Forty Years of Winter: Cetaceans Observed During the Southbound Migration of Gray Whales, *Eschrichtius robustus*, Near Granite Canyon, Central California

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Introduction

The coastal waters of central California provide foraging habitat and migration corridors for a variety of temperate and warm-water cetacean taxa. In Monterey Bay and south of Carmel, deep submarine canyons penetrate the continental shelf, in some places reaching within meters of shore (Greene et al., 2002). The continental shelf narrows to within 4 km of shore south of Carmel Bay then fans out seaward to roughly 15 km off Point Sur (Fig. 1). The variety of bathymetric features provides a unique region where pelagic and coastal species intermingle.

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From 1967 to 2007, 25 censuses of southbound migrating gray whales, *Eschrichtius robustus*, were conducted in winter (primarily mid-December to mid-February) at shore-based stations just south of Carmel, Calif. (Reilly et al., 1983; Rugh et al., 2001; Shelden et al., 2004). Gray whales were the target species for the census; therefore, the study was timed to include virtually all of their southbound migration.

During these gray whale surveys, observers also recorded the presence of other cetacean species. We examined these shore-based records and observations obtained during aerial surveys in January 1988, 1993, 1994, and 1996 (Shelden and Laake, 2002), to document cetacean occurrence in winter off this portion of the central California coast. Our objective here is to describe which cetaceans are within the study area during winter, but because the gray whale sightings have been thoroughly documented elsewhere (Shelden et al., 2004; Laake et al., 2009), this species is not included in this report.

Historically there has been little dedicated survey effort documenting cetaceans off central California during the winter months of December through February. We are aware of only two studies. The first, a pelagic fur seal study, during which cetacean sightings were recorded incidentally, occurred in 1958, 1959, and 1961 (Fiscus and Niggol, 1965), which was before the first census of gray whales in central California. The second study (Dohl et al.[1,2]) occurred during a period (1980–83) which coincided with years when the gray whale census was not in operation. The results of those two studies are included in this review.

Methods

The study area for our review includes waters between Carmel Bay and Point Sur, Calif., extending from the coast to roughly 37 km (20 n.mi.) offshore (Fig. 1 box). Near the research sites used to count gray whales (Yankee

ABSTRACT— From December to February in most years from 1967 to 2007, observers counted gray whales, Eschrichtius robustus, *from shore sites south of Carmel in central California. In addition to gray whales, other cetacean species were also recorded. These observations were summarized and compared among survey platforms and to ocean conditions. Eleven cetacean species were identified including eight odontocete species (killer whale,* Orcinus orca*; Pacific white-sided dolphin,* Lagenorhynchus obliquidens*; common dolphin,* Delphinus *spp.; bottlenose dolphin,* Tursiops truncatus, *northern right whale dolphin,* Lissodelphis borealis*; Risso's dolphin,* Grampus griseus*; Dall's porpoise,* Phocoenoides dalli*; and harbor porpoise,* Phocoena phocoena*) and three mysticete species (humpback whale,* Megaptera novaeangliae*; minke whale,* Balaenoptera acutorostrata*; and blue whale,* Balaenoptera musculus*). As expected, the detection of certain species among survey platforms (shore-based census watches, 25-power "Big Eye" binocular watches, and aerial surveys) was limited by species surfacing behavior and/or bathymetric preference. Comparisons among the shore-based census efforts showed a significant difference in sightings rates from 1967–84 ($n = 14$, mean $= 0.11$, $SD = 0.11$) to 1985–2007 ($n = 11$, mean $= 1.48$, $SD = 0.47$; t-Test: $p < 0.001$, $df = 23$). The warm period observed during the 1990's may partially explain the increase in sighting rates and diversity of species observed at the census site compared to the much cooler temperatures of the 1970's.*

[1]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. Final Rep. Minerals Manage. Serv. Contr. 14-12-0001-29090 prep. by Cent. Mar. Sci., Univ. Calif., Santa Cruz. OCS Study MMS 84-0045, 284 p.

