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POPULATION BIOLOGY AND ECOLOGY OF THE PACIFIC WHITE-SIDED DOLPHIN LAGENORHYNCHUS OBLIQUIDENS IN THE NORTHEASTERN PACIFIC

PART I

Distribution, Seasonal Movements and Abundance with a Bibliography and Summary of Specimen Material

by

Stephen Leatherwood and William A. Walker

ADMINISTRATIVE REPORT LJ-82-18C

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I. INTRODUCTION

The Pacific white-sided dolphin, Lagenorhynchus obliquidens, (Figure I-1) is one of the most widely distributed delphinid species occuring in the northeastern Pacific. It has been reported from temperate waters between about latitude 23°N (Leatherwood and Reeves, 1978; Leatherwood et al., 1982) and latitude 61°N (Scheffer, 1950), from the coast to at least the seaward edge of the continental shelf.

Within their northeastern Pacific range L. obliquidens are a highly visible resource, relating to human activities in various ways. An estimated 80 to 115 individuals have been live-captured for public display or research since 1966 (Walker, 1975; National Marine Fisheries Service (NMFS), Washington, D. C., 1982, unpublished records). Small numbers have been taken incidentally in fishing operations for tuna, anchovy and salmon in subtropical, midtemperate and northern temperate waters, respectively (U. S. Dept. Commerce, 1981). Individuals of the species feed routinely on various commercially valuable fish and squid (Jones, 1981; Stroud et al., 1981).

In 1979, under contract from the Southwest Fisheries Center, NMFS, we began a study of the population biology and ecology of white-sided dolphins in the northeastern Pacific. The study is being conducted in two phases. During Phase I, results of which are reported herein, we 1) reviewed and analyzed all available data on distribution, seasonal movements and abundance, 2) inventoried specimens collected from the study area and obtained for analysis all available data on specimen materials - photographs, external measurements, skeletons and osteological data, reproductive organs, teeth, parasites and stomach contents, 3) tabulated all raw and derived data and 4) assembled and reviewed available technical literature and prepared a bibliography. During Phase II, results of which will be reported separately, we are obtaining readings of layers in

thin-sectioned teeth and performing analysis of all data, following Perrin (1975) and Walker (1981). Goals of analysis are to characterize geographic variation, morphology and general biology of Lagenorhynchus obliquidens in the northeastern Pacific Ocean.

II. DISTRIBUTION, SEASONAL MOVEMENTS AND ABUNDANCE

Background

Gill (1865) initially described L. obliquidens from two specimens (U. S. National Museum Numbers 1963 and 3886) taken off the California coast. Scammon (1874), referring to those dolphins with which he had become acquainted while whaling in the northeastern Pacific, reported that "this species has a wider range and congregates in larger numbers than any other of the dolphin family." True (1889) gave the species' distribution as the North Pacific Ocean, Puget Sound, and the coast of California. Subsequent accounts have added limited regional and seasonal information while restating the more generalized descriptions of range made by these early authors.

In the northeastern Pacific, individuals of L. obliquidens have since been reported from the southern tip of Baja California (about latitude 23°N) northward along the coasts of California, Oregon, Washington, British Columbia and Alaska to 61°N (Scheffer 1950) and westward through the Gulf of Alaska and North Pacific to Amchitka Island (Scheffer and Slipp, 1948; Cowan and Guiguet, 1956; Brown and Norris, 1956; Pike, 1956, 1960; Norris and Prescott, 1961; Brownell, 1964; Fiscus and Niggol, 1965; Walker, 1975; Wahl, 1977; Barham, 1978; Leatherwood and Reeves, 1978; Everitt et al., 1979; Dohl et al., 1980; Consiglieri and Braham, 1982).

In the western North Pacific these dolphins have been reported to occur from Taiwan northward along the coasts of Japan and Asia to the Kurile and Commander islands (Okada and Hanoaka, 1939; Tomilin, 1957; Sleptsov, 1961(d); Nishiwaki, 1967; Mitchell, 1975(b)). They have not been reported reliably from the Bering Sea (Nishiwaki, 1967; Leatherwood and Reeves, 1978; Consiglieri and Braham, 1982).

The statement that L. obliquidens "can be seen in the center of the North Pacific including the Hawaiian Islands" (Nishiwaki, 1967) has not been substantiated, although recent sightings at about latitude 40°N, longitude 180°W (G. Naftel, personal communication*) indicate that they do occur in the pelagic mid-Pacific at temperate latitudes. Nishiwaki (1967) also claimed that Pacifc white-sided dolphins are known from as far south as Panama in the eastern Pacific, but we are not aware of any confirmed records from below 20°N. Their occurrence in partially enclosed areas, such as Osaka Bay (Kuroda, 1953), Puget Sound (Scheffer and Slipp, 1948) and the Inside Passage along the coast of British Columbia (Pike and MacAskie, 1969) is well documented. They have been reported on one occasion to enter the Gulf of California as far north as Gorda Bank (23°00'N 109°30'W)(Leatherwood and Reeves, 1978; Leatherwood et al., 1982). Although a skeleton was collected from Valdez, Alaska in Prince William Sound (latitude 61°N) in 1901 (Scheffer, 1950), no white-sided dolphins were seen inside the Sound during recent extensive aerial and ship surveys (Hall, 1979).

Seasonal shifts in distribution have been reported. Pacific white-sided dolphins are said to be more common in coastal waters during fall and winter, moving to offshore waters during spring and summer (Brown and Norris, 1956; Cowan and Guiguet, 1956; Norris and Prescott, 1961; Brownell, 1964; Pike and MacAskie, 1969; Barham, 1978; Leatherwood and Reeves, 1978; Everitt et al., 1979; Dohl et al., 1980). They are thought to occur only in warmer seasons in the northeastern

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Gulf of Alaska (Consiglieri and Braham, 1982) and to be more numerous in cooler seasons south of Point Conception, California (Leatherwood and Reeves, 1978). These movements have been suggested to be related to changes in prey distribution (Norris and Prescott, 1961; Brownell, 1964; Barham, 1978) and water temperature (Leatherwood and Reeves, 1978; Dohl et al., 1980).

Since Scheffer's (1950) summary of records along the North American coast, no comprehensive review of the Pacific white-sided dolphin's distribution and movements in the northeastern Pacific has appeared in the literature. The only published estimates of population size are Nishiwaki's (1972) statement that there are 30,000 to 50,000 in Japanese waters and Fox's (1977) estimate that about 24,000 inhabit an approximately 1.5 million km^2 area off California and Baja California. Leatherwood and Walker (1979) considered it one of the three most abundant delphinids, along with Lissodelphis borealis and Delphinus delphis, in Southern California waters during midwinter.

In this report we examine information available through 1979, from sightings and collections made north of latitude 15°S and east of longitude 180°W, for patterns of distribution, movements and abundance of the species in the northeastern Pacific.

Materials and Methods

Records of sightings of L. obliquidens in the northeastern Pacific for the years 1949 through 1979 were available from the literature and various unpublished sources.* Principal contributors are summarized in Table II-1 and their approximate areas of coverage are shown in Figure II-1. As in 3 previous efforts of this kind investigating other small cetaceans

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*A complete file containing all the distribution data obtained for this report has been filed with the Southwest Fisheries Center, NOAA/NMFS.

(Leatherwood and Walker, 1979; Leatherwood et al., 1980; Dahlheim et al., 1982), we pooled all acceptable data to describe overall distribution and to search for trends in distribution and abundance by season and latitude. Many of the sightings represented incidental observations from programs for for which characterizations of survey effort were unavailable and therefore could not be considered in any depth. Other incidental records resulted from programs for which survey effort could be subjectively described, e.g., in terms of general periods and areas of coverage. These records were considered in somewhat more depth. The most important records were those obtained from the following three programs which provided quantitative data on survey effort:

Southwest Fisheries Center (SWFC) NMFS (See Table II-1: IA1 and IA2) - Scientific observers aboard American tuna vessels and U. S. Government research vessels operating in the eastern tropical Pacific have supplied sightings made in the area from about latitudes 35°N to 15°S, between the shore and about longitude 160°W. Sightings from this program were subjected to critical scrutiny using methods detailed by Leatherwood (1978). Unverifiable sightings were not included. Effort (time during which a NMFS marine mammal observer was on watch) was calculated as number of hours of watch within each 5-degree square (see Figure II-2). All minutes in a watch series were assigned to the 5-degree square in which the watch series began. Additional information concerning the protocol for data collection in this program is available in the NMFS Observer's Handbook (unpubl. manuscr., SWFC, La Jolla).

Naval Ocean Systems Center (NOSC) (see Table II-1: IIA and IIB) - Regular aerial surveys were conducted by the Naval Undersea Center (now NOSC) from January 1968 through April 1976 over the California continental shelf, principally between latitudes 32°N and 34°N (Figure II-3). The methods

employed in these surveys were described in detail by Leatherwood (1974), Evans (1975), Leatherwood and Walker (1979) and Leatherwood et al. (1980). Sightings were critically evaluated using the same review procedures of the SWFC system referred to above, and unverifiable sightings were discarded. Effort was retained as plots of transect lines (Figure II-3 inset) and estimates of nautical miles flown.

University of California, Santa Cruz (UCSC) (see Table II-1: IIIB1 and IIIB2) - Shipboard and aerial surveys sponsored by the U.S. Department of the Interior, Bureau of Land Management (BLM), were conducted in the California Bight during 1975 and 1976 by the Coastal Marine Laboratory, University of California, Santa Cruz (Dohl et al., 1980). Transects were designed to provide uniform coverage of the entire study area throughout the year. Methods of quality control on sightings data were not reported. Therefore, because original data entries were unavailable to us for review we have simply accepted sightings on the assumption that they were subjected to adequate quality control by the program's internal review process. Effort was characterized as the number of times each 5-minute block was surveyed (see Figures II-4 and II-5) and as the number of nm covered. Note the substantial overlap in aerial coverage between NOSC (Figure II-3) and UCSC surveys.

Other Sources (see Table II-1) - In addition to the unpublished sources of data we examined scientific publications and extracted sighting records. For all sighting records we collected, as available, date, location, number of animals and information source. We assembled a total of 1300 reliable records, 1104 unpublished accounts from various programs and 196 previously published. Except for obvious misidentifications or obscure references with unreconcilable disparities, we assumed published

records reflected correct identification. Sightings published twice or more were only entered in the data base once. Each known at-sea collection for which date, location and number of animals was available was also considered to represent a sighting of a herd. For each map and analysis we used all appropriate sightings. For those sightings in which herd size was recorded as a range (e.g., 45 - 50 animals), we used the midpoint rounded to the lowest integer (e.g., 47).

Data were grouped by various combinations of quarter, 1-and 5-degree latitude belts, and depth zones (inside or outside the 2000m isobath), and maps, histograms, descriptive statistics and frequency distributions were obtained for examination and grouped or paired samples were compared to ascertain patterns in occurrence (Table II-2). For numbers of herds and numbers of animals we determined sample sizes (N), sum, mean ($\bar{x}$), standard deviation (S), standard error ($S_{\bar{x}}$) and range (see Appendix II-1).

