surveys in the Cessna 172. One observer sat behind the pilot on the left side and the other next to the pilot on the right side of the plane. The aft observer recorded data on a standard form and the front observer directed the flight and computed position regularly from two VOR (aircraft navigation aid) readings (providing azimuth information from fixed navigational stations). A programmable calculator converted VOR data to latitude and longitude data. The primary lines flown in search of whales followed latitude lines every 4 minutes throughout the study area. Later surveys followed longitude lines through the center of the study area west of 122° 56'.

Upon sighting an animal, observers measured sighting angle below the horizon with a clinometer. This depression angle and altitude measurement provided a measurement of sighting distance off transect. After measurements were taken, the plane sometimes would break transect to confirm species identity and count. Dye bags dropped from the plane enabled a position in the water to be marked and circled so the plane could wait on station for animals to resurface.

Photogrammetry

Whales were photographed from the air and measured with photogrammetric techniques to discern age-class structure of animals residing in the National Marine Sanctuary. Vertical photographs were taken with a hand-held 35mm Nikon FE equipped with a 200 mm fixed focal length lens and electronic level that audibly signaled the photographer when the camera back was within 5 degrees of parallel to the ground. Altitude of aircraft was recorded to the nearest 10 ft. Film was either color negative

Table 2. Aerial surveys attempted and flown during 1986.

Date	Time TKO	Time Lnd	Elapsed Time	Comp- pleted?	Area and comments
5/13	0855	0934	0:39	No	Severe fog and high winds
7/22	1302	1349	0:47	No	Fog and low ceiling
8/01	1418	1733	3:15	Yes	Farallons and south in study area
8/14	1303	1649	3:46	Yes	Farallons and north in study area
8/28	1209	1553	3:44	Yes	Off Bodega head and northern study area
9/06	1440	1524	0:44	No	Fog and high wind
9/09	1037	1427	3:50	Yes	Along contour north of study area
9/10	1140	1401	2:11	Yes	South of Farallons, mechanical problem
9/10	1435	1753	3:18	Yes	Between Farallons and Pt. Reyes.
9/11	1052	1126	0:34	No	Fog
9/12	1600	1905	3:05	Yes	Bodega Head to North Farallons
9/16	1525	1839	3:14	Yes	Pt Reyes to south of Farallons (Area of highest humpback concentration).
10/21	1339	1432	0:53	No	Fog, low ceiling
10/23	1147	1639	4:52	Yes	Bodega head to S of Farallons
10/24	1230	1443	2:13	Yes	Pt Reyes to Farallons
Total			37:06		

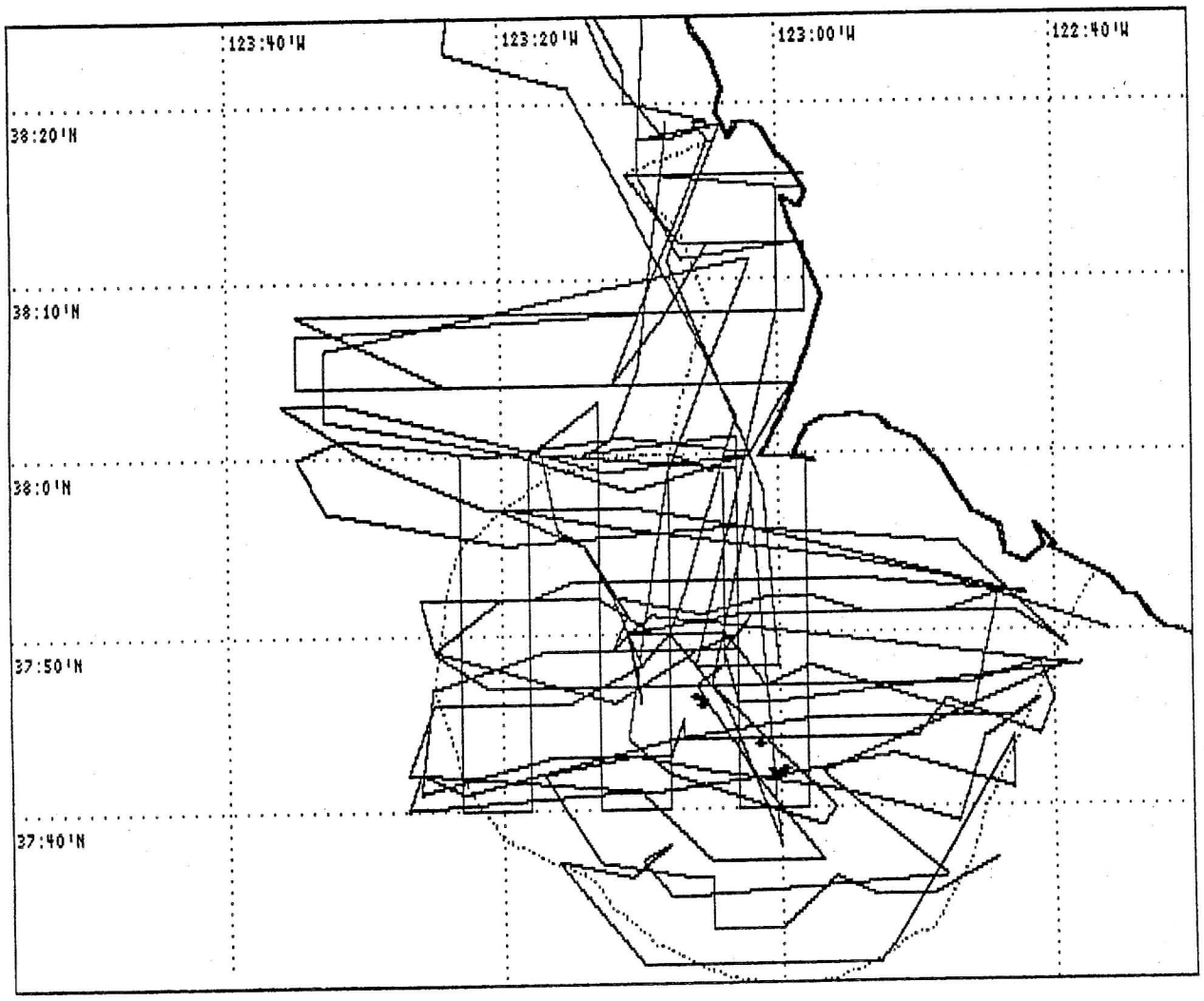


Figure 2. Tracklines of all aerial surveys for humpback whales from 13 May to 24 October 1986.

or color slide film. Photo scale was derived from calibrated focal length of the lens and barometric altitude calibrated with photograph measurements of known-sized targets (boats) near whale sightings.

ANALYSIS METHODS

Photographic Identification

A catalogue of identifiable whales encountered during the study was developed by comparing all photographs taken of individual whales. Of several thousand photographs printed, the collection was merged and purged until well-identified individual whales were recognized as distinct. These remaining photographs became the catalogue of individuals for the first year of this study.

Catalogue comparison to other collections

Matching of humpback photographs from different areas of the North Pacific is currently accomplished by eye. To aid in comparisons with catalogues located in various places and in various states of organization (and sometimes numbering thousands of photographs), we sent the photocopied catalogue to collaborating researchers (Appendix 1), and asked for information about any matches with their catalogue that they might find. Different researchers were able to devote differing amounts of time to this task, but most at least were able to conduct preliminary comparisons.

To compare catalogue photographs and to encourage other researchers to examine their catalogues for matches with the Gulf of the Farallones collection, one of us (KCB) travelled to Hawaii and Mexico in March 1987 to confer with collaborating researchers. Our catalogue was thoroughly compared with the collection of photographs compiled and curated by Carlos Alvarez and Jorje Urban of the Universidad Nacional Autonoma de Mexico in Mexico City. Of 86 photographs in the collection, 80 were compared with our collection. The Gulf of the Farallones catalogue was compared with the collection of 804 photographs of individual humpback whales in the Hawaiian region compiled and curated by the Pacific Whale Foundation at Kehei Maui. Photographs taken in the Gulf of the Farallones area by the Farallon Research Associates before 1986 were also compared to this year's photographs in the Farallones Area.

Computer Analysis and Plotting

Sightings and vessel tracks were viewed with custom-made plotting routines at Cascadia. These plots allowed search of errors made in entering data (dubious tracks and locations) as well as a review of relative geographical abundance.

Aerial Survey Density

A population estimate derived from aerial survey data was calculated based on strip census techniques. A survey with adequate coverage to gather an estimate of the number of humpback whales in the study area, during acceptable weather conditions and in areas of whale abundance occurred on only one day. The width of the strip wherein all animals at the surface are seen was determined from the function of number of animals seen vs distance from the trackline. Corrections for animals submerged while the aircraft passed were applied to the overall sighting density data.

Mark-Recapture Analysis

Population estimates were made from two datasets: 1) all photographs where an individual was identified and 2) photographs selected for image quality criteria independent of whether the whale was identified. The selected photographs had to have a 10mm fluke span on negative, good focus and exposure, and have 80% of the fluke visible. These selection criteria reduce bias in recapture probability of individual whales based on the distinctness of their fluke markings. However, little evidence of bias appears in the sample of all photographs because of the absence of any difference in capture probability between flukes with varying grades of distinctive markings. By culling photographs that do not meet strict selection criteria, however, another bias may be created in the capture probability if some whales were consistently less likely to let us approach close enough to meet our distance selection criteria or did not tend to show 80% or more of the fluke. We therefore conducted the population estimates using both the unselected (data set 1) and the selected (data set 2) sets of photographs.

Mark - recapture estimates of the Point Reyes/Farallon Island feeding aggregation of humpback whales present during August and September 1986 were made following three accepted procedures:

1) Closed population - Modified Peterson estimate (Chapman 1951)

$$N=[n_1(n_2+1)(n_2+1)/(m_2+1)]-1$$

where n_1 is the number of whales identified in the first sample; n_2 is the number of whales identified in the second sample; and, m_2 is the number of whales identified common to both samples.

2) Closed population - Schnabel estimate (Schnabel 1938)

$$N=E(C_tM_t)/R \quad [E=summation]$$

where C_t is the total number of whales identified on day t; M_t is the the total number of whales identified at the start of day t (i.e. previously identified); and, R is the total number of reidentifications during the study period.

3) Open Population - Triple-catch estimate (Bailey 1951)

$$N_2=M_2(C_2+1)(R_{13})/(R_{12}+1)(R_{23}+1)$$

where N_2 is the estimate of population after the second sample period; M_2 is the number of whales marked in the second sample; C_2 is the number of whales examined in the second sample; R_{13} is the number of whales in the third sample which were marked in the first sample; R_{12} is the number of whales in the second sample which were marked in the first sample; and R_{23} is the number of whales in the third sample which were marked in the second sample. An estimate of emigration (mortality) can be obtained by:

$$S_{12}=M_2R_{13}/M_1(R_{23}+1)$$

and an estimate of immigration (natality) can be obtained by:

$$R_{23}=R_{12}(C_3+1)/C_2(R_{13}+1)$$

where M1 is the number of whales marked in the first sample; and C_3 is the number of whales examined in the third sample.

Photogrammetry

Images of whales taken with the photogrammetric system described earlier were measured with a stereo dissecting microscope (25x) equipped with an ocular reticle calibrated with a stage micrometer that allowed measurements to the nearest 0.04mm. The lens was calibrated to 203.0 mm with methods described by Wolf (1983). Known-sized vessels near the photographed whales were used to calibrate the altimeter. The mean difference between the expected scale based on altitude and focal length and the true scale based on the ratio of image and object sizes of the vessels provided a correction for the altimeter-based scale.

The equation used to measure whales was:

$$\text{Whale size} = \text{image size} \left(\text{altitude}/\text{CFL}\right) + C$$

where CFL is calibrated focal length and C is correction and is based on the mean difference of altimeter-based scale (altitude/CFL) and measured scale (Object size/image size) of photographs of known-sized objects near the whales. The average scale of the photographs were about 1:800.

Whale images were graded according to observed whale flex and resolution of the image. Flex was graded from 1 to 5 with 5 being unacceptable and 1 straight. Clarity and resolution were also graded from 1 to 5 with 1 being clear and 5 being unusable.

RESULTS AND DISCUSSION

Results of humpback whale research are presented first in the following sections. Other marine mammal sightings and aspects of distribution are noted later. Blue whales were seen in surprising abundance in the study area in 1986 and we were able to conduct some in-depth research on blue whales without compromising the major emphasis of this study. A report of the blue whale study is being submitted separately. This report is one portion of results of this study. In addition to this report all data were converted to dBase III relational database system and was turned into the Gulf of the Farallones National Marine Sanctuary. Also on file at the Sanctuary office is a catalogue of fluke photographs taken in 1986.

Distribution and Number of Sightings

A total of 256 sightings of 711 humpback whales were recorded during dedicated vessel surveys and 40 sightings of 162 humpbacks were made during aerial surveys. Locations of all dedicated vessels when humpback whales were seen are shown in Figure 3 (aerial sightings are not included). Relative densities of humpback whales seen per hour of survey from the Noctilio provide some measure of the more likely areas of humpback whale occurrence in the study area and are shown in Figure 4. Most animals were seen and photographed in the region between Pt. Reyes and Fanny Shoal north of the North Farallon Islands. No calves were seen throughout the surveys.