[2]Dohl, T. P., M. L. Bonnell, R. C. Guess, and K. T. Briggs. 1983. Marine mammals and seabirds of central and northern California 1980–1983: synthesis of findings. Final Rep. Minerals Manage. Serv. Contr. 14-12-0001-29090 prep. by Cent. Mar. Sci., Univ. Calif., Santa Cruz. OCS Study MMS 84-0042, 248 p.

Point[3] and Granite Canyon[4]), the shelf extends 4.2 km (2.25 n.mi.) offshore where it rapidly descends from 140 m to 200 m within 0.37 km (0.2 n.mi.). For all datasets, we limited the analysis of sightings to the months of December, January, and February.

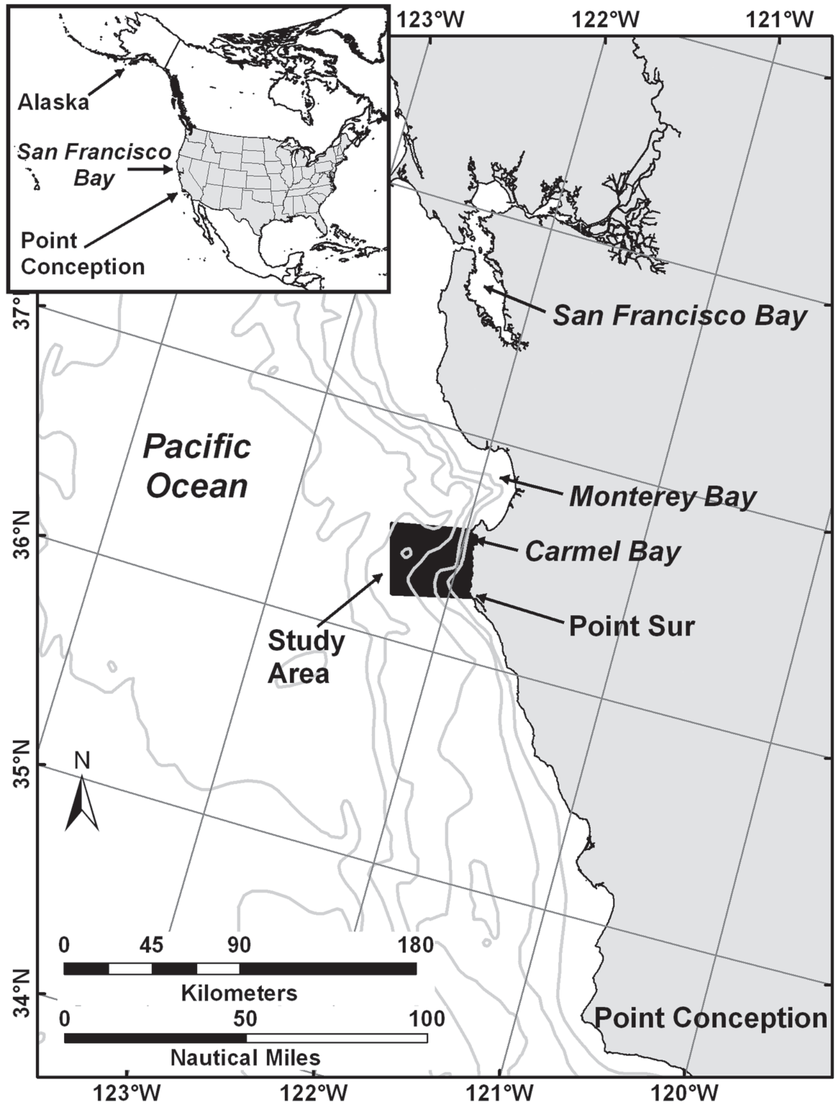


Figure 1.—Study area (box) showing place names mentioned in the text.

Survey Datasets

Vessel Surveys 1958–61

Vessel surveys were conducted in the waters between Point Reyes (near San Francisco Bay) and Point Sur in 1958 (1 Feb.–10 Apr.), 1959 (20 Jan.–8 Apr.), and 1961 (5–15 Jan. and 16 Feb.–1 Apr.) (Fiscus and Niggol, 1965). Effort during these vessel surveys was focused from the 100 fathom (fm) curve (183 m isobath) to 185 km (100 n.mi.) offshore. Watches occurred from 0600 to 1800 h daily, and the vessel left the trackline to confirm cetacean sighting identifications only when seals were not present. Unidentified cetaceans were not recorded. Sighting and catch data presented in tables and text in Fiscus and Niggol (1965) were entered into an MSExcel[5] spreadsheet and imported into ArcView (ESRI) to determine which fell within the boundary of the study area. Unfortunately, it was not possible for us to determine the amount of effort or where survey tracklines occurred within the study area based on the figures and descriptions provided in Fiscus and Niggol (1965).