For analysis of latitudinal effects only groupings by 5-degree latitude belt resulted in adequate sample sizes. One-degree belts were retained for mapping. Maps were produced showing numbers of herds (Figures II-6 and II-7) and number of animals (Figures II-8 and II-9) by one-degree squares for all samples combined. Charts were made on a DEC-PDP 11/34 using the "W63 World Coastline Database and Mapping Package", University of Washington. Densities for each square on the sighting charts were calculated by summing the number of herds and number of animals sighted in each square each quarter. For example, all the animals sighted from longitudes 117°00'W to 117°59'W and from latitudes 32°00'N to 32°59'N were counted as being in the square 32°N by 117°W.

The following problems with data contraindicated the use of significance tests on any of the data sets: sightings were not collected at random; sightings could not be assumed to be independent of one another, because of aggregating

patterns of the animals and variability among observers in defining and scoring groups as separate small herds or "superherds"; and pooled effort was impossible to quantify. We feel that if statistical significance were to have been demonstrated we would have been unable to ascribe any biological significance to the results. Therefore, to define patterns for the area overall we depended on our examination of graphic results (Table II-2).

Data from the Southern California Bight were examined in somewhat greater detail. For the NOSC aerial surveys we calculated number of herds per hundred nautical miles and number of dolphins per nautical mile flown (Table II-3, I_1 and I_2, respectively). Because herd size was not estimated for each sighting in constructing the I_2 values, we 1) found that no significant variability in herd sizes among months could be demonstrated and 2) assumed that those for which herd size estimates were available (72) were representative of all 95 herds. Therefore, in estimating number of animals seen/month each empty cell was filled with the overall mean ($\bar{x}$ = 145.7, S = 271.2). For comparison, we converted indices of density of Lissodelphis borealis in the same area, reported by Leatherwood and Walker (1979) as the number of herds or animals per square nautical mile, to I_1 and I_2 values and presented those in Table II-3. For the University of California aerial survey data (Dohl et al., 1980) we also calculated monthly I_2 values (Table II-4).* Trends indicated by the 2 programs were graphically compared (Figure II-11) but no attempt was made at a rigorous analysis of observed patterns.

Results and Discussion

Herds of white-sided dolphins were seen in all 5-degree latitude

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*Estimates of density and indices of density from previous programs are presented in the units reported. Original data were unavailable to us, so we were unable to translate to common units.

belts between latitudes 20°N and 60°N in all quarters of the year, except for latitudes 55°-60°N in quarter I, January - March. The 1300 herds (112,138 individuals) included in the analysis were widely distributed from the continental shelf throughout the pelagic temperate northeastern Pacific, although records were more abundant within the few coastal 1-degree blocks in each latitude belt (Figures II-6 through II-9). The apparent coastward concentration as well as the areas of higher density observed north to south along the coast clearly reflect levels and centers of observational effort (Figure II-10), with sightings clustered near Seattle, near the Monterey/Santa Cruz area, and within the 35° to 30°N and 30°N to 25°N latitude belts.

The steady decreases in number of sighting records throughout the year, from 409 herds in the first to 178 herds in the fourth quarter, also clearly reflects effort. In fact, in examining the sample overall there were no detected trends in distribution of herds which could not be explained readily on the basis of the survey effort alone. It is only when records are examined regionally, with emphasis on the three programs permitting quantitative analysis, that any significant patterns can be discerned.

Sample sizes north of latitude 40°N are small and effort unquantifiable. Within that area sightings do occur throughout the year, although almost all the more northerly records are reported for quarters II and III, spring through fall, and almost all the sightings for quarters IV and I are in coastal regions. In the Gulf of Alaska, the seasons when white-sided dolphins are reported most frequently and widely are the periods of most intensive fishing and research activity. We have no way of determining whether this apparent seasonal pattern in distribution of white-sided dolphins is real or an actifact of this effort. Consiglieri and Braham (1982), based on opportunistic sightings from various sources of 3, 8, 50, and 15 herds in quarters I through IV, respectively,

concluded that "this species indeed occurs seasonally in the Gulf of Alaska". They further concluded, based on those sightings, that in the southeastern and southern Alaskan waters white-sided dolphins occur principally over the continental shelf. Further evidence that white-sided dolphins are seasonal off southern Alaska is provided by Hall and Tillman (1977) and Hall (1979), who reported that despite extensive year-round aerial and ship surveys in Prince William Sound and immediately adjacent to its entrances, they observed white-sided dolphins only once, in October just outside Montague Strait. Current data are opportunistic in nature or limited in region, therefore inconclusive. The question of seasonality of occurrence of white-sided dolphins in the Gulf of Alaska and North Pacific above latitude 40°N, particularly in pelagic regions, cannot be resolved without systematic seasonal sampling over a broad area.

From available data we are unable to verify the reported occurrence of white-sided dolphins in the Bering Sea (Clark, 1945). The various programs of NMFS/NMML (see Table II-1) and the same incidental sources used by Consiglieri and Braham (1982) very likely provided adequate coverage of the waters north of the Aleutians to judge whether these dolphins occur regularly in the Bering Sea. The absence of records is taken to mean that they do not.

Similarly, we regard as very convincing the evidence that white-sided dolphins do not occur regularly south of about latitude 23°N (see Figures II-6 and II-8). Coverage of the waters south of Baja California has been extensive in area and season.

Although principal observer effort, from the NMFS dolphin-tuna program, generally decreased from quarter I to quarter IV according to the fishing schedule of the tuna fleet, there was some effort in a broad area

south of latitude 30°N year-round (Figures II-1 and II-2). In addition to the shipboard observations, three extensive aerial surveys of the tropical Pacific tuna grounds have been conducted by NMFS (Smith, 1975; Barham et al., 1975; Barham and Powers, 1977; Powers and Barham, 1977; Holt and Powers, 1982). Therefore we consider the presence of only five confirmed sightings south of latitude 23°N, the southernmost at 20°N, to be biologically meaningful. If appreciable numbers of dolphins had been present, there undoubtedly would be more records.

Northern and southern limits of the species' range are clearer than inshore-offshore limits. There are few sightings from inside the 100 fathom contour although white-sided dolphins have been found in water as shallow as 20 fathoms (Consiglieri and Braham, 1982; NOSC unpublished records; Leatherwood personal observations). Seaward of those depths these dolphins have been encountered widely in continental shelf and offshore zones. Because of uncertainty of position records we cannot report maximum depth, although the westernmost records in the study area were plotted at locations in which surrounding water for a radius of at least 100 nm was greater than 3000 fms deep.

The probable North Pacific range of white-sided dolphins, inferred from records presented herein and published records from the northwestern Pacific, is shown in the inset to Figure II-6. Available data suggest a continuous range across the North Pacific. In the area covered by this report sightings fall off in the area west of longitude 135°W and south of latitude 45°N, but there has been insufficient observation effort in pelagic areas to confirm existence of a hiatus between northeastern and northwestern Pacific "populations".

In the northeastern Pacific portions of the range little can be said about the relative frequency of occurrence of white-sided dolphins in the various depth regions. The fact that overall most of the sightings were made inshore of the

2000m isobath simply reflects effort patterns. So also does the apparent seasonal pattern between latitude 35°N and 55°N, where sightings offshore occurred almost exclusively in quarters I - III. The number of reported sightings was much lower in that area in quarter IV (Figures II-7 and II-9). We assume both low numbers of sightings and absence of offshore records reflect paucity of effort in that quarter. There does appear, however, to be a tendency for these animals to occur nearer to the coast in the area south of about latitude 30°N. The effort in pelagic waters between latitudes 20°N and 30°N was appreciable, and the encounters with white-sided dolphins few. The only two portions of the study area in which observed distribution patterns are not clearly an artifact of sampling effort are the waters off Baja California and those in the Southern California Bight. Off Baja California, the effort is tied to fishing and research activities of the tuna fishery, essentially declining steadily throughout the year with a slight increase again in the fourth quarter associated with research cruises and early departures from San Diego of fishing vessels bound for the eastern tropical Pacific (Figure II-2). Despite this declining trend in effort, the number of sightings per quarter was roughly constant throughout the first three quarters, dropping off only in quarter IV (Figure II-7, Table II-5). Furthermore, in the area between latitudes 25°N and 30°N in the third quarter the total number of animals observed increased substantially over that observed during the previous two quarters (Figure II-9, Table II-5, Appendix I). The sharp increase in numbers during a period of relatively low sampling sampling effort is noteworthy. Presumably, this increase represents a significant influx of animals into this area. That influx does not appear to be arriving from offshore waters. From published accounts about the seasonal movements of white-sided

dolphins south of Point Conception (e.g. Brown and Norris, 1956; Leatherwood and Reeves, 1978; Leatherwood et al., 1982) it is possible that this represents an influx of dolphins from the area off Southern California between latitudes 30°N and 35°N.

The monthly indices of density from the NOSC aerial surveys indicate that white-sided dolphins are at their peak density/numbers off Southern California from November through April, and are less common from late spring through late fall (Figure II-11, Table II-3).

This seasonal pattern is consistent with that reported for the area by previous investigators, based on subjective impressions (e.g., Norris and Prescott, 1961; Leatherwood et al., 1972) or on preliminary analysis of the NOSC data (Leatherwood and Reeves, 1978; Leatherwood et al., 1982). It is also very similar to the seasonal pattern reported by Leatherwood and Walker (1979) for Lissodelphis borealis, a sympatric species with which white-sided dolphins have a strong affinity in coastal waters (Table II-3). From these data, white-sided dolphins appear to reach their lowest densities off Southern California during the periods discussed above, when they are apparently at their highest densities off Baja California. However, we are unable to demonstrate any relationship between these two phenomena and resist the temptation to speculate. The source of the apparent "immigration" into Baja California waters in quarter III and the destination for the "emmigrants" from Southern California in quarters II and III remain unknown. Peak densities off Southern California are 1.42 individuals/nm (Figure II-11), off Baja California they are reported to be 0.06 individuals/nm^2 (Fox, 1977).

The trends indicated by results of the UCSC aerial surveys are slightly out of phase with those from the NOSC program, which covered a largely overlapping though slightly more coastal area. The densities from that 10-month program

fluctuate considerably, with about 1-2 individuals/nm^2 in May, July and November and much lesser densities at all other months. The disparity may well reflect small sample sizes and short period of coverage in the UCSC program. However, if not an artifact, the results may indicate a shift of the Southern California portion of the population offshore and northwestward in quarters II and III.

Even considered collectively, all the above data do not permit clear definition of movement patterns for white-sided dolphins in the northeastern Pacific. The few substantive data do suggest seasonally variable periods of occupation of northern and southern extremes of the range and of Southern California waters. The seasonal margins of various portions of the range and the oceanographic factors affecting them are undefined. Hubbs (1961) described a major transition zone for marine fauna occuring along the outer coast of Baja California at about 24°N latitude, in the vicinity of Magdelena Bay. Au, Perryman and Perrin (1979) noted another water-mass change at the mouth of the Gulf of California, where the fauna tends to change from temperate to tropical. As a temperate-zone species, the Pacific white-sided dolphin probably is influenced by these oceanographic changes. In the areas of most intensive observations, 20°-30°N, the species was observed mainly shoreward of the outer margin of the California current (Owen, 1974; 1980) suggesting that it is principally an inhabitant of rich upwelling waters.