Seasonal patterns

There were dramatic variations in the occurrence of humpback whales in the study area during the season. Figure 5 summarizes the effort and locations of sightings of humpback whales divided into four periods. Humpback whales were present only in small numbers before mid-August and most sightings were south of the Farallones. From 14 to 20 August, when the first large aggregation was seen, whales were concentrated in the area between Point Reyes and North Farallon Island. After 20 August few whales were seen until the 27th and 28th of August when large numbers occurred off Bodega Head. Relatively small numbers of humpback whales were seen until 10 to 15 September, when we found large numbers southwest of Point Reyes extending west of Fanny Shoal. Overall, the main aggregation of whales appeared to be very mobile and moved into different areas every few days. Periods when we did not find large numbers of humpback whales likely were times when the main concentrations were out of the study area, though some whales likely occurred in portions of the study area we did not sample.

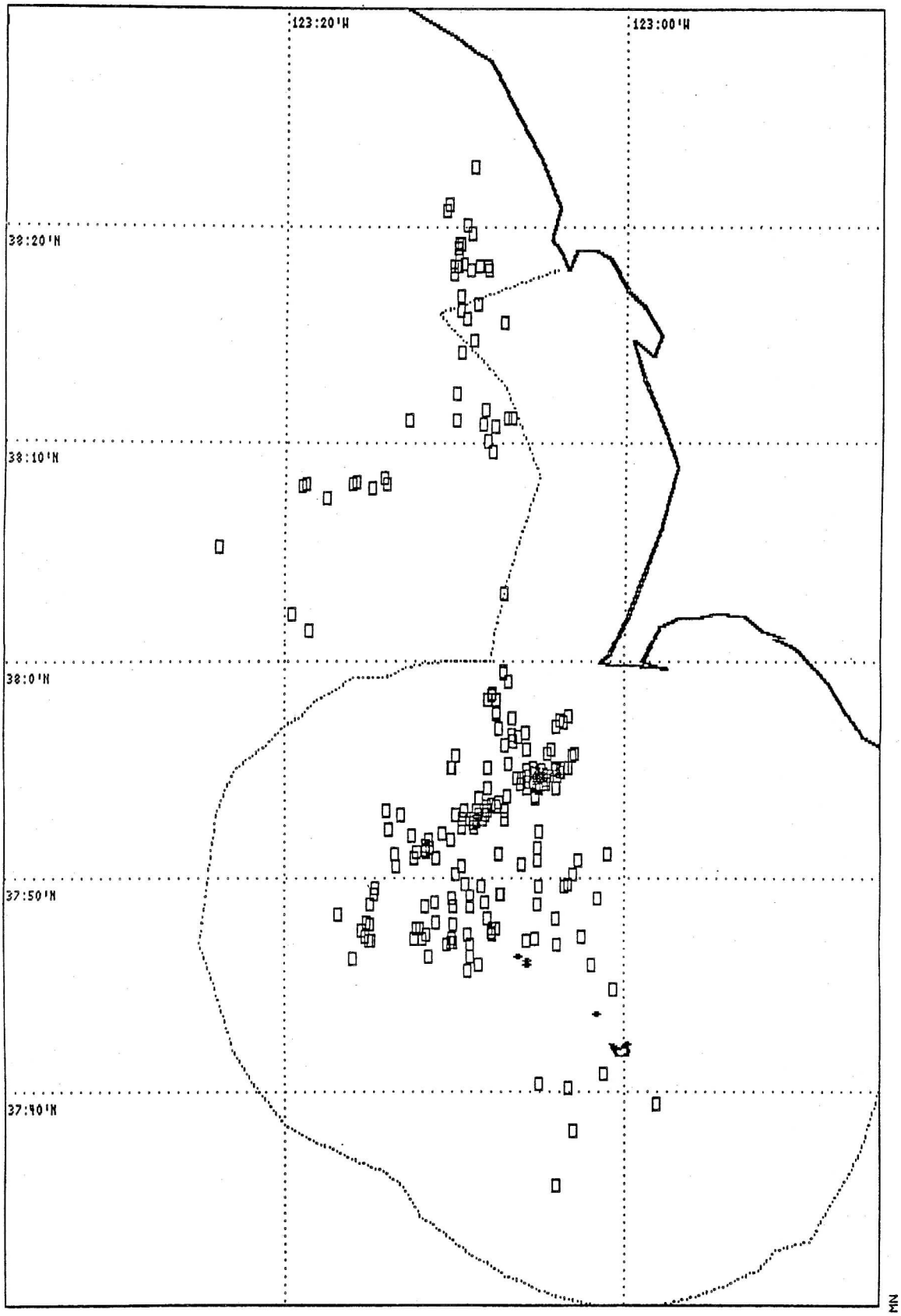


Figure 3. Locations of sightings of humpback whales from 23 July to 15 September 1986 (seen from dedicated vessels only).

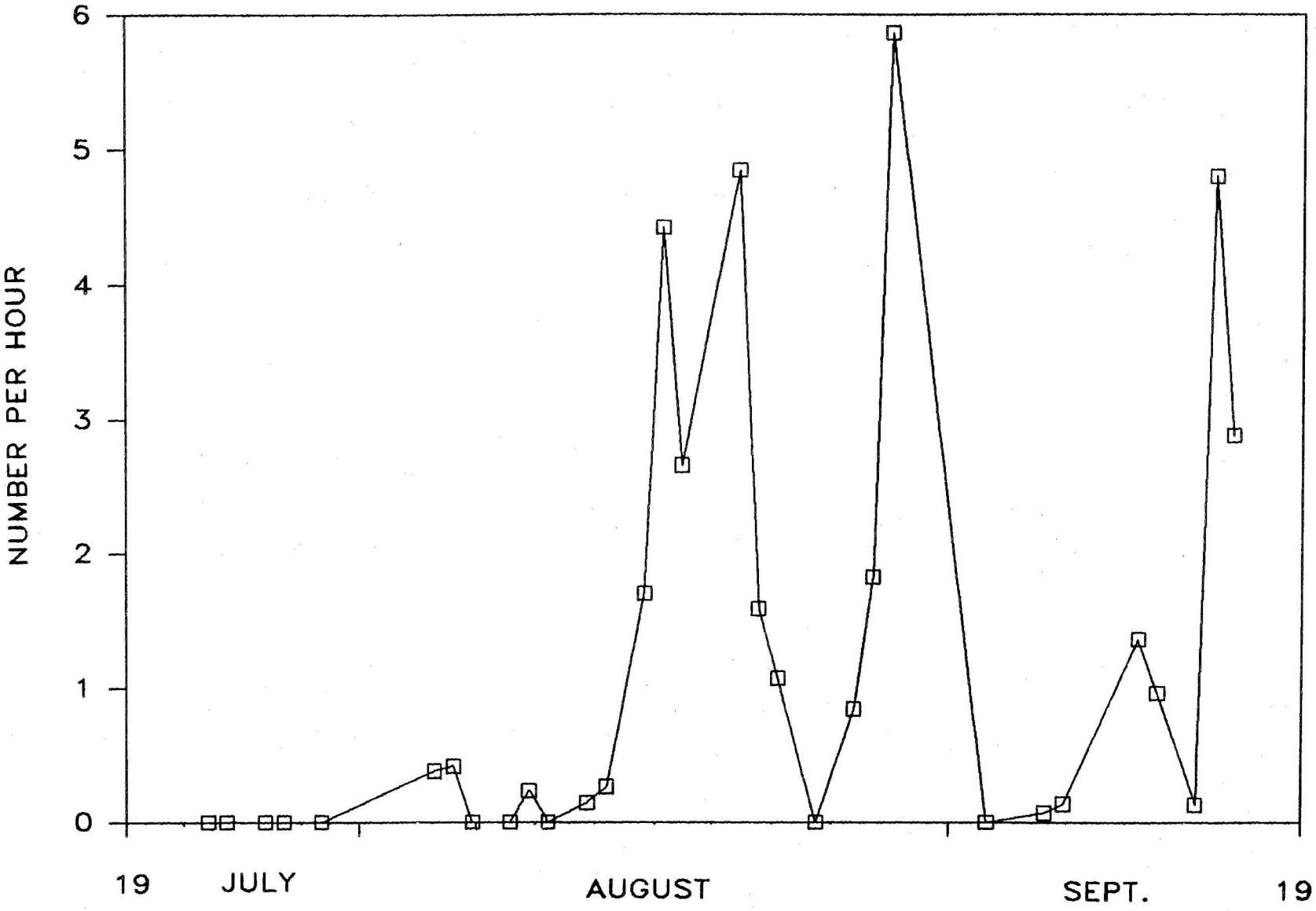


Figure 4. Effort-corrected sighting frequency (number of whales seen per hour) of humpback whales seen from the Noctilio throughout the study period.

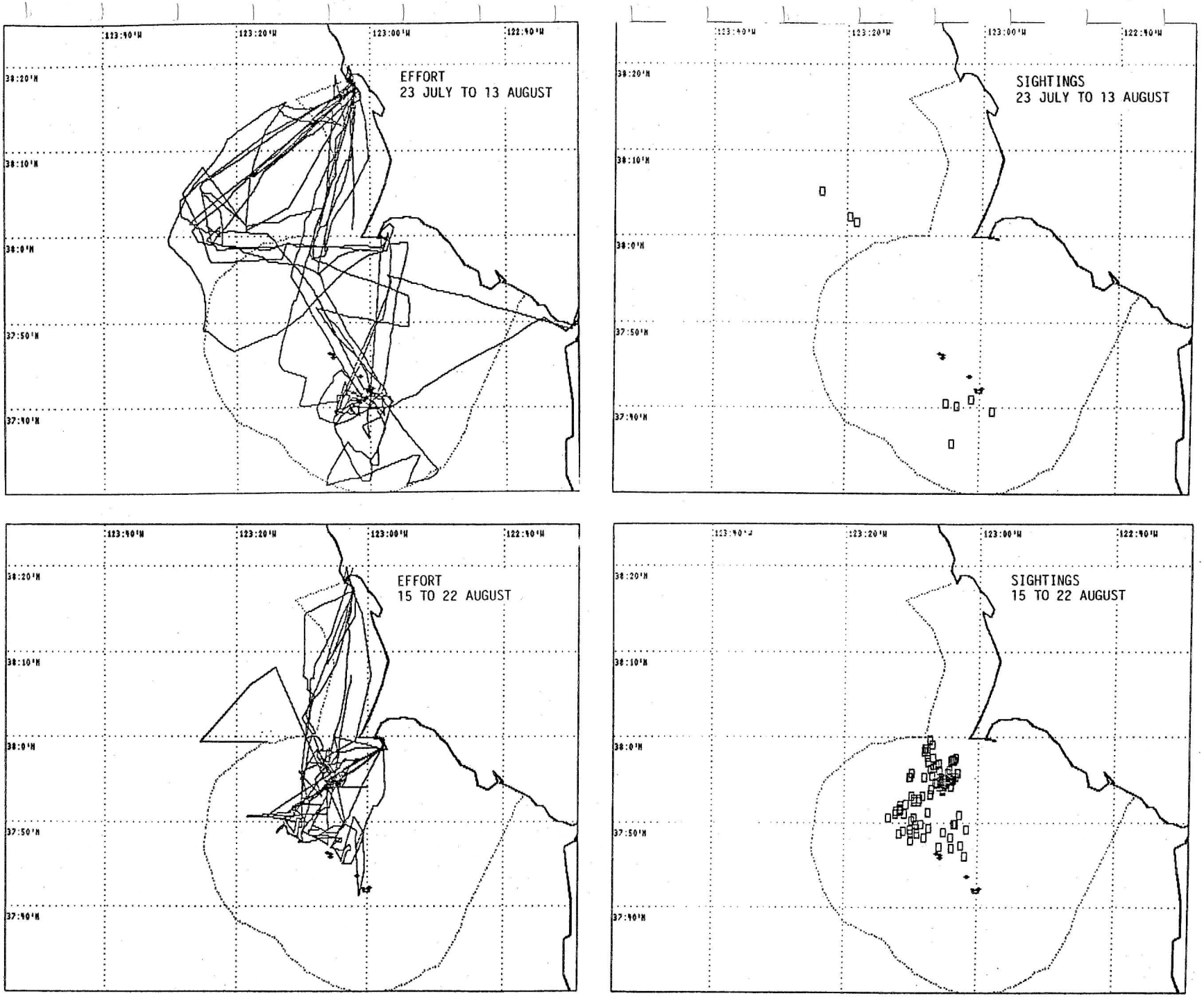


Figure 5a. Effort and sightings of humpback whales from dedicated vessels by time period.