Shore-based Census 1967–80

Systematic shore-based censuses of the southbound gray whale migration began in 1967 at Yankee Point (lat. 36º 29′30″N) at a site 23 m above sea level. In 1974, the census site was moved a few kilometers farther south to Granite Canyon (lat. 36º 26′41″N), to the edge of a cliff 21 m above sea level (Fig. 2). During watches, single observers rotated on 5-h shifts throughout all daylight hours (0700 to 1700 h), conducting independent searches across a 150° viewing area (Reilly et al., 1983).

Records included effort (start and stop time of systematic searches), environmental conditions (visibility, Beaufort sea state, and wind direction), and details on sighting time and location. Sighting effort was calculated for entire watch periods as portions of a day (24 h) where average visibility was ≤4 (all but "poor" or "useless" viewing conditions) and Beaufort was ≤4 (sea state calmer than when there are moderate waves with many whitecaps; <30 km/h). Distances of the animals from shore were estimated during this period without any calibrations, so they are not considered reliable. Therefore, sighting locations could not be mapped in ArcView. Instead, these sightings are presented in tabular form. It appears that

[3]Yankee Point is a residential area. A house with an excellent view of the sea was made available for documenting the gray whale migration from 1967 to 1974.

[4]Granite Canyon is a research station owned by NOAA since the mid 1960's. The site has been used by California Department of Fish and Game for aquaculture research, University of California (UC) Davis for water pollution/quality studies, and a consortium including UC Santa Cruz, the Naval Postgraduate School, and Cal State University Monterey Bay to monitor ocean currents with high frequency radar (http://www.envtox.ucdavis.edu/GraniteCanyon/SettingHistory.html).

[5]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Figure 2.—A view from sea level of the Granite Canyon research site 13 km south of Carmel in central California. This is the site from which gray whale counts have been conducted most winters 1967–2007.

the data forms and sighting protocol remained the same throughout this period. Although for the 1978–79 census, a new data form and accompanying instructions were introduced to ease key punching the hand-written data, field methodology did not change.

Aerial Surveys 1980–83

Low (60 m = 250 ft) and high (300 m = 1,000 ft) altitude aerial surveys were flown bi-weekly to document marine mammals and seabirds in the waters off central and northern California from 1980 to 1983 (Dohl et al.[1,2]). The project was undertaken to provide data to the Pacific Outer Continental Shelf (OCS) Region of the Minerals Management Service in regard to oil and gas lease areas. East-west tracklines (92 in all) extended from shore out approximately 175 km and were broken into coastal (0–99 fm) and offshore (100–999 fm) segments. Of these, 3 of the 92 tracklines fell within our study area. Sighting data for the south-central sector, which included waters between Point Sur (lat. 36° 20' N) and Russian River (lat. 38° 30' N), were kindly provided by Bonnell and Ford[6], after accessing the Dohl database through OBIS-SEAMAP (Read et al.[7]). Similar to the Fiscus and Niggol (1965) dataset, sightings were imported into ArcView to determine whether any fell within the study area. Unfortunately, we could not determine how often survey tracklines were flown in the study area or if the segment flown was coastal or offshore from the descriptions and figures provided in Dohl et al.[1,2]

Shore-Based Census 1984–2007

After a 4-yr hiatus, gray whale census operations resumed once again in the winter of 1984–85. During this census, the same methods used during the earlier censuses were followed to allow for inter-year trend analysis (Dahlheim and Rugh[8]), and the same data form and instructions were used from 1979 to 1988. However, some adaptations have been made through the years:

1) Beginning with the 1985–86 census, observers rotated on three shifts covering 10 daylight hours per day (3.5 h, 3 h, and

[6]Bonnell, M. L., and R. G. Ford. 2001. Marine mammal and seabird computer database analysis system. MMS-CDAS Version 2.1. CD ROM prepared by Ecological Consulting, Portland, Oreg., for the Pacific OCS Region, Minerals Manage. Serv., Order No. 14-12-001-30183.