The overall distribution of herd sizes is shown in log-transform as Figure II-12. The 1269 sightings for which "group" size estimates were available ranged from 1 to 6000 individuals about a mean of 88. Above about 20 individuals the "pulses" in group size are probably rounding errors resulting from classification into easy-to-use units. Herds were

not the same size over the entire range (Figure II-13). Those north of latitude 55°N and south of latitude 30°N were significantly larger than those between 30°N and 55°N ($n = 1268$, $F = 3.69$, $P < 0.01$). In the northernmost area, where sea-surface conditions are consistently inhospitable to cetacean surveys, it is conceivable that bad weather and observer bias resulted in a tendency to see and record only large herds. However, in the other two areas we place higher credence in the ability of observers to detect herds of various sizes and in the overall ability of most participants to consistently estimate herd size. Therefore, we believe these observed differences to be actual rather than artifact. We are at a loss to explain why herds are larger off Baja California than elsewhere. Perhaps it is related to inherent differences in herd-size estimation from aircraft (the principal method used from 30-35°N) and vessels (almost exclusively the method used further south).

Summary

1. In the northeastern Pacific and Gulf of Alaska, white-sided dolphins occur from about latitude 20°N to latitude 61°N in continental shelf and offshore zones. They are present in the mouth of the Gulf of California and inland marine waters of Washington and British Columbia but apparently do not enter the Bering Sea or regularly penetrate Prince William Sound. They appear to be continuously distributed across the temperate North Pacific.

2. Seasonal movements cannot be unequivocally demonstrated in any area although observed peaks suggest regular seasonal influxes into waters north of latitude 40°N in spring/summer and between latitudes 25°N and 30°N in fall. Evidence for seasonal use is most convincing off Southern California, where peak numbers occur inshore in November through April, lesser numbers the remainder of the year.

3. No population estimate is possible with currently available data. In the well studied Southern California Bight they occur in peak frequencies of 1.42 individuals per nm flown (because perpendicular sighting distances were not recorded consistently for these sightings we are unable to estimate survey strip width or translate this figure into an estimate of density). In a region off Baja California they have been estimated to occur in densities up to 0.06 individuals per nm^2. They appear to be the second or third most abundant delphinid in Southern California waters in winter, behind common and northern right whale dolphins, but may be the most abundant delphinid in the temperate northeastern Pacific.

4. The 1300 herds sighted averaged 88 individuals (S = 366). Herds were significantly larger in southern (<30°N) and northern (>55°N) than in central (30°-55°N) portions of the range (one-way Anova, n = 1268, $F = 3.69$, $P < 0.01$).

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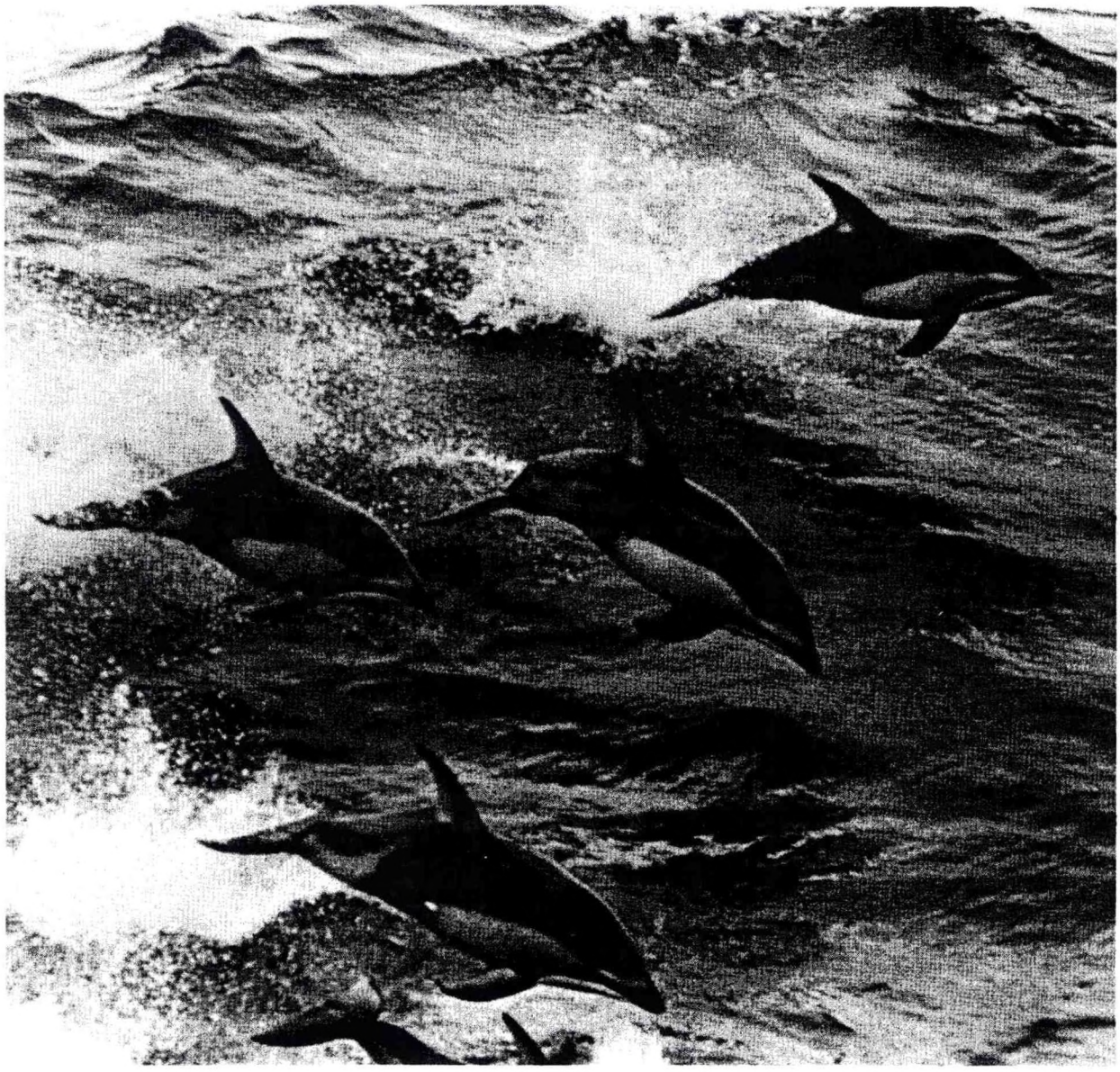

Figure I-1. Pacific white-sided dolphins "porpoising" beside a fishing vessel south of Adak, Alaska. The prominent bicolored dorsal fin, absence of a well demarcated beak and striking pattern of black, gray and white markings make these dolphins easy to recognize at sea (Photo courtesy of NMFS, NMML).

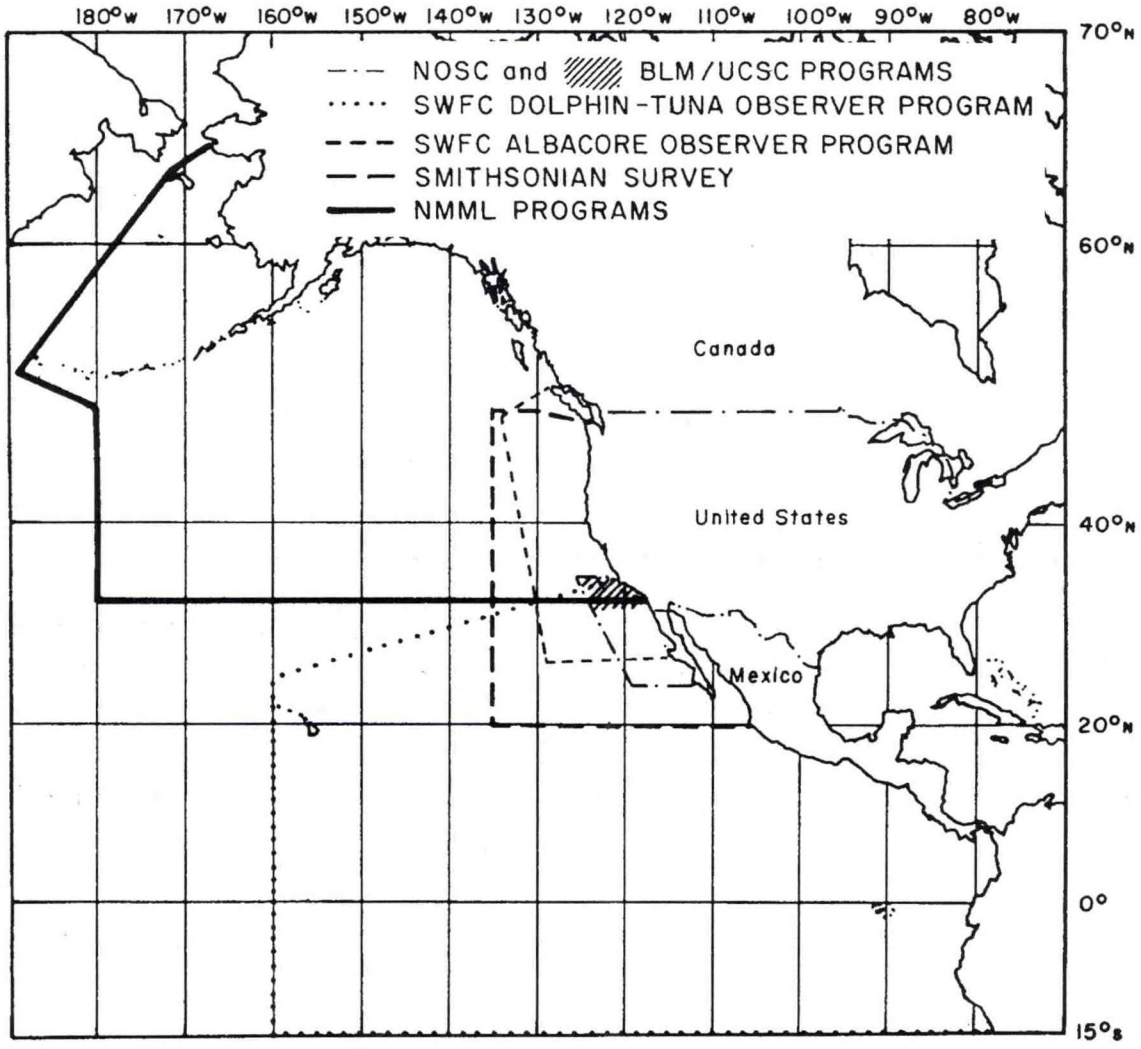

Figure II-1. Approximate areas covered by the principal programs providing sightings of Pacific white-sided dolphins (modified from Leatherwood et al., 1980).