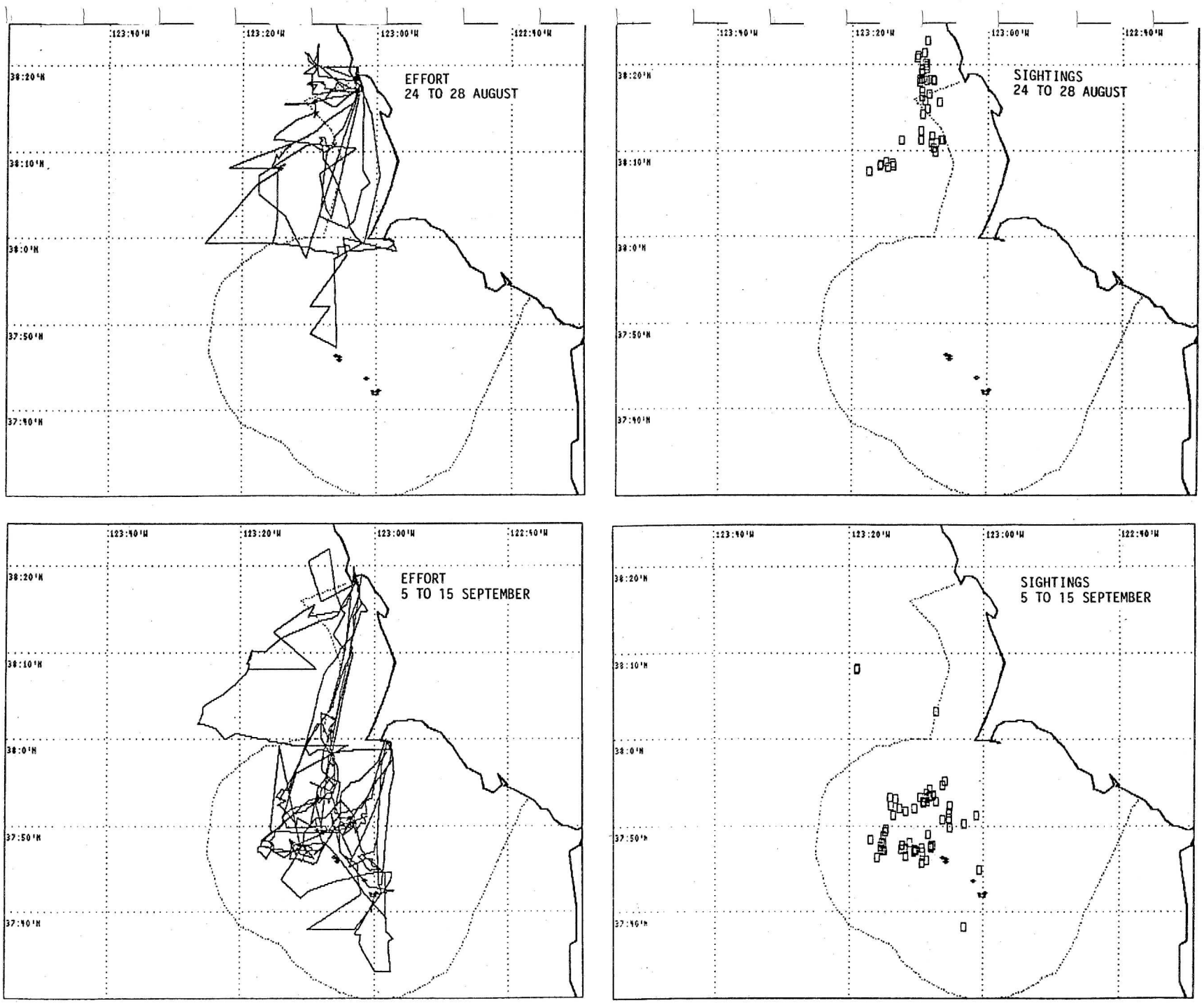


Figure 5b. Effort and sightings of humpback whales from dedicated vessels by time period.

The consistent resighting of the same whales in these mobile aggregations (discussed later) indicate they are the same group and not new animals moving into the area.

Figure 6 shows the sightings of humpback whales from Oceanic Society trips to the Farallon Islands between 7 June and 26 October 1986. These surveys, though covering only a limited portion of the study area, extend through a broader time period than the dedicated vessel surveys. Few humpback whales were seen by the Oceanic Society or Cascadia Research vessels until 16 August. Numbers of humpback whales seen by the Oceanic Society did not peak until early October and remained high throughout October. The total number of humpback whales seen on any one day was never higher than 15 animals. The high number of whales seen in October may reflect two possibilities: 1) there were more whales in the entire study area during October than previous months, or 2) there was no increase in October but whales were more concentrated in the vicinity of the Farallon Islands where the Oceanic Society trips focussed their effort.

Association with depth

Humpback whale sightings were strongly associated with water depth for 494 of the 628 whales sighted from dedicated vessels were seen in water depths of 250 to 350 feet. Because different water depths were not sampled equivalently, sighting frequency by depth must be corrected for effort to test for whale preference. Figure 7 shows the number of humpback whales seen from the Noctilio (the vessel with the best effort data) per hour of effort at different water depths. Sightings per hour varied significantly by depth (chi-square, $p<0.001$). The highest number of sightings occurred at the 250-300' depth class but the rate per hour was slightly higher at the 300-350' depth class. Only one sighting was made at a water depth of less than 200' (none from the Noctilio). Sightings in deep water were infrequent; the sole exception was a single sighting of two humpbacks whales in 1,000' of water.

Association with birds

We found a significant association between humpback whales and the presence of marine birds. Though a majority of humpback whale sightings occurred when marine birds were not in the area, sightings of humpback whales was significantly higher than would otherwise be expected when marine birds were in the area (chi-square, $p<0.001$). This significance was primarily the result of a very high sighting frequency of humpback whales when more that 25 marine birds were noted within 300 m of the survey vessel.

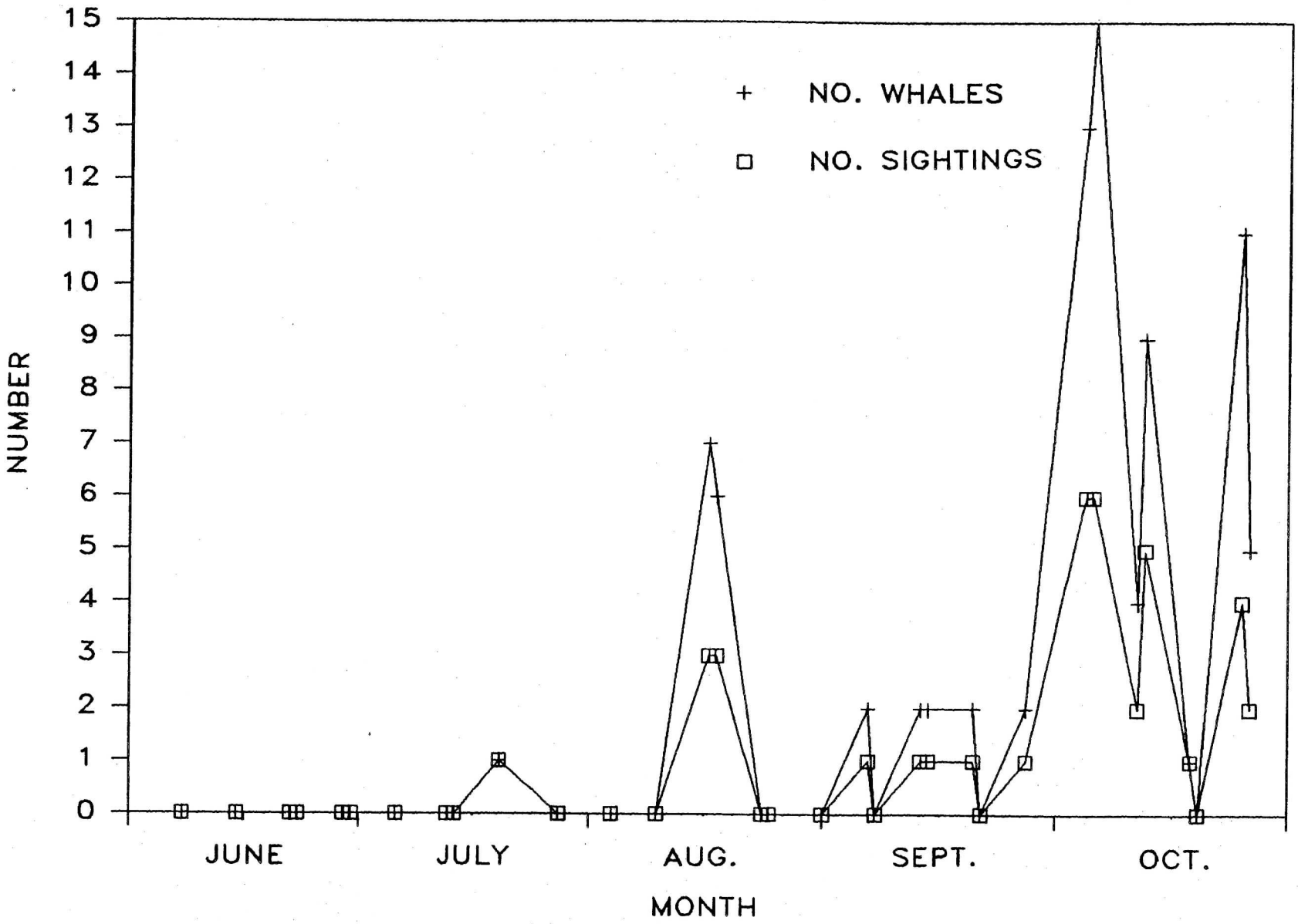


Figure 6. Number of sightings and whales seen by day by Farallon Research Associates from Oceanic Society nature trips in the Gulf of the Farallones in 1986.

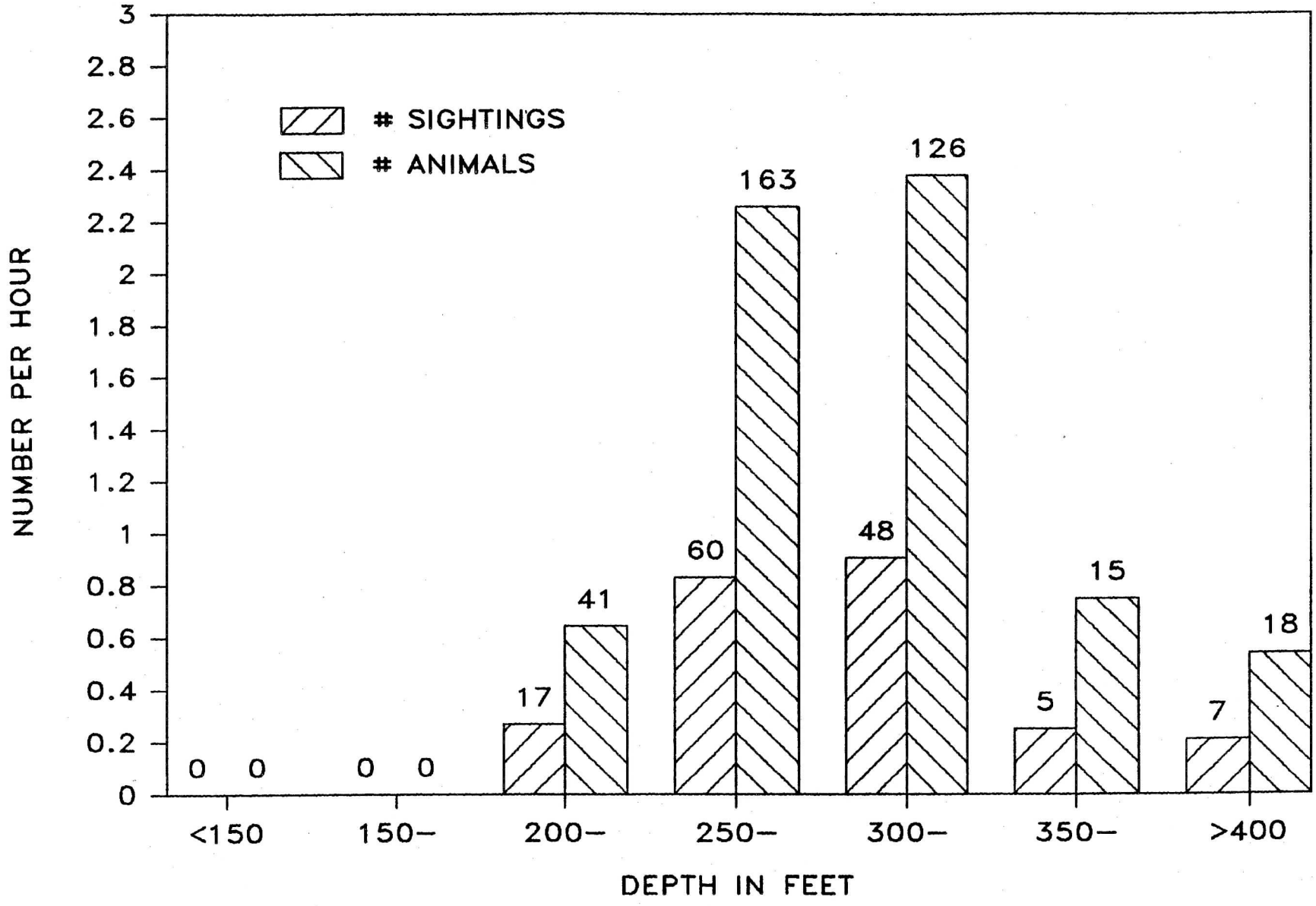


Figure 7. Humpback whale sightings and number per hour of effort by depth (from the Noctilio) in 1986. Scale is effort corrected and numbers obove bars show actual number of sightings and whales.

Association with ships

No relationship was found between the occurrence of humpback whales and the presence or absence of shipping traffic. There was no significant difference in sighting frequency from the Noctilio between when ships were within 2 nm and when none were in the area (chi-square, $p>0.05$). Any possible association between humpback whale distribution and small boat traffic could not be evaluated because the presence of Cascadia's survey vessels in the area with the whales biases the results.