[7]Read, A. J., P. N. Halpin, L. B. Crowder, K. D. Hyrenbach, B. D. Best, E. Fujioka, and M. S. Coyne (Editors). 2006. OBIS-SEAMAP: mapping marine mammals, birds and turtles. World Wide Web electronic publication. Accessed 24 May 2006 [http://seamap.env.duke.edu].

[8]Dahlheim, M. E., and D. J. Rugh. 1991. A historical review of censusing gray whales. Unpubl. pap. presented to the Scientific Committee of the International Whaling Commission, SC/A90/G4, 8 p.

3.5 h) instead of only two shifts (each 5 h), and after 1993, each of the three watches was 3 h, covering 9 h per day.

2) In January of each year since 1985, part of the census operation included concurrent, independent watches (Rugh et al., 1990). For our analysis, cetacean sighting records from these concurrent watches (South Shed and North Shed: Fig. 3) were considered separate sightings when both observers recorded the same species at about the same time and location because the efforts were completely independent.

3) Since 1987, magnetic compasses and vertical reticle marks in handheld 7×50 binoculars provided data on sighting locations (Rugh et al., 1990). The focus of the sighting effort was along a line perpendicular to the coastline, at 241° magnetic.

Cetacean sighting locations (latitude and longitude) were determined using the compass bearing and reticle provided at the time of the sighting, and altitude and location (latitude and longitude) of the survey shed (NewPosLat and NewPosLon functions for Excel[9]). Distances to sightings were calculated using the RetDist7×50 function in Excel.[9] The sightings were then plotted in ArcView and joined to nearest sounding in National Oceanic and Atmospheric Administration (NOAA) electronic nautical charts (ENC).

In most census years, any cetacean sighting other than a gray whale was treated as a comment entry in the database. Starting in December 1987, data forms were modified to include a behavioral code for gray whales associated with other species, but all other cetacean sightings were still entered as comments. In December 2001, a dedicated code was introduced on the data form to identify all other cetaceans.

All cetacean sighting (other than gray whales) were entered into an Excel spreadsheet. Unidentified cetaceans were reclassified to species only if time, location, and descriptions were similar between the paired records when only one of the observers provided a species identification. Sighting effort was limited to daily effort values in portions of a day (24 h) when the average visibility was ≤4 and Beaufort was ≤4. For data prior to 1987, the exclusion of effort was for a whole 5-h watch period at a time because changes in environmental conditions were not indicated except when sightings occurred. From 1987 onward, the data protocol included an independent code indicating when visibility or weather changed. This made it possible to exclude select portions of watch periods from the analysis.

Aerial Surveys 1988–96

Cetacean sightings were also documented during aerial surveys conducted concurrent to censuses in January 1988, 1993, 1994, and 1996 (Shelden and Laake, 2002). These aerial surveys were designed to characterize the offshore distribution of gray whales by flying tracklines perpendicular to the shore in the vicinity of the station at Granite Canyon. Earlier aerial surveys conducted in January 1973 (Sund and O'Connor, 1974) and during the 1978–79 and 1979–80 censuses (Reilly et al., 1983), also designed to characterize the gray whale migration corridor, did not report cetacean sightings other than gray whales. Therefore, only the 1988–96 surveys are used here.

Cetacean sighting locations during aerial surveys were obtained by interpolating distances from shore relative to time of sighting on the trackline (i.e. dead-reckoning) or, beginning in 1994, using global positioning system (GPS) location data (Shelden and Laake, 2002). These sighting locations were imported into ArcView. Sighting distances were compared among the three datasets: shore watch, aerial surveys, and 25× "Big Eye" binocular watches (presented in the next section) for each January when all three studies were in operation.

"Big Eye" Watches 1992–2007

Watches conducted with 25× "Big Eye" binoculars started in December 1992 at Granite Canyon (Rugh et al., 2002). Thereafter, "Big Eye" watches occurred every January, and in 2001 and 2002 the watches extended into February. Paired