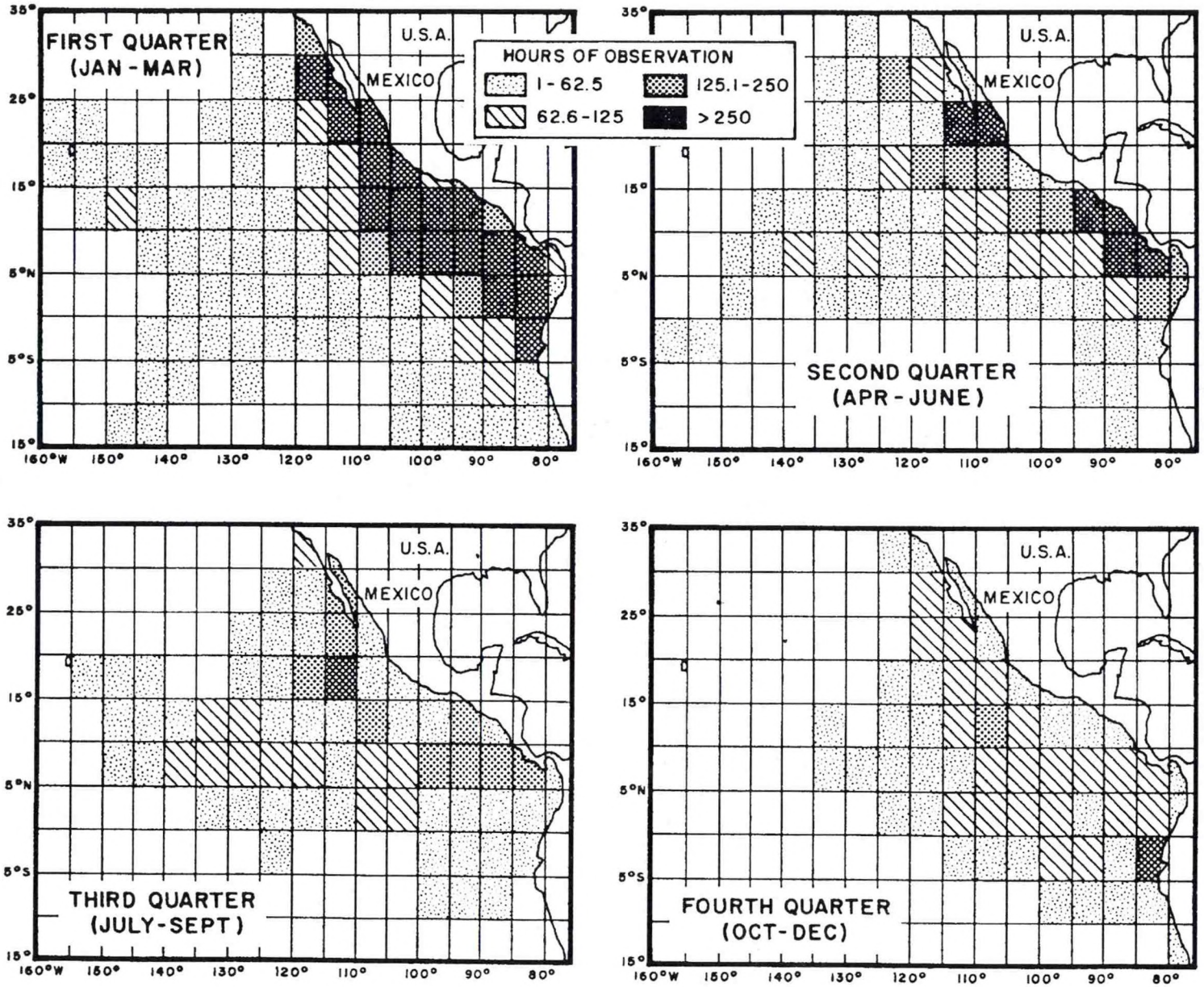

Figure II-2. Ship survey effort by NMFS dolphin-tuna observer program, 1974 to 1979, by quarter.

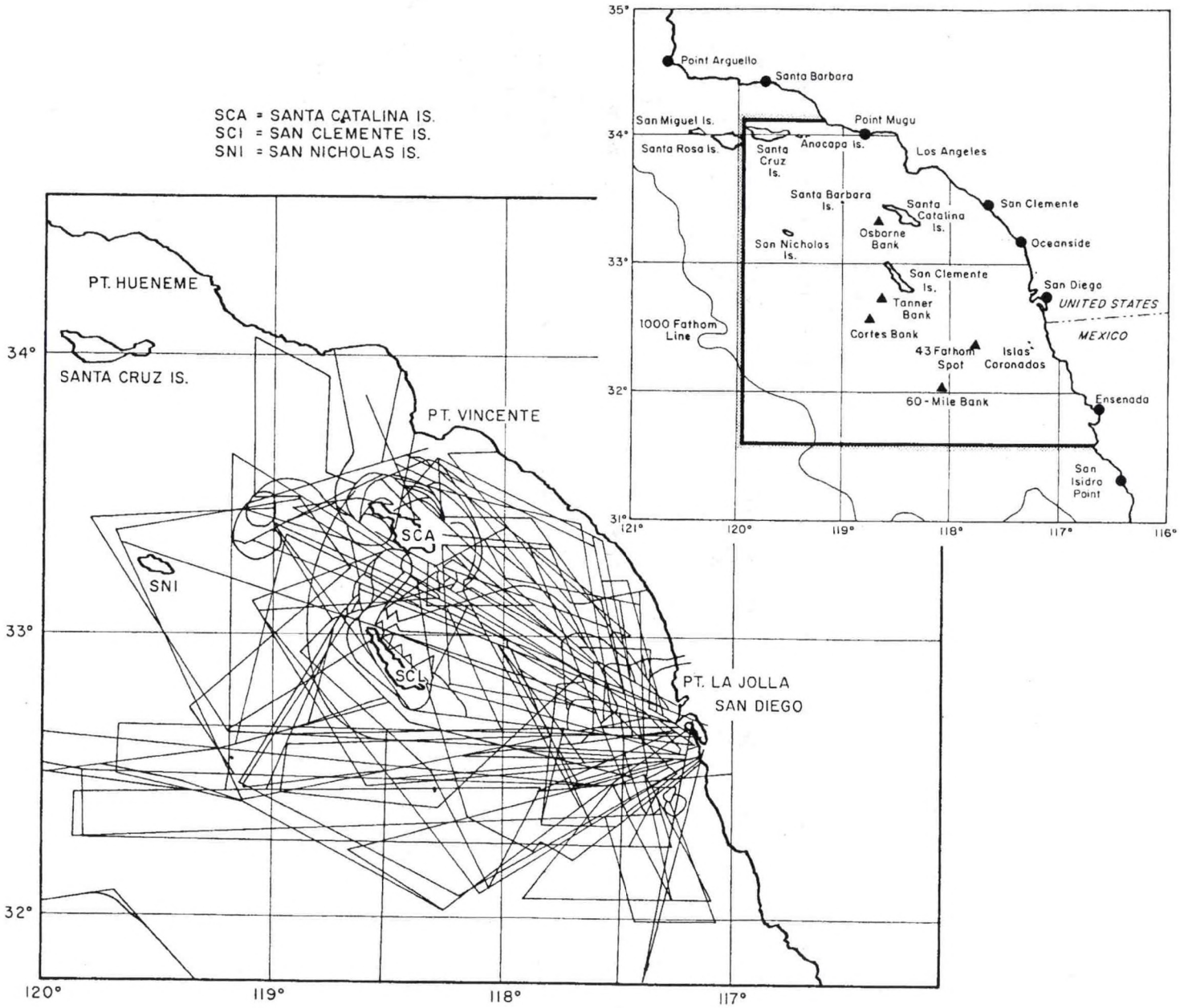

Figure II-3. Area covered by Naval Ocean Systems Center (NOSC) aerial surveys, 1968 through 1976. Inset shows principal transects flown.

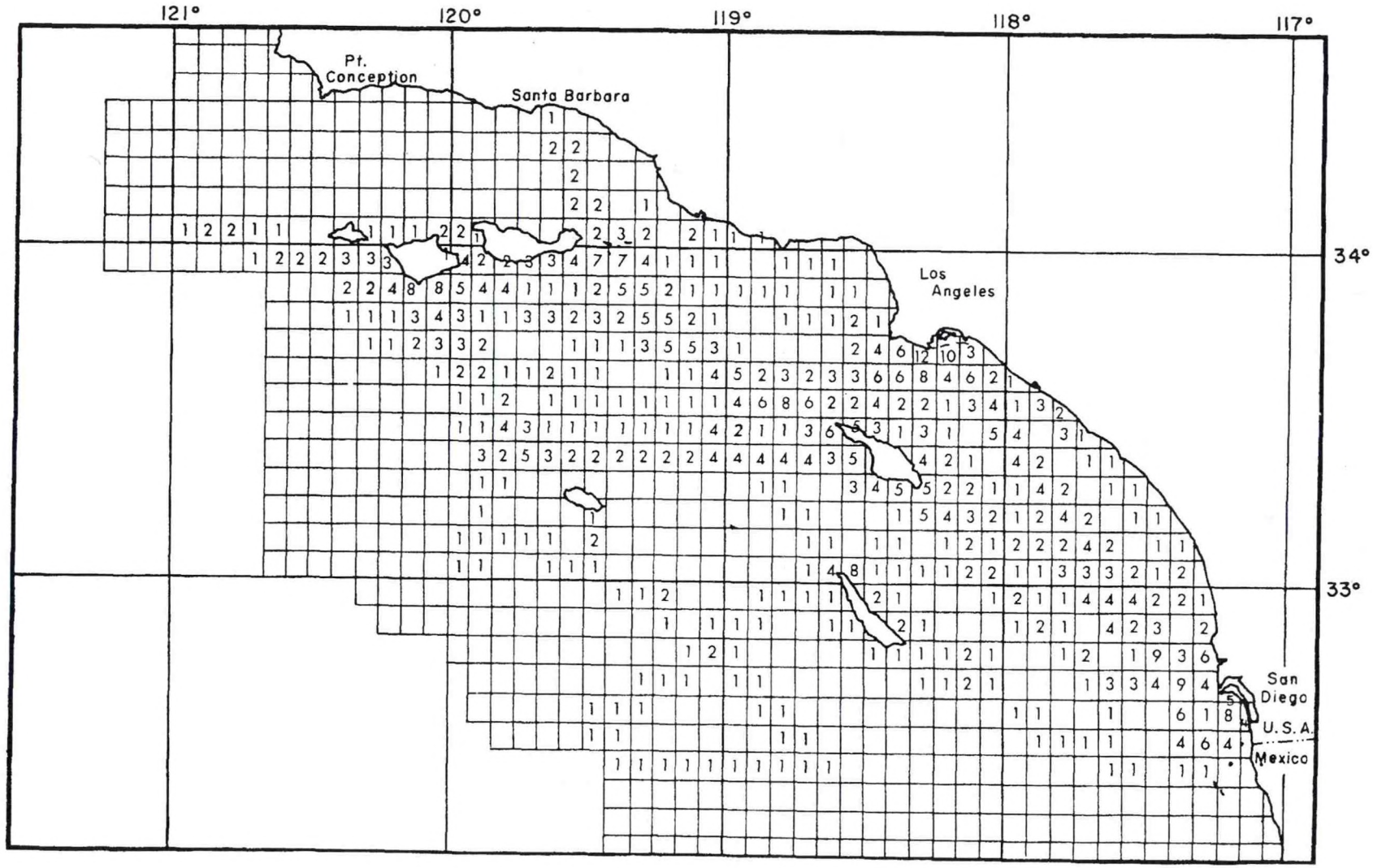

Figure II-4. Ship survey effort by University of California, Santa Cruz (UCSC) April 1975 to March 1976. Numbers in 5-degree squares denote number of times that area was surveyed by ship during the study period (Dohl et al., 1980).