Individual Identification

We individually identified a minimum of 88 humpback whales from dedicated vessel surveys starting on 9 August, when the first whale was identified, to 15 September when surveys ended. Over 5,000 photographs, mostly of humpback whales, were taken in the study, indicating the high degree to which individual whales were photographed many times, both during and between different sightings.

The current fluke catalogue has been modified slightly since the catalogue of 87 whales was submitted to the National Park Service and the Gulf of the Farallones National Marine Sanctuary. Four whales have been dropped from the earlier catalogue: 1) two internal duplicates (Cat. #10080, matching #100060, and #10072, matching #10086), 2) Cat. # 10066, believed to a photograph of the leading side of the fluke of #10005, and 3) Cat. #10085, which was photographed well north of the study area. Five whales have been added to the catalogue and given catalogue numbers from 10088 to 10092. These whales were given new numbers rather than assigning them numbers of whales that were dropped to avoid any confusion in data analysis. The current catalogue contains 88 whales.

Individual whales were resighted up to 20 times on up to 9 different days from dedicated vessels in the study area. Individually identified whales were resighted an average of 5.2 times ($n=88$, $s.d.=3.9$) on 3.1 days ($s.d.=1.8$). Whales sighted multiple times on the same day include sightings made by different vessels or later encounters with the same vessel. The number of times a whale was resighted does not appear to be related to the degree to which it is distinctly marked; the resighting frequency among four categories of individual whales grouped by their coloration and degree of scaring was not significantly different (ANOVA, $p>0.05$).

As the season progressed, a decreasing proportion of whales seen had not been seen before. Figure 8 shows the cumulative number of different

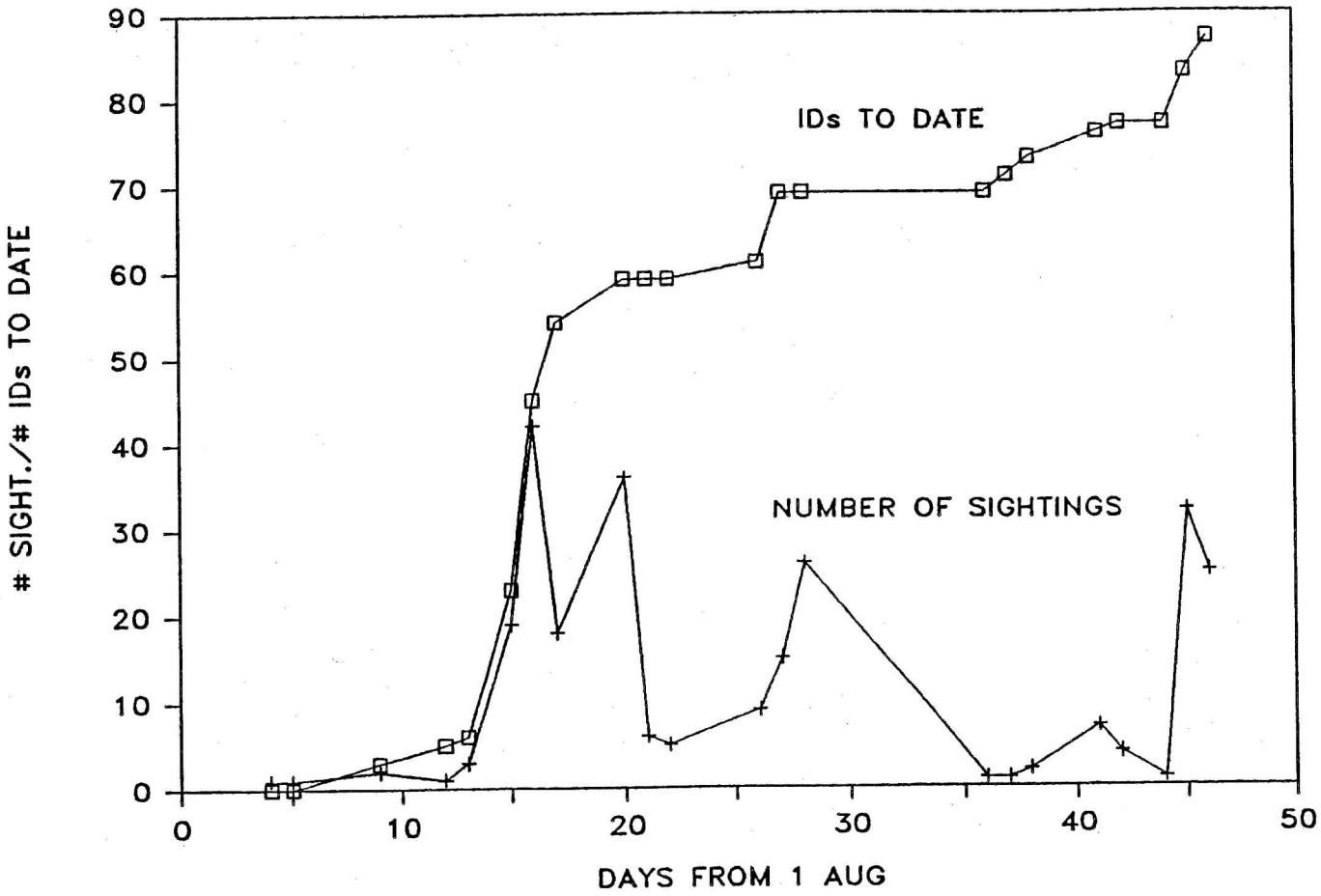


Figure 8. Cumulative whales identified and number of sightings from dedicated vessels by day.

whales identified and the number of whales sighted by day during the study period. An increase in the proportion of new whales would indicate immigration of a new group of animals into the study area. This apparently did not occur during the period we sampled, though this does not rule out the possibility that new animals entered the study area after the end of our study period. Resolving this question of emigration and immigration will be an objective of our research in Year 2.

Figure 9 shows the sighting locations of some of the most frequently resighted whales. These movements are similar to those described earlier for overall sightings. These figures verify that the shifts in locations of overall sightings were the result of the same general group of animals shifting location, rather than a new group moving into a different area.

Comparison to photographs taken by other researchers

Gulf of the Farallones. Photographs taken by Farallon Research Associates during 1986 and previous years were compared to our catalogue for matches. Of three good photographs taken at the same time as our effort, two matched and one did not. Seven photographs were taken after our field season in 1986 and of the five good quality photographs, three matched our identifications, one did not, and one was a tentative match. These frequencies of matches are too small to test statistically but are consistent with our conclusions that we had photographed most of the whales in the study area.

Nineteen photographs of humpback whales in the Gulf of the Farallones taken from 1981 to 1985 were examined. Of the 12 that were of good quality, 3 (25%) matched and 9 did not match with whales we had seen in 1986. This incidence of resighting is lower than would be expected if the same group of whales was returning every year.

Mexico. Matching of photographs with those taken by researchers in Mexico is still underway. As of the time of this report, nine of the whales in our catalogue had been matched to whales photographed in Mexico. Most of these matches were found by Mexican researchers and confirmed by Cascadia Research personnel. One match of note was Humphrey, the errant whale that swam up the Sacramento River in 1985. Humphrey was photographed by Cascadia Research on three days in 1986 in the Gulf of the Farallones National Marine Sanctuary. He was earlier photographed 2 miles NE of Isabel Island, Mexico on 29 December 1983 by Carlos Miguel Alvarez Flores (Alvarez 1987). The eight other matches with Mexico that we and collaborators have found were also from Bahia de Banderas/Isla Isabel, suggesting a very strong affiliation between that breeding/calving area and

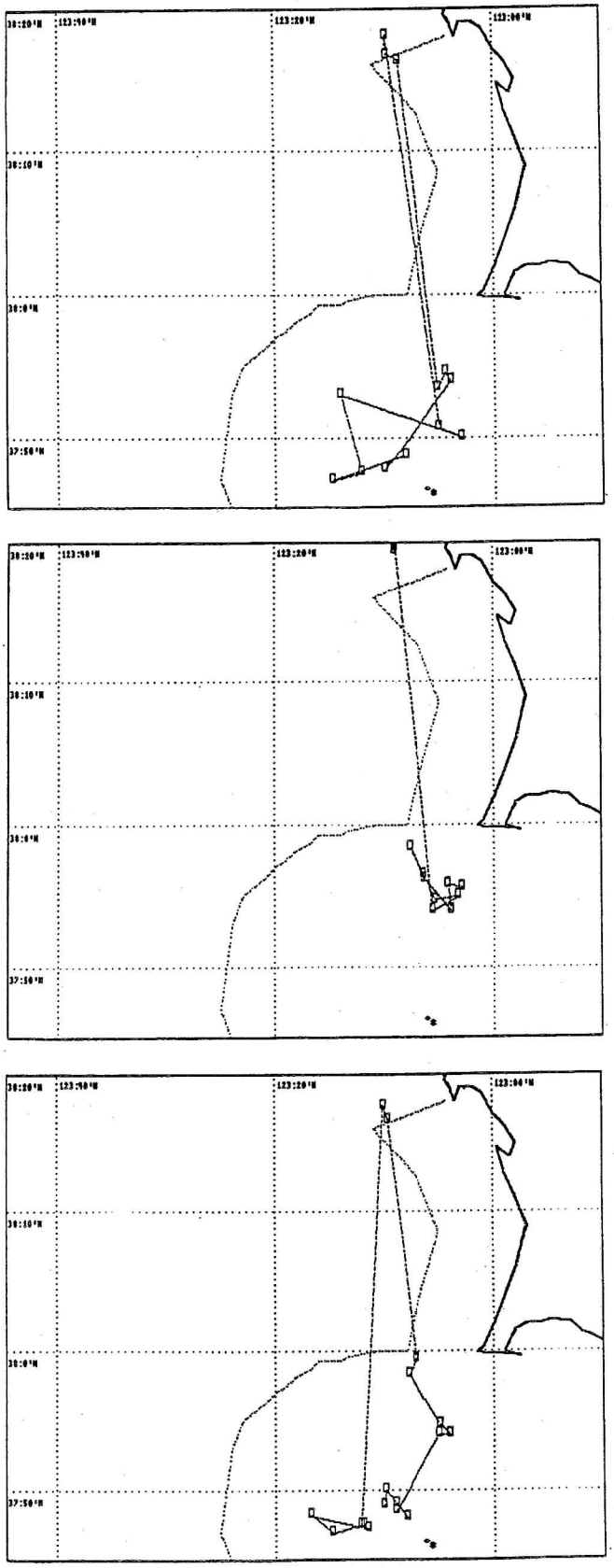


Figure 9. Resighting locations of three identified whales during the study period (23 July to 15 September). Top is for Cat. No. 10019, middle is for No. 10021 (Humphrey), and bottom is for whale No. 10039. All resights, even on the same day are shown.

the humpbacks off central California. This rate of "matching" between a North Pacific feeding area and the breeding areas off Mexico is much higher than any reported to date (Baker et al. 1986: 1 of 326 from Southeast Alaska, 1 of 55 from Prince William Sound; n=43 from Mexico).

Hawaii. Matching of photographs with Hawaii is still underway. At the time of this report, no matches have been found between our catalogue and the Hawaiian breeding area, and only one had been reported in the literature (Sczepaniak 1985, Baker et. al. 1986). This apparently low affiliation between the Gulf of the Farallones feeding area and the Hawaiian breeding area contrasts markedly with the high interchange between Hawaii and other northern feeding areas (Baker et al. 1986: 65 of 326 from Southeast Alaska, 8 of 55 from Prince William Sound, and 4 of 15 from the western Gulf of Alaska; n=604 from Hawaii).

Local Population Estimate

Mark-recapture population estimate

We estimated the number of animals in the Gulf of the Farallones based on photo-identification and several mark-recapture procedures. The minimum population estimate for the Gulf of the Farallones humpback whale feeding aggregation is at least 88 individuals (the number in the catalogue). As discussed earlier, most animals were resighted frequently, suggesting that a "resident" feeding aggregation exists around the Farallon Basin. Figure 10 shows resightings of individual whales through the study season. It is also possible that animals from other areas arrived later in the season when high numbers of humpbacks were reported in the area but were not photographed. Though estimates based on mark-recapture statistics between years will provide a good estimate of the resident group size and site fidelity of humpbacks whales, we can also calculate the number of animals present during this first year by comparing frequencies of reidentification of animals photographed in different periods of the study. Population estimates were made from two datasets: 1) all photographs where an individual was identified and 2) photographs selected for image quality criteria independent of whether the whale was identified.

Modified Peterson estimate. The Peterson estimate, as modified by Chapman, was used to examine estimates of population size from both selected and unselected photographs and from different time periods for marking and recapturing animals within the season. Two cut-off dates to separate the mark and recapture periods were used: 23 and 29 August. Both have roughly equivalent sample sizes in the two periods and result in similar population estimates (Table 3). The unselected photographs (Data set 1)

Table 3. Mark-recapture figures using the modified Peterson estimate two cut-off dates and two datasets: 1) only those photographs meeting specific criteria (described in text), and 2) using all identifications.

Cut-off date for 2 samples	No. per period 1	2	No. recaptured	Populat. estimate	Variance
Selected photos					
23 August	51	63	34	94	1302
29 August	62	51	33	95	1437
All photos					
23 August	58	72	42	99	1093
29 August	68	58	38	103	1566

yielded slightly higher values than the selected photographs (Data set 2). The range of estimates of 94 to 103 whales are only slightly higher than the minimum number of animals represented in the catalogue total of 88 whales.