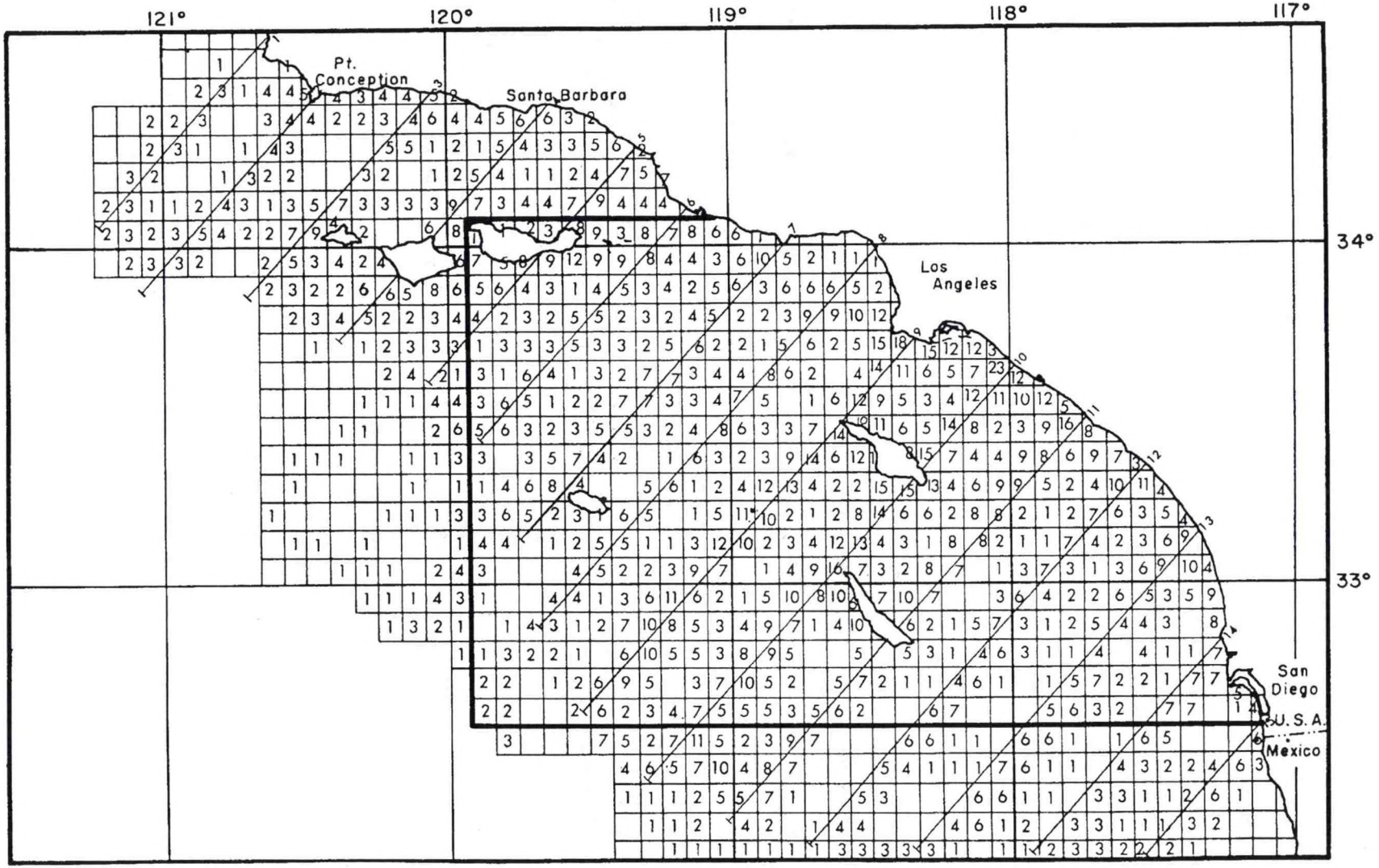

Figure II-5. Aerial survey effort by UCSC, May 1975 through March 1976. Numbers in 5-degree squares denote number of times that area was surveyed by air during the study period. The blocked area corresponds to the area covered by NOSC aerial surveys 1968 to 1976 (see Figure II-3). The diagonal lines are the UCSC transects (from Dohl et al., 1980).

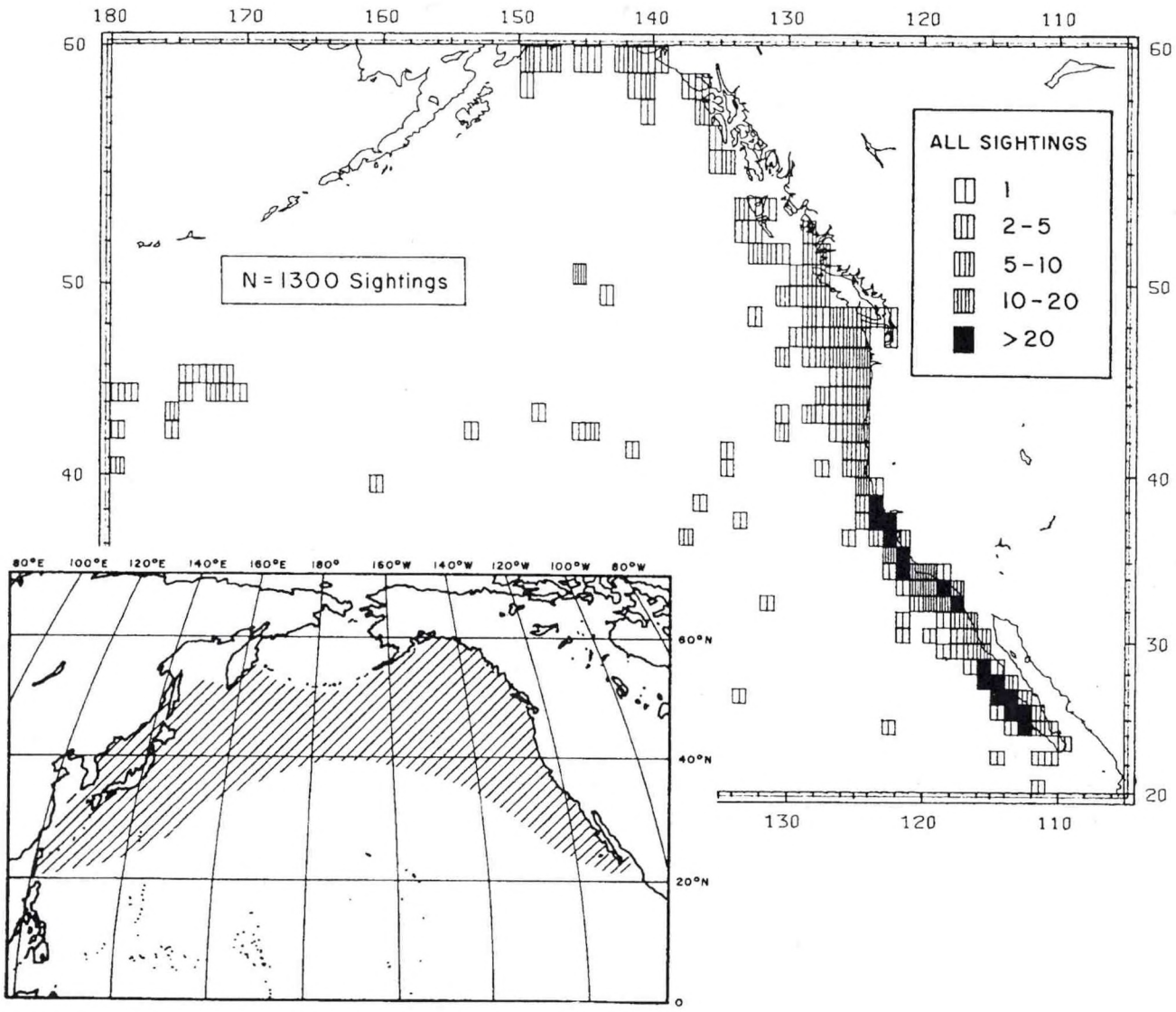

Figure II-6. Number of sightings (herds) of white-sided dolphins by 1-degree square from all seasons and all sources, 1949 to 1979. The inset illustrates the species' probable range.

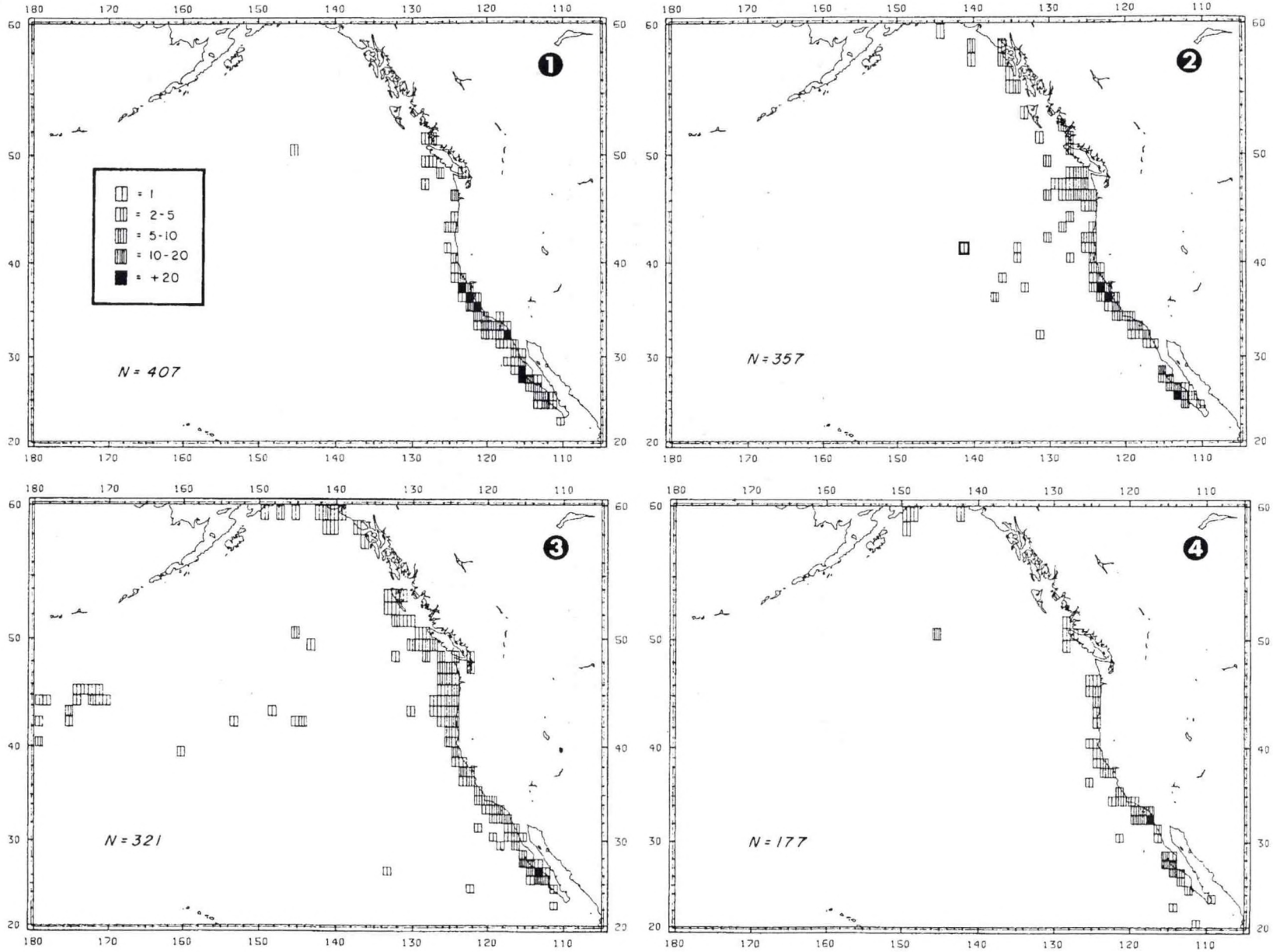

Figure II-7. Number of sightings (herds) of white-sided dolphins by 1-degree square by quarter, from all sources 1949 to 1979.

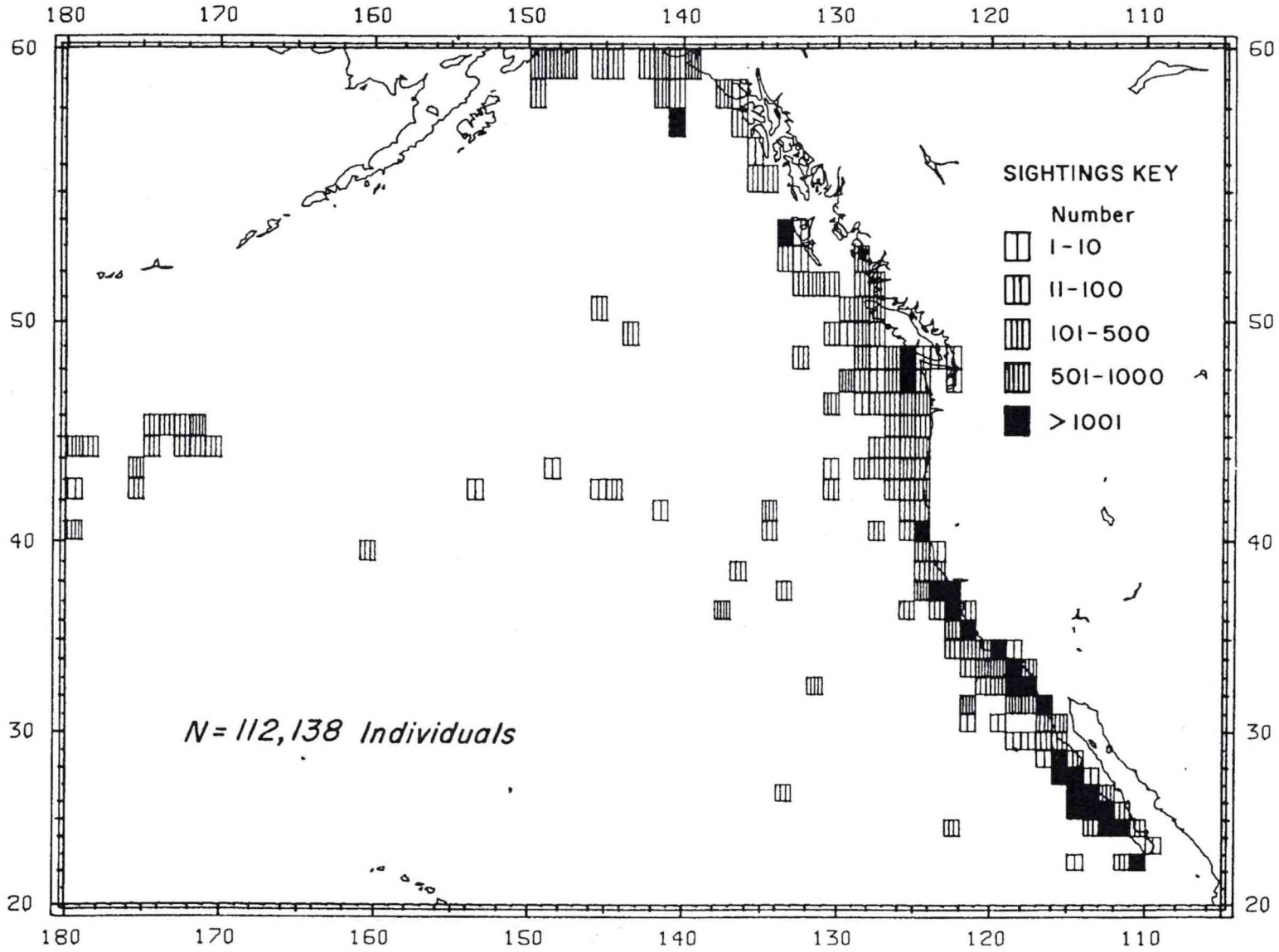

Figure II-8. Total numbers of white-sided dolphins observed by 1-degree square, from all sources 1949 to 1979.

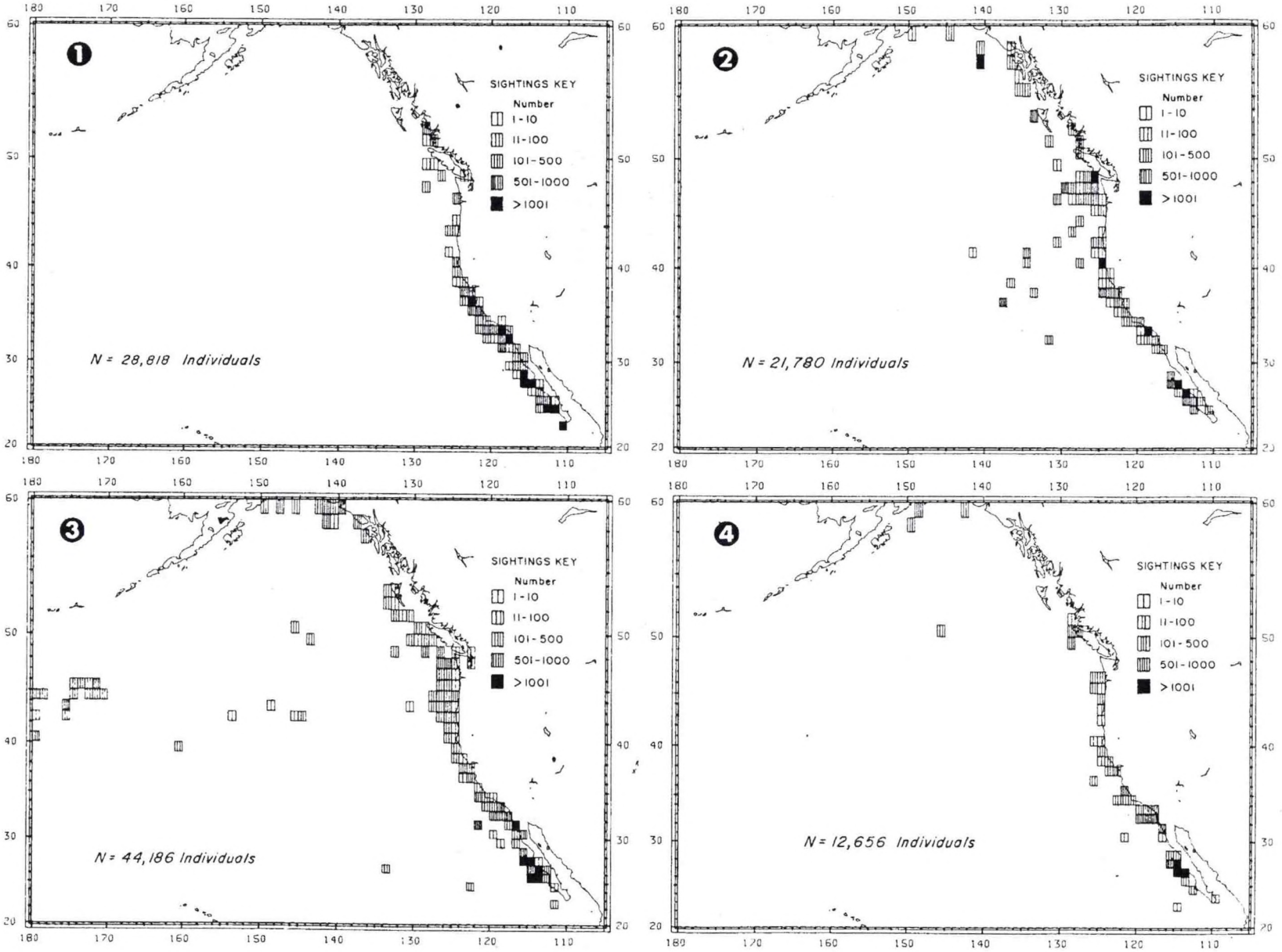

Figure II-9. Total numbers of white-sided dolphins observed by 1-degree square by quarter, from all sources 1949 to 1979.

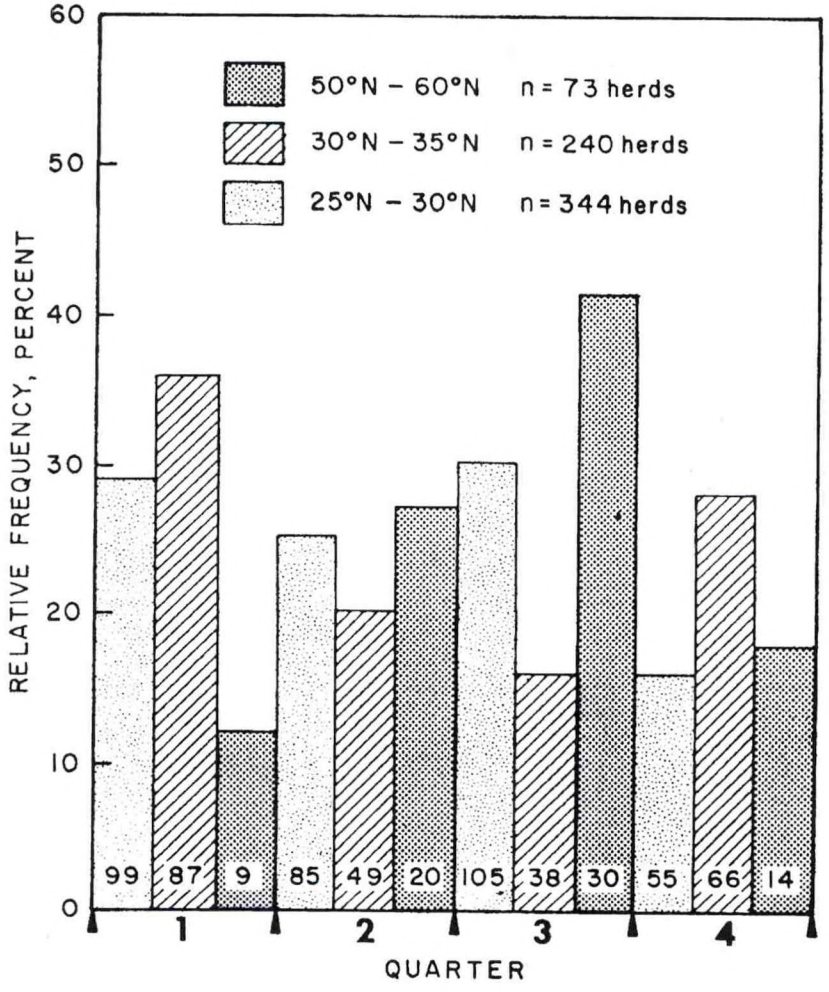

Figure II-10. Relative distribution of sightings by quarter within the three areas of greatest interest. The number of herds comprising each class interval is shown.