Schnabel estimate. The Schnabel estimate of population size provides an alternate technique using animals identified on each day as separate samples. Results of this analysis are given in Tables 4 and 5 for the selected and unselected photographs, respectively. Analysis of both the selected and unselected identifications give the same result, an estimate of 82 whales. Surprisingly, this estimate is lower than the total number of marked whales.

Bailey triple-catch estimate. This estimate, based on 1986 data broken down into 3 sample periods, is summarized in Table 6. The estimates of population at the end of the second period (28 August) are 72 using the selected sample and 73 with the unselected sample. Both estimates are very low but the calculations also indicate an estimated 24% and 28% immigration between periods 2 and 3 for data sets 1 and 2. With these immigration estimates, there were 90 and 93 animals at the end of the study period. These adjusted numbers are similar to those found using the Peterson estimate.

Accurate mark-recapture estimates rely on several assumptions about the population being examined. Some of these assumptions are:

1) Photographed (marked) individuals become randomly mingled with the remainder of the population between sample periods.

2) The photographed individual is not affected by the photographic pursuit (marking) and thus the probability of a later photograph being taken (capture) is not affected by earlier markings and captures.

3) All animals are equally available for photography (recapture) and all samples are taken randomly.

4) No tag loss occurs. That is, once a whale is photographed and "marked", if it is photographed again with sufficient resolution, it will be identified.

The first two models are designed for "closed" populations and have a fifth assumption of negligible emigration, immigration, natality or mortality during the sample period. In the first two models a sixth assumption is that there are no gains or losses to the population.

Table 4. Calculations for Schnabel estimate of population. Analysis is based on the use of photos selected to meet specific quality criteria (see text).

Date mo.	Date dy.	No. seen	Marked start	Recaptures	Population estimate
8	9	1	0	0	-
8	12	1	1	0	-
8	15	14	2	0	-
8	16	28	16	8	60
8	17	16	36	5	81
8	20	24	47	20	66
8	22	4	51	4	64
8	26	7	51	4	67
8	27	9	54	4	72
8	28	18	59	15	72
9	5	1	62	0	73
9	6	1	63	0	74
9	7	2	64	0	76
9	10	10	66	6	79
9	11	5	70	5	78
9	14	24	70	20	79
9	15	31	74	25	82

Final estimate = 82
95% Confidence interval = 69-102

Table 5. Calculations for Schnabel estimate of population. Analysis is based on the use of all photos where whales could be identified.

Date mo.	dy.	No. seen	Marked start	Recap-tures	Population estimate
8	9	3	0	0	-
8	12	2	3	0	-
8	13	1	5	0	-
8	15	18	6	1	119
8	16	37	23	15	61
8	17	19	45	10	70
8	20	28	54	24	67
8	21	3	58	3	66
8	22	5	58	5	66
8	26	9	58	7	67
8	27	18	60	10	72
8	28	26	68	26	71
9	5	1	68	1	71
9	6	2	68	0	72
9	7	2	70	0	74
9	10	16	72	12	76
9	11	7	76	6	77
9	14	37	77	31	80
9	15	37	83	32	83

Final estimate = 83
95% Confidence interval = 71-98

Table 6. Population estimates based on Bailey triple-catch method.

Period	Dates start	Dates end	No. marked/ examined	No. captured from period 1	No. captured from period 2
Selected photographs only					
1	9 Aug.	17 Aug.	47		
2	20 Aug.	28 Aug.	43	28	
3	5 Sept.	15 Sept.	51	26	24
Estimated population (period 2) = 72 Immigration (period 2 to 3) = 24% Emigration = -1% Revised population (w/ immigration) = 90					
All photographs					
1	9 Aug.	17 Aug.	54		
2	20 Aug.	28 Aug.	52	38	
3	5 Sept.	15 Sept.	58	32	31
Estimated population (period 2) = 73 Immigration (period 2 to 3) = 28% Emigration = -1% Revised population (w/ immigration) = 93					

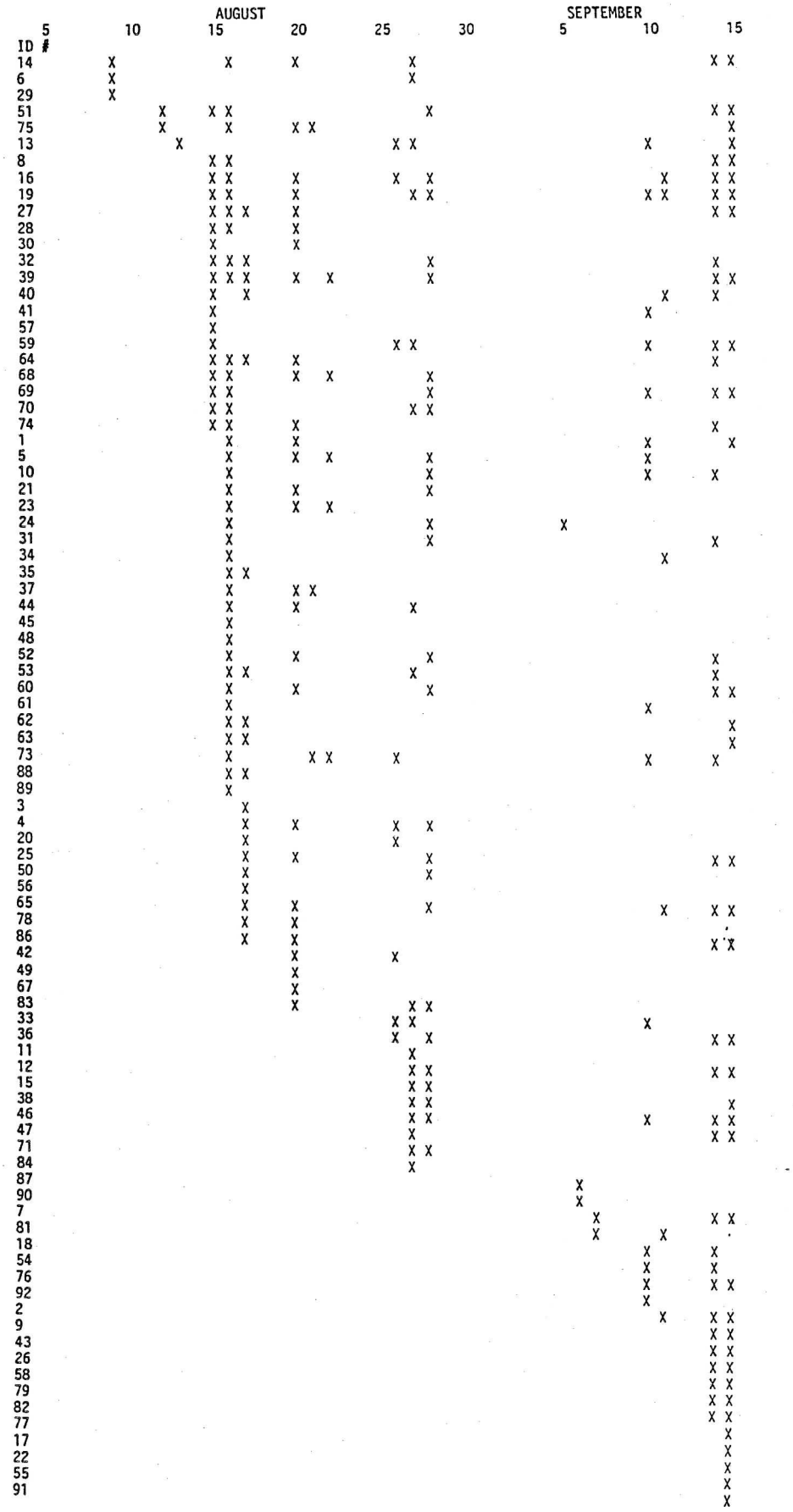


Figure 10. Resightings of individual humpback whales by day in the order they were first encountered. ID # refers to the catalogue number.

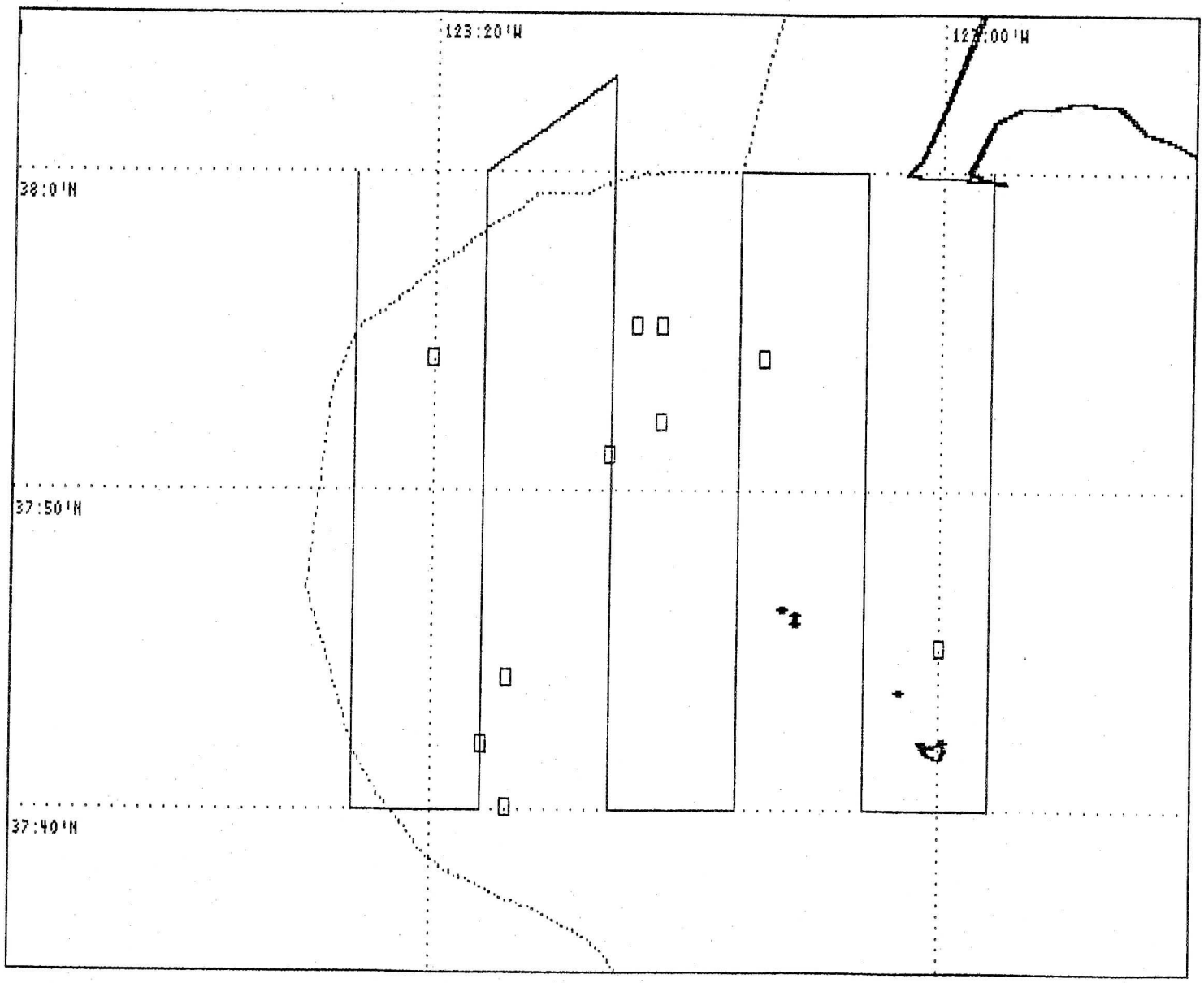


Figure 11. Survey track and locations of humpback whale sightings for 16 September 1986 aerial survey used for population estimate.

Though some of these assumptions are violated, the extent of the violations in all cases are likely small. Assumption #1 is probably violated to some degree by the short time between sample periods. This assumption will be less of a problem when samples from different years can be compared. We saw no evidence that assumption #2 was violated to a significant extent. Resightings shown in Figure 10 do not indicate significant violations of assumptions 1 and 2, as the patterns of resightings showed no change through the season (i.e. animals photographed many times early in the season are still rephotographed at the same rates as animals first seen near the end of the season). Assumption #3 is likely violated because of evidence that all age-classes do not fluke equivalently (Perkins et al. 1985, Kaufman et al. 1987), resulting in negative bias in the population estimates. Any bias is likely small, since calves appear to be the age group least likely to fluke, and they were not present in the study area. We will further examine this potential source of bias in the second year of research. Assumption #4 is not a problem; markings do not appear to change appreciably over time and we resighted even poorly marked whales as often as distinctly marked whales. The assumption of a closed population is likely violated to some degree, but as violations of this assumption lead to a positive bias in the population estimate, and our estimates are equivalent or only slightly higher than the number of whales in the catalogue, this does not seem to be a major source of bias. Overall the mark-recapture estimates appeared reasonable and agreed with the number of whales in our catalogue and our impression that we had photographed almost all the whales in the study area.