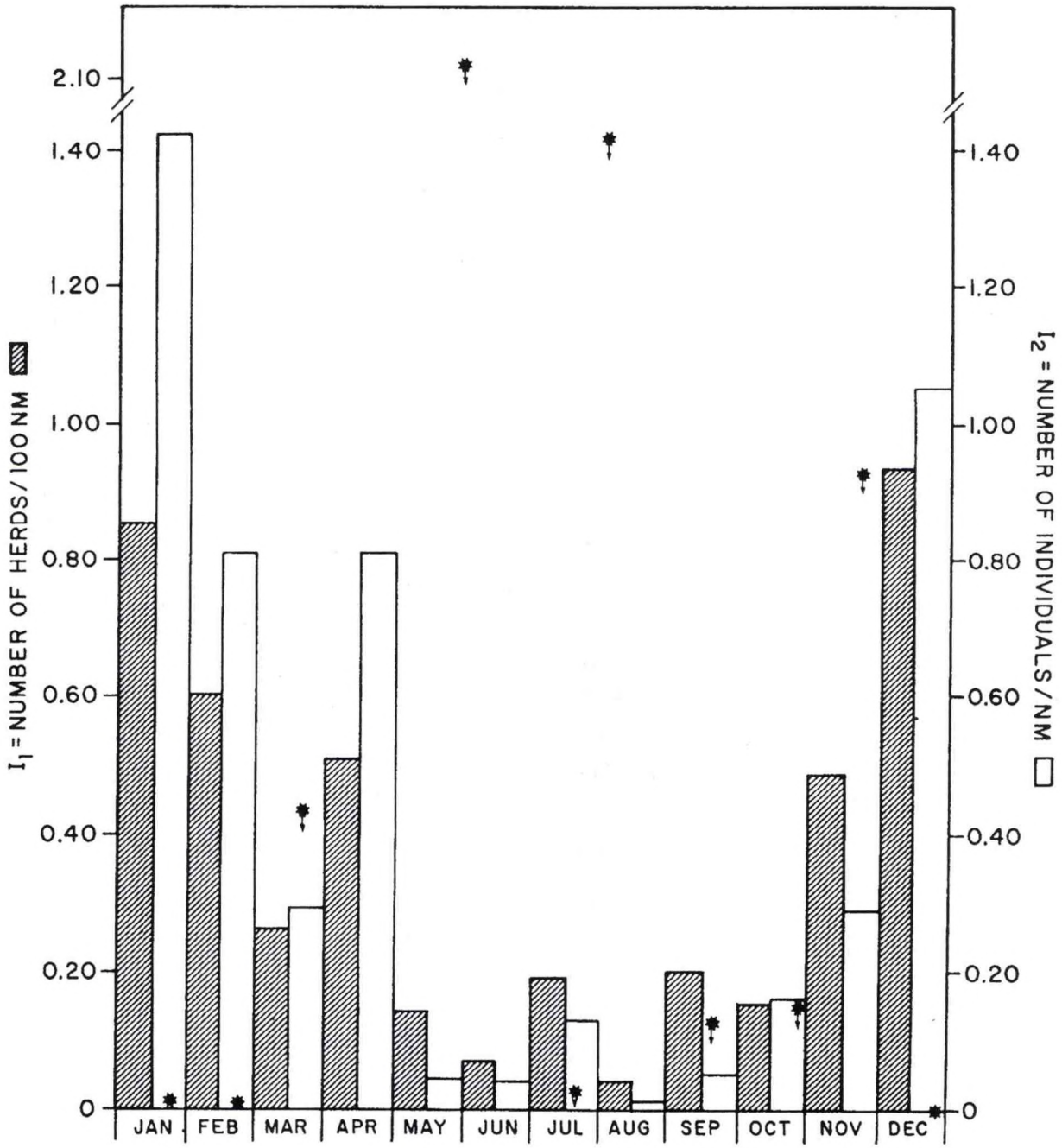

Figure II-11. Indices of abundance of white-sided dolphins off Southern California 1968 through 1976, based on NOCS aerial surveys. The * indicates I_2 values calculated from Dohl et al., 1980, Table III-93, for aerial surveys of the same area May 1975 to March 1976.

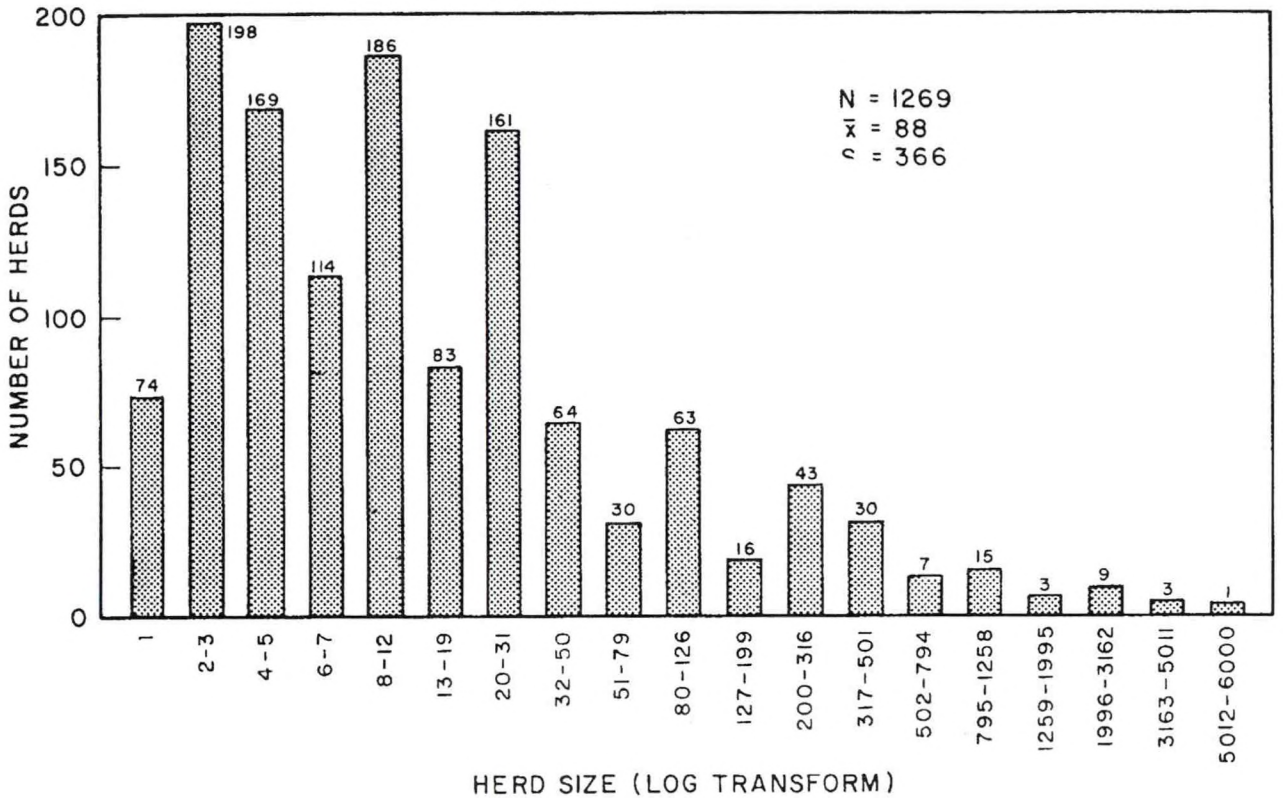

Figure II-12. Log transform of sizes of herds of white-sided dolphins observed in the northeastern Pacific 1949 to 1979. Number of herds comprising each class interval is shown. The log transform was performed strictly for presentation. No analysis was conducted on logs of data.

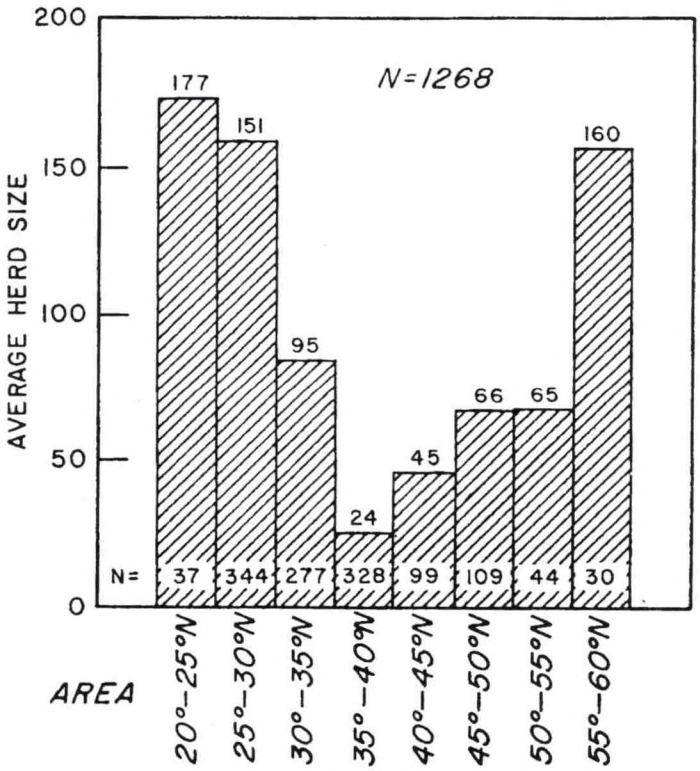

Figure II-13. Mean herd sizes by 5-degree latitude belts, from all sources 1949 to 1979. Mean values are shown above each class interval. Number of herds comprising each class internal is shown.