Aerial census

The primary emphasis of the aerial survey was to provide reconnaissance for the vessel-based work. Given the wide variance found in aerial surveys of abundance (Davis et al. 1982, Dohl et al. 1983), we considered population estimates from aerial censuses secondary to population enumeration made by mark-recapture estimates. One advantage of aerial survey however, is that it yields an estimate of the minimum number of animals in the study area on one day. The mark-recapture statistics provide an estimate of the number of animals in the area over the study period.

The most complete aerial survey flown in excellent viewing conditions through areas of primary whale concentration was on 16 September. Figure 11 shows flight lines and humpback whale sightings. A total of twenty-eight whales were seen in 10 sightings. Distance of sightings from the trackline are shown in Figure 12. We delineated the width of the effective strip at one nautical mile on either side of the plane. This width is

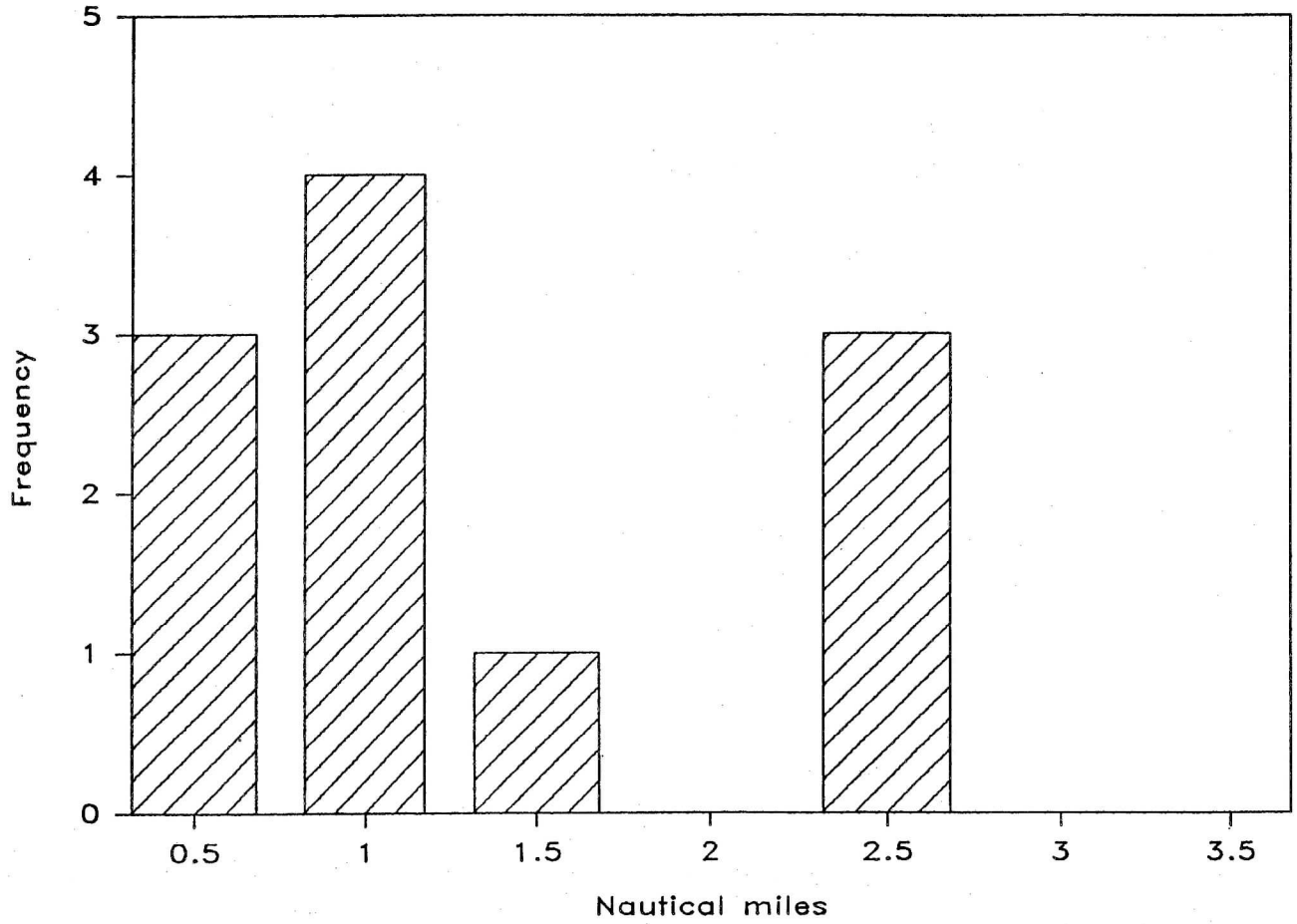


Figure 12. Distance from trackline of humpback whale sightings made from 16 September aerial survey,

larger than that used by most surveys for mysticetes, but the excellent weather conditions (Beaufort <= 2, low sun angle, unlimited visibility) allowed for great visibility of whale blows. If the strip is considered to extend 1 mile off transect, then 50% of the area was surveyed (lines at 4 mile intervals).

Of the 28 whales seen, six sightings of 18 humpbacks occurred within the 1 mile strip. If this density is extended to the entire survey area, at least 36 humpbacks were in the survey area. We sought to apply a possible correction for the percentage of animals missed entirely because they were submerged when the survey plane flew by. This correction can be applied to the uncorrected population estimate as follows:

$$P_c = P_u / C_1$$

where P_c is corrected population estimate, P_u is uncorrected estimate, and C1 is the probability of an animal in the area being at the surface.

This correction factor is not easily derived. For bowhead whales, Davis et al. (1982) used a value of 0.26 for C1. This mysticete probably dives longer than feeding humpbacks and so this C1 value is probably too small to be applied to humpbacks. Dohl et al. (1983) report density estimates of humpback whales observed from aerial surveys in the Gulf of the Farallones area but do not report if the correction C1 was used. Scott and Winn (1980) report comparisons of aerial and vessel surveys for humpback whales. Observers in aircraft flying at 120 kts saw, on average, 27.6% of the humpback whale pods seen from vessels in the same area at the same time. Our aircraft flew slower (80 kts) and thus the correction that needed to be applied for C1 (animals submerged when the plane passed) would be less than with a faster airplane that remained over the whales for a shorter time. Baker et al. (1982) report that undisturbed humpback whales remain below the surface 60% of the time (described as total time in dive). As a crude approximation we used this value as a probability (0.4) that humpback whales will be at the surface when the aircraft flew by. This value is higher than any reviewed above and would thus tend to make estimates of abundance low and conservative.

Applying this correction, we estimate 90 humpback whales were in the area surveyed (approximately 1370 km^2) for an estimated density of 0.066 humpback whales/km^2. This estimate agrees well with the mark - recapture estimate and suggests that many of the marked animals were in the study area simultaneously.

Size Classes of Humpback Whales

Fourteen humpback whales images of sufficient quality (grade 3 or better flex and resolution, see Methods) were measured. Review of the size classes by day follows:

Date	N	Size (meters) Range	Mean	SD
14 Aug	3	12.4–12.8	12.6	0.2
28 Aug	4	10.5–12.4	11.5	0.8
10 Sep	7	10.6–13.0	12.0	0.8

Two animals were less than 11 meters long and thus were immature (Nishiwaki 1959). The rest are adult-sized and are thus over 5 years old. This is a low percentage (14%) of immature animals compared with the 24% immatures found on the wintering grounds in the Atlantic (Scott and Winn 1980). This low number of immatures is consistent with the lack of any calf sightings from either the vessel or aerial surveys during this study. This overall low rate of immature animal sightings suggests the Gulf of the Farallones may support primarily non-reproductive adults (males and "resting" females) and that adult females with calves may be found in other areas. Dohl et al. (1983) reported only four sightings of "juvenile" humpbacks from three years of surveys off the coast of California.

Other Marine Mammals

Sightings of other marine mammals, incidental to our humpback whale research, were recorded. We present a brief summary of these sightings for each species below.

Blue whale

Blue whales were seen frequently during surveys conducted by Cascadia starting with an initial sighting during an aerial survey on 1 August 1986 through the end of the field season on 15 September. The first blue whale seen during the Oceanic Society nature trips was on 27 July. The last was on 25 October 1986. Just under 100 sightings of blue whales were made during dedicated vessel surveys in the study area (Figure 13). Additional results of the blue whale research are presented in a separate report.

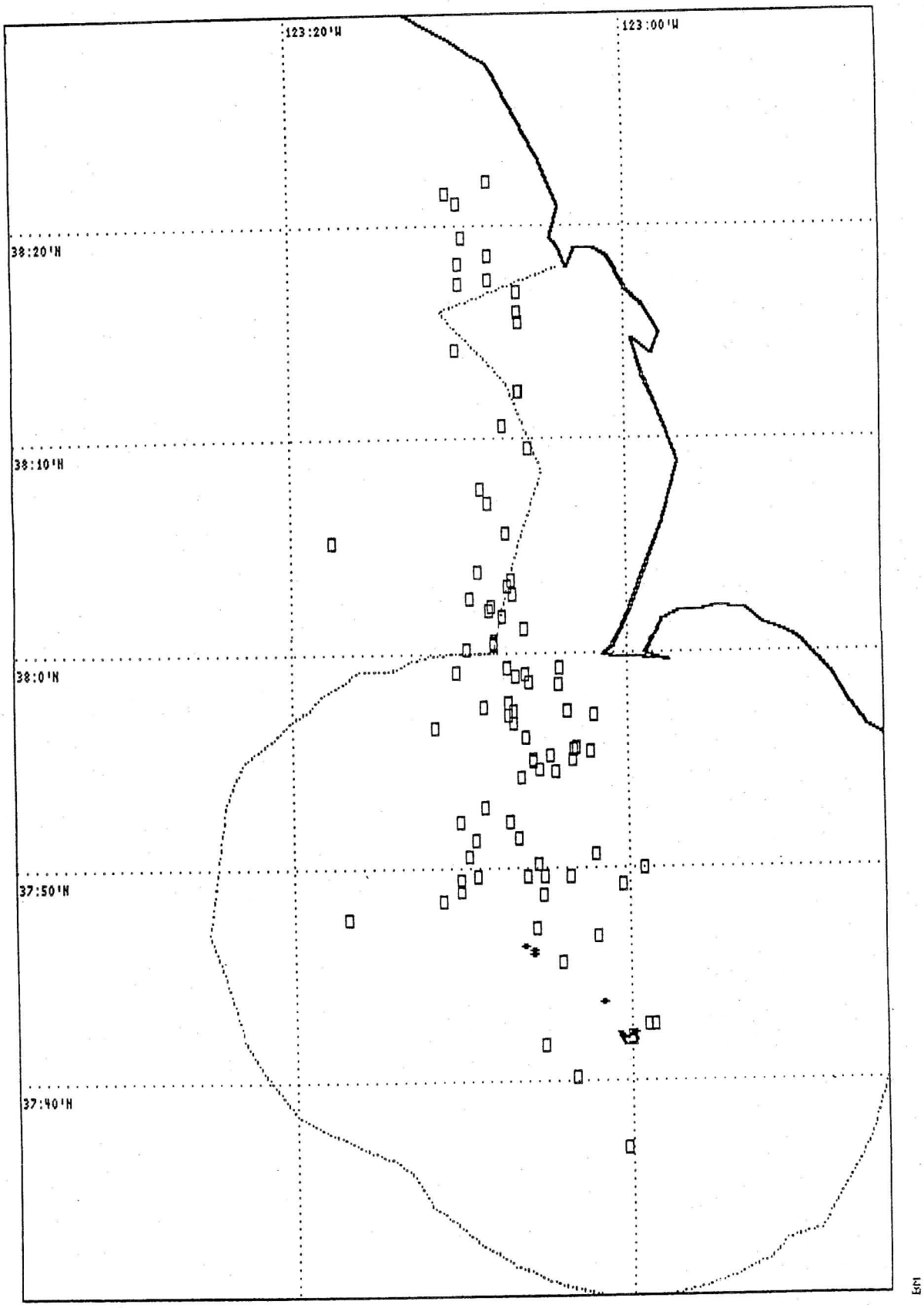


Figure 13. Locations of sightings of blue whales from dedicated vessels, 23 July to 15 September 1986.

Minke whale

Eleven sightings of 13 minke whales were made during dedicated vessel surveys in the study area (Figure 14). Sightings were made from 6 August to 5 September with four sightings on 16 August. All sightings were of single animals with the exception of two sightings of pairs. All sightings occurred in water depths of 240 to 360 feet.

Sei whale

Five sightings of solitary sei whales were made from dedicated vessels with one additional sighting during an aerial survey and one during the supplemental 15 September cruise aboard the "Avant-Garde". All sightings were between 3 and 15 September. Photographs from these sightings indicate that at least two different animals were present, though a number of the sightings were of the same animal. The whales in these sightings were often associated and appeared to be feeding with one or more blue whales. Sightings occurred in water depths of 150 to 280 feet and all were north of 38° Latitude.

One of the animals individually identified from the photographs was determined to be the same individual photographed in the study area two years ago during an Oceanic Society nature trip. The individual was identified at the time as a fin whale creating, to our knowledge, the first documented inter-species photographic match. The true species identity of this individual remains in doubt.

Fin whale

Only one tentative sighting of a fin whale was made on 15 August. Since this animal was not seen closely the sighting is regarded as tentative.

Killer whale

Two sightings, both of a pair of killer whales, were made from dedicated vessels on 16 August and 15 September. Examination of the photographs of these animals indicate that the same adult male was present in both sightings, accompanied by a different second animal.

Risso's dolphin

Two sightings, both from the air, were made of Risso's dolphin on 1 August and 10 September. One was a group of 44 animals in association with

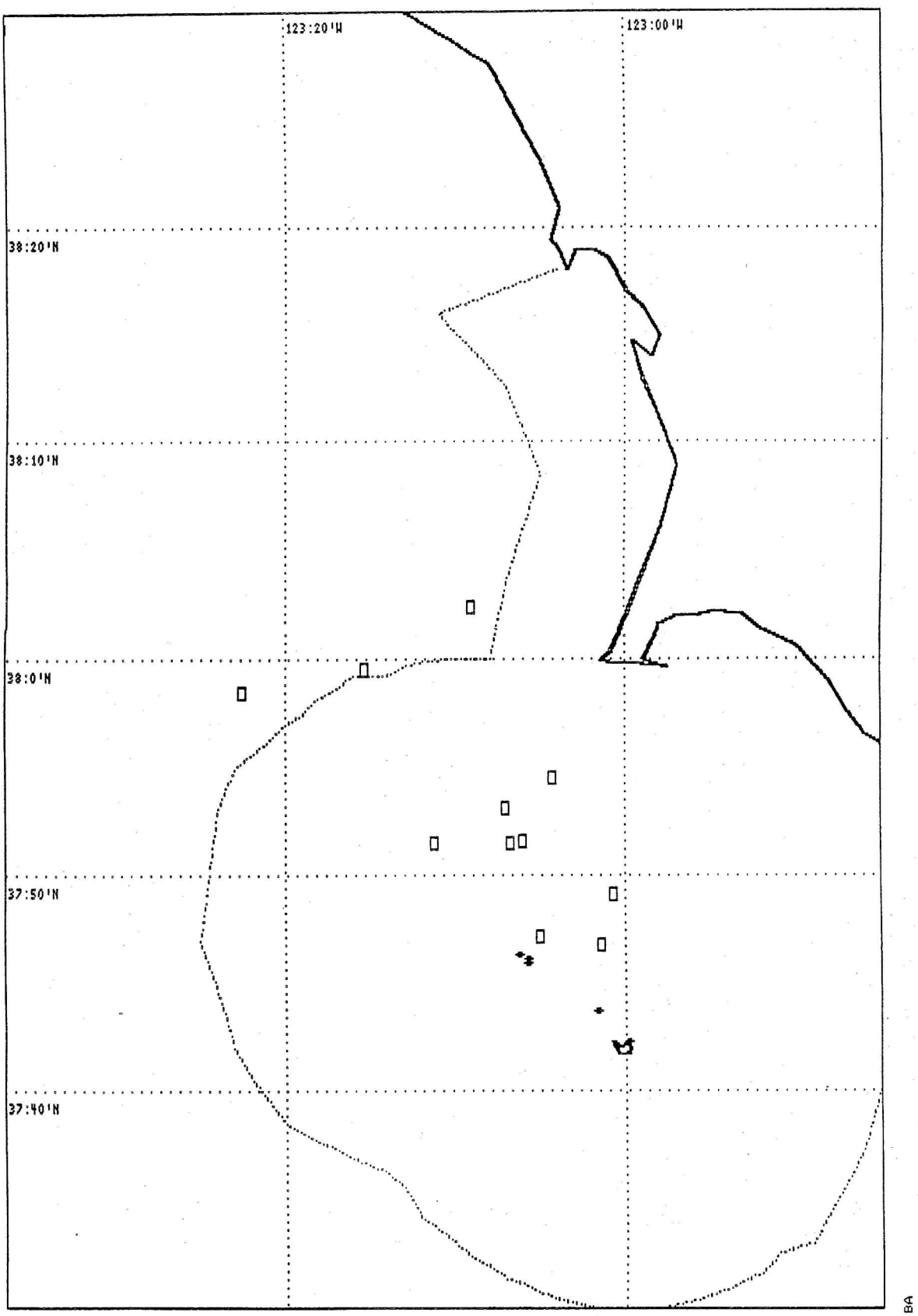


Figure 14. Locations of sightings of minke whales from dedicated vessels, 23 July to 15 September 1986.

Pacific white-sided dolphins and the second was a single animal. Both sightings occurred in deep water at the southwestern end of the study area.

Pacific white-sided dolphin

Pacific white-sided dolphins were seen on three occasion from the air (64 animals total) and two occasions from dedicated vessels (7 animals). All but one sighting occurred south of 37° 45' in the more southern portion of the study area. Sightings occurred between 1 August and 10 September.

Dall's porpoise

Dall's porpoise was the most frequently seen small cetacean from both dedicated vessels and aerial surveys with a total of 58 sightings of 231 animals in the study area (Figure 15). Sightings occurred at water depths of 160 to 1000 feet. Sightings occurred at a disproportionately higher rate in water more than 400 feet deep (chi square, $p<0.025$). A high number of sightings were also seen in the vicinity of Cordell Bank. Dall's porpoise were frequently seen with humpback whales, sometimes swimming directly in front of the whales. Sightings occurred throughout the study period from 23 July through 15 September.

Harbor porpoise

Thirty four harbor porpoise were seen in 22 sightings from dedicated vessels (Figure 16). All but five of the sightings were north of 38°. Sightings occurred in depths of up to 450 feet, though most were in much shallower water. The majority of the sightings were made from two vessels on 23 July 1986 when a large number of harbor porpoise were seen in the northern portion of the study area. A far greater number of harbor porpoise were seen during the Oceanic Society nature trips, but the vast majority of these sightings were made just off the entrance of San Francisco Bay, an area we did not survey.

California sea lion

California sea lions were the most often sighted pinniped with 129 sightings of 2,504 animals made from dedicated vessels. Several hundred California sea lions were frequently seen hauled out in July and August just off Bodega Head. Much smaller groups were seen at this site in September. Singles and groups of up to 50 California sea lions were seen in the water throughout shallow and deeper portions of the study area (Figure 17).

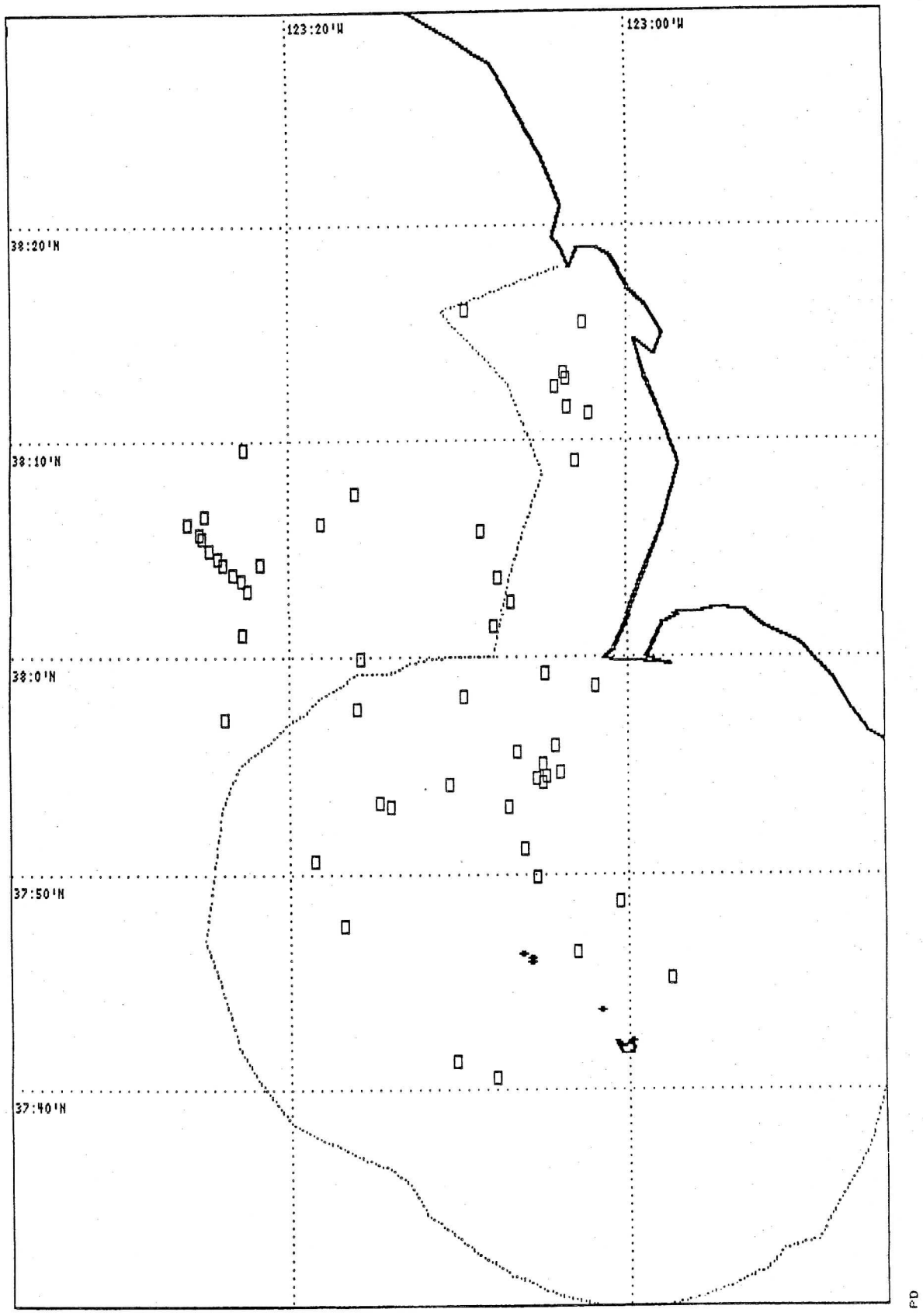


Figure 15. Locations of sightings of Dall's porpoise from dedicated vessels, 23 July to 15 September 1986.

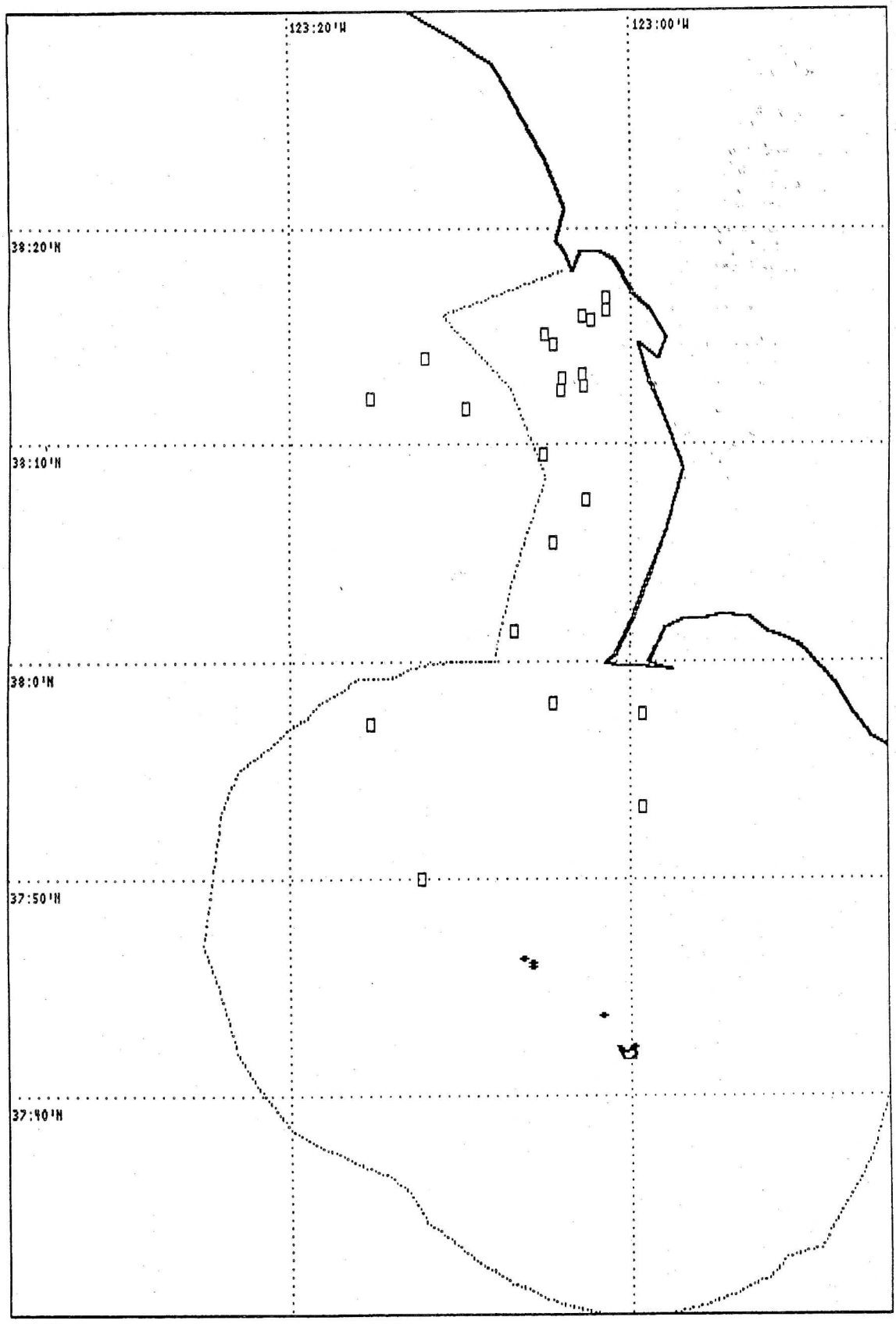


Figure 16. Locations of sightings of harbor porpoise from dedicated vessels, 23 July to 15 September 1986.