INSTITUTION/ACTIVITY	PRINCIPAL AREA(S) COVERED	EFFORT	PERIOD(S) AND EFFORT	TOTAL # USED
I. U.S. National Marine Fisheries Service				421
A. Southwest Fisheries Center		*		
1. Dolphin-tuna observer program and associated research cruises, 1968 through 1973.	Latitudes 35°N to 15°S, coast to approximately longitude 160°W		Heavy effort nearshore Jan - Feb declining and moving seaward March through remainder of year. Some coastward research Qtr. 4.	
2. Dolphin-tuna observer program and associated research cruises, 1974 through 1979.	Latitudes 35°N to 15°S, coast to approximately longitude 160°W.	+	Same as above, but effort data available as number of ship survey hours per 5° square (see Figure II-2).	
3. Albacore observer program and associated research cruises, 1971 through 1979.	Latitudes 25°N to 46°N, within 250 nm of coast.	*	33 vessels, May through September, generally moving south to north through season.	
B. National Marine Mammal Laboratory				410
1. Pelagic fur seal program				
a. 1958 through 1979	Latitudes 32°N to 62°N, east of USA/USSR Convention line in Bering Sea, east of longitude 180°W in remainder of Gulf of Alaska and N. Pacific.	•	Sporadic coverage, largely in summer, principally searching for and collecting fur seals. (See various reports of North Pacific Fur Seal Commission; Kajimua et al., 1980; Stroud et al, 1981). Effort characterized but summary unavailable in useable format.	
b. 1960's	Latitudes 21°N to 35°N, within 150 nm offshore and offshore Baja California as far as Islas Revillagigedos	•	Cruises working north to south in winter and spring, January through April. (Fiscus and Niggol, 1965; Rice 1963a,b; 1974). Effort characterized subjectively but summary unavailable in useable format for this report.	
2. Dall porpoise program 1978 and 1979	Southern Bering Sea and northern Pacific Ocean, near Aleutian Islands. Some cruises in Gulf of Alaska.	•	Observers aboard mother ships and research vessels much of summer. Sighting conditions often poor. Effort summaries described by Bouchet (1981) but unavailable in useable format for present report.	
3. Platforms of opportunity	All areas.	•	Coverage opportunistic, no effort data available.	
II. Naval Ocean Systems Center				140
A. Ship surveys 1965 through 1975	Within 150 nm of coast from latitudes 22°N to 35°N including Gulf of California. Some cruises north to Kodiak, Alaska in spring.	•	Effort data not consistently recorded. Cruises conducted all seasons, but principal effort winter and spring.	
B. Aerial surveys 1968 through 1975	Continental Shelf waters (shore to longitude 121°W) between latitudes 31°30'N and 34°N (Southern California Bight).	+	Total 29,000 nm surveyed, all months. Effort data retained as transect lines by month (see Fig. II-3).	
III. University of California				54
A. Scripps Institution of Oceanography - La Jolla	Principally within 100 nm of coast of California and Baja Calif. and in Gulf of California.	•	1950-1979 - miscellaneous cruises with no indication of survey effort by area or season.	
B. Coastal Marine Laboratory Santa Cruz				
1. Ship surveys	Continental Shelf waters between latitudes 31°N and 34°N (Southern California Bight)	+	Effort available as total nm surveyed by month.	
2. Aerial surveys	Continental Shelf waters between latitudes 31°N and 34°N (Southern California Bight)	+	Effort available as total nm surveyed by month.	
IV. Smithsonian Institution Pacific Ocean Biological Survey	Latitudes 27°N to 35°N, coast to longitude 120°W.	•	1967-1968 - unable to quantify effort by area or season.	47
Additional sources include: The University of Southern California, the Natural History Museum of Los Angeles County, San Diego Museum of Natural History, Marineland of the Pacific, Sea World, and numerous colleagues.				33 unpublished 196 published

Table II-1. Principal sources of unpublished records of sightings of white-sided dolphins in the northeastern Pacific (modified from Dahlheim, Leatherwood and Perrin, 1982). The notations in the middle column indicate whether, for purposes of this report, the listed program's survey effort has been characterized subjectively (*), quantitatively (+) or not at all (•).

Table II-2. The various combinations in which available sightings data were examined.

	Overall	Quarterly		Depth zone by 5° belt and quarter
		1° belt	5° belt	
# Herds	M D H	M D H	D H	D H
# Individuals	M D H	M D H	D H	D H
Herd size	F D	-	-	-

M - maps
H - histograms
D - descriptive statistics
F - frequency distribution

Table II-3. Indices of density of white-sided dolphins (L.o.) in the Southern California Bight (32°N to 34°N) 1968-1976, from NOSC aerial surveys. The total number of herds seen is followed in parentheses by the number of herds for which estimates of numbers were available. Also shown are indices of density for northern right whale dolphins (L.b.) for the same area (from Leatherwood and Walker, 1979).

Month	Effort flown in n.m.	Total no. of herds L.o.	I_1 - Herds per 100 n.m.		Total no. of indiv. L.o.	I_2
			L.o.	L.b.		L.o.
January	1890	16(15)	0.85	3.30	2687	1.42
February	2005	12(18)	0.60	11.48	1626	0.81
March	2645	7	0.26	1.38	766	0.29
April	4475	23(15)	0.51	2.04	3626	0.81
May	2150	3	0.14	0.39	90	0.04
June	1390	1	0.07	0	50	0.04
July	2120	4	0.19	0	268	0.13
August	2267	1	0.04	0	6	<0.01
September	1470	3	0.20	0	68	0.05
October	1795	3(2)	0.17	0.36	296	0.16
November	550	3(2)	0.55	0.54	159	0.29
December	2025	19(13)	0.94	1.77	2123	1.05
Totals	24,762	95(72)	0.384	-	11,766	0.48

Table II-4. Summary of effort and sightings of white-sided dolphins between latitudes 32°N and 35°N and a calculated index of density from UCSC aerial surveys May 1975 - March 1976.

Period	Nautical miles flown	Number of animals seen	I_2 Number of indiv. per n.m.
May	954	2024	2.120
July	2080	2540	1.220
August	1383	70	0.050
September	765	100	0.140
October	1935	292	0.150
November	2034	1892	0.930
December	934	0	0
January	3255	12	0.003
February	2520	7	0.003
March	1800	768	0.043

Table II-5. Details of effort and sightings of L. obliquidens between latitudes 25°N and 30°N, from NMFS dolphin-tuna program, 1974 through 1979. I_1 and I_2 values are number of herds and number of individuals per survey hour respectively.

Quarter	Approximate number of survey hours	Number of sightings	I_1	Number of animals	I_2	Mean herd size $\bar{H}$
1	>375	99	<0.27	9096	<24.26	92
2	565	85	0.15	5544	9.83	65
3	250	105	0.44	30665	3738.66	292
4	190	55	0.29	6570	34.58	119

latitude belt	20-25	20-25	20-25	20-25	25-30	25-30	25-30	25-30	30-35	30-35	30-35	30-35	35-40	35-40	35-40	35-40
quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
# herds	23	7	3	4	99	85	105	55	87	49	38	66	154	119	38	16
total # animals	6196	210	105	46	9096	5544	30665	6570	8722	4324	5425	3217	3565	2444	851	996
mean herd size	269.39	30	35	11.50	91.88	65.22	292.05	119.45	100.25	88.24	142.76	48.67	23.15	20.54	22.39	62.25
st. dev	682.28	44.99	35	9.95	466.24	250.72	936.48	321.03	217.41	209.02	417.03	115.84	59.57	64.20	49.31	125.10
st. error	142.27	17.00	-	4.98	46.86	27.19	91.39	43.29	13.31	29.86	67.65	14.26	4.80	5.89	8.00	31.28
min. herd size	1	1	10	1	1	1	1	1	1	1	1	1	1	1	1	1
max. herd size	3000	125	75	20	3500	2000	6000	1750	1000	1000	2500	750	500	500	300	450

latitude belt	40-45	40-45	40-45	40-45	45-50	45-50	45-50	45-50	50-55	50-55	50-55	50-55	55-60	55-60	55-60	55-60
quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
# herds	8	28	56	8	17	47	39	6	9	8	15	11	-	12	15	3
total # animals	522	1731	2220	71	184	3914	2658	484	535	1399	204	748	-	2215	2057	529
mean herd size	65.25	61.82	39.64	8.88	10.82	83.28	68.15	80.67	59.44	174.88	13.60	68	-	184.58	137.13	176.33
st. dev.	112.68	160.69	61.58	14.67	10.31	210.74	163.68	94.09	43.41	337.83	15.32	107	-	572.17	258.15	280.31
st. error	39.84	30.37	8.23	5.19	2.50	30.74	26.21	38.41	14.47	119.44	3.96	32.26	-	165.17	66.65	161.84
min. herd size	2	1	1	2	1	1	1	2	5	3	1	1	-	2	1	12
max. herd size	300	725	275	45	30	1000	900	250	250	100	1000	50	-	2000	1000	500

Appendix 1. Number of herds, total number of animals, and herd sizes for white-sided dolphins by quarter and 5° belt, 20-60°N latitude.

III. INVENTORY OF SPECIMEN MATERIALS

During Phase I we obtained information on 329 specimens of Lagenorhynchus obliquidens (Table III-1). A file containing all data assembled for this report has been deposited with the SWFC. During Phase II we will complete preparation and reading of growth layers in teeth and continue to add appropriate specimens until intensive analysis of data begins.

Institution	Total no. Specimens	Measurements		Post-cranial skeletons	Teeth	Reproductive data or tracts	Stomach	Photos
		External	Cranial					
British Columbia Provincial Museum, Vancouver	3	0	0	0	0	0	0	0
Burke Museum, Seattle	1	1	1	0	1	0	0	1
NMFS/NWAFC, Seattle	46	46	40	4	39	36	33	13
Museum Natural History, Univ. Puget Sound, Tacoma	8	7	3	1	4	6	6	2
Marine Science Center, Oregon State Univ., Newport	2	2	0	0	1	1	1	2
Vertebrate Zoology Museum, Humboldt State Univ., Arcata	5	4	4	2	4	3	3	2
California Academy of Sciences, San Francisco	25	15	21	8	1	4	4	0
Museum of Vertebrate Zoology, Univ. Calif., Berkeley	17	6	11	4	12	2	4	2
San Jose State Museum	43	4	10	7	9	2	3	1
California Polytechnic State Univ., San Luis Obispo	19	13	9	0	6	4	1	0
Santa Barbara Natural History Museum	16	8	12	10	7	1	2	2
Los Angeles County Natural History Museum	58	18	43	15	40	5	13	2
San Diego Museum Natural History	17	11	16	3	15	3	3	1
NMFS/SWFC, La Jolla	9	8	6	7	7	3	2	7
American Museum, New York	5	0	4	0	1	0	0	0
National Museum Natural History, Washington, D. C.	47	14	20	6	15	4	4	5
Museum Comparative Zoology, Harvard Univ. Museum, Cambridge	3	0	3	0	2	0	0	0
Others	5	1	3	0	0	0	0	0
TOTALS	329	158	206	67	184	61	79	40

Table III-1. Summary of data and specimen materials of Pacific white-sided dolphins Lagenorhynchus obliquidens located and examined during Phase I.

IV. BIBLIOGRAPHY

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