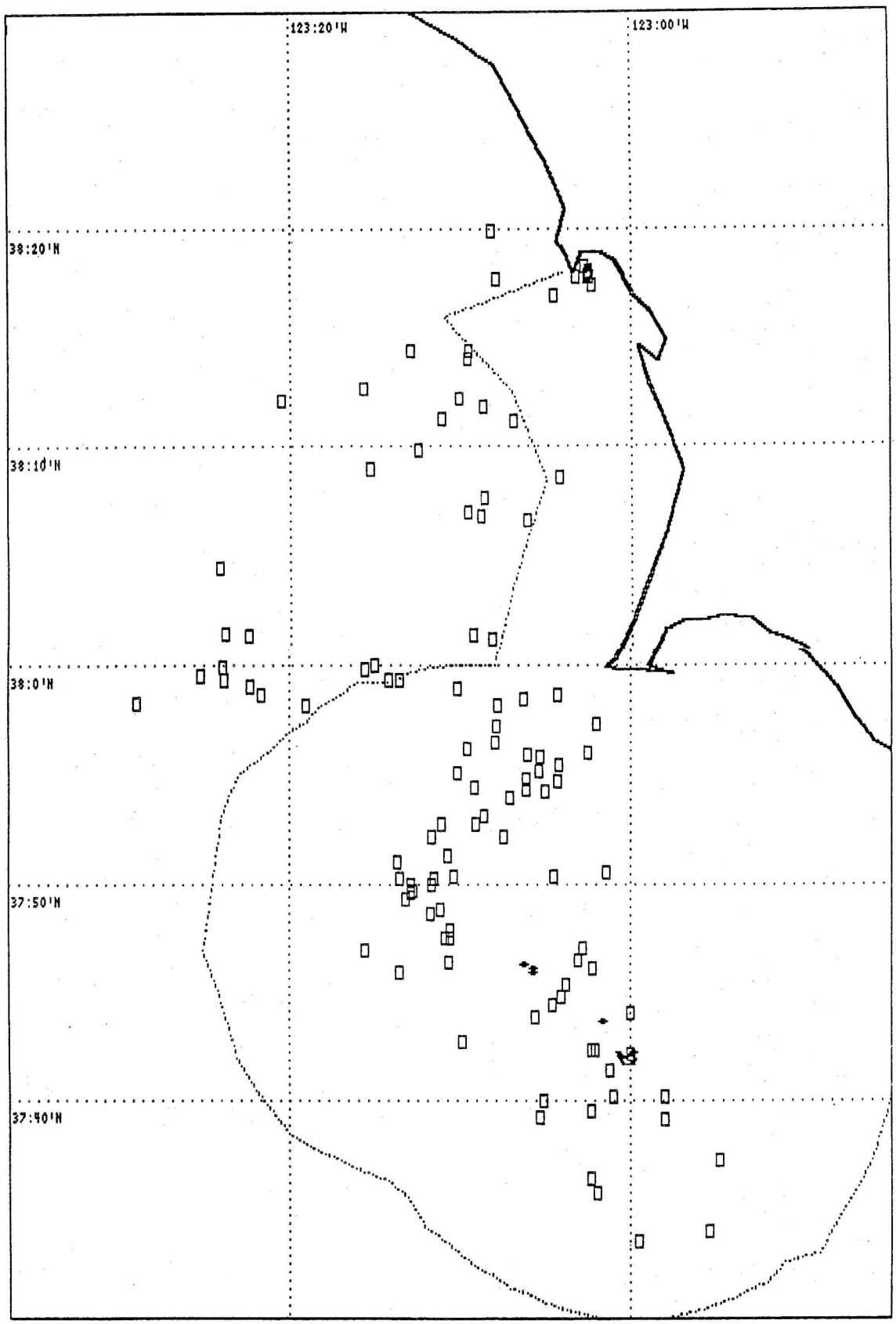


Figure 17. Locations of sightings of California sea lions from dedicated vessels, 23 July to 15 September 1986.

Northern sea lion

We made 22 sightings of 216 northern sea lions from dedicated vessels in the study area between 23 July and 15 September. These included animals hauled out off Bodega Head and at the Southeast Farallon Islands and sightings in the water scattered through the study area. Figure 18 shows the locations of all sightings.

Harbor seal

Harbor seals were seen during dedicated vessel surveys primarily close to shore or at their haul out areas. Forty-six sightings of 677 harbor seals were made between 23 July and 13 September. The majority of these sightings were of hauled out harbor seals at low tide just off the entrance to Bodega Bay, where up to 65 animals were seen. Though generally in shallower water, one sighting was made in 380 feet of water.

Elephant seal

The only sightings of elephant seals were made on Southeast Farallon Island on the few occasions where we approached the island close enough to identify pinnipeds on the shore.

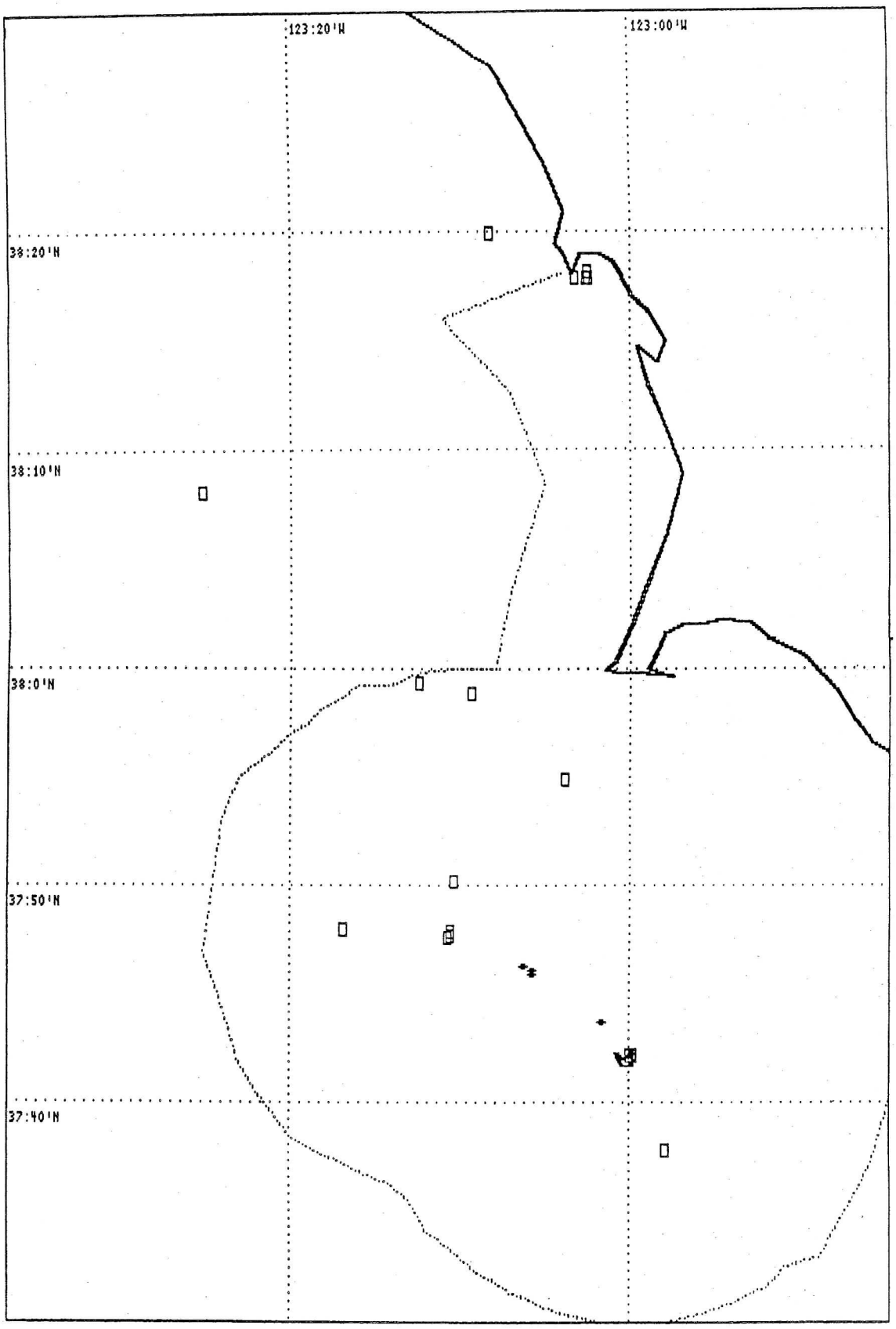


Figure 18. Locations of sightings of northern sea lions from dedicated vessels, 23 July to 15 September 1986.

REFERENCES

Alvarez, C.M. 1987. Foto identificacion del rorcual jorobado, Megaptera novaeangliae, en las aguas adya ceintes a Isla Isabel, Nay. Tesis Profesional, Univ. Nation. Autonoma des Mexico.

Bailey, N.T.J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38:293-306.

Balcomb, K.C., S.K. Katona, and J.M. Breiwick. 1983. Mark-Recapture estimate of western North Atlantic humpback whales using fluke photographs. Rep. Int. Whal. Commn. 34:141.

Baker, C.S., L.M. Herman, A. Perry, W.S. Lawton, J.M. Straley, A.W. Wolman, G.D. Kaufman, H.E. Winn, J.D. Hall, J.M. Reinke, and J. Ostman. 1986. Migratory movement and population structure of humpback whales (Megaptera novaeangliae) in the Central and Eastern North Pacific. Mar. Ecol. Progr. Ser. 31:105-119.

Baker, C.S., L.M. Hermann, B.G. Bays, and W.F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeastern Alaska. Reportfor Contr. No. 81-ABC-00114.

Chapman, D.G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. Univ. Calif. Publ. Stat. 1:131-160.

Darling, J.D. and C.M. Jurasz. 1983. Migratory destinations of North Pacific humpback whales (Megaptera novaeangliae). In: R. Payne (Ed.). Communication and behavior of whales. AAAS Selected Symposia Series, Wash. D.C.

Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans, and W.G. Alliston. 1982. Distribution, numbers and productivity of the Western Arctic Stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, Summer 1981. Rep. by LGL Ltd., Toronto, Ontario, to Dome Petroleum Ltd., Calgary, Alberta, and to Sohio Alaska Petroleum Co., Anchorage, AK. 135pp.

Dohl, T.P., R.C. Guess, M.L. Duman, and R.C. Helm. 1983. Cetaceans of central and northern California, 1980-1983: Status, abundance, and distribution. OCS Study MMS 84-0045.

Frady, T. [ed.], 1987. Workshop on humpback whale photo identification: a summary of proceedings. Alaska Sea Grant Publication AK)SG)87)1, Fairbanks, Alaska.

Hammond, P.S. 1986. Estimating the size of naturally marked whale populations using capture-recapture techniques. Rep. Int. Whal. Commn., Spec. Issue No. 8:253-282.

Kaufman, G.D., M.A. Smultea, and P. Forestell. 1987. Use of lateral body pigmentation patterns for photographic identification of east Australian (Area V) humpback whales. Cetus 7(1): 5-13.

Nishiwaki, M. 1959. Humpback whales in Ryukyuan waters. Scientific Reports of the Whales Research Institute. 14:49-87.

Payne, R. and L.N. Guinee. 1983. Humpback whale (Megaptera novaeangliae) songs as an indicator of "stocks". In: R. Payne (Ed.). Communication and behavior of whales. AAAS Selected Symposia Series, Wash. D.C.

Perkins, J.S., K.C. Balcomb III, and G. Nichols Jr. 1985. Status of the West Greenland humpback whale feeding aggregation, 1981-1983. Rep. Int. Whal. Commn. 35:379-383.

Rice, D.W. 1963. Progress report on biological studies of the larger cetacea in the waters off California. Norsk Hvalfangst-Tidende 7:181-187.

Rice, D.W. 1977. The humpback whale in the North Pacific: distribution, exploitation, and numbers. Prepared for Workshop on humpback whales in Hawaii, July 1977. 21 pp.

Scammon, C.M. 1874. The marine mammals of the North-western coast of North America, described and illustrated: together with an account of the American whale-fishery. John Carmany and Co., San Francisco. 319 pp.

Schnabel, Z.E. 1938. The estimation of the total fish population of a lake. Amer. Math. Mon. 45:348-352.

Scott, G.P. and H.E. Winn. 1980. Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of humpback whales (Megaptera novaeangliae). NTIS PB81-109852 Rept. to the U.S. Marine Mammal Commission for Contract #MMC-77-24, 95 pp.

Sczepaniak, I.D. and M.A. Webber. 1985. Summer and Autumn sightings of marine mammals in the Gulf of the Farallones, California 1983-1984. Unpubl. Rept. to Oceanic Society Expeditions, San Francisco.

Wolf, P.R. 1983. Elements of photogrammetry. New York: McGraw-Hill Book Company.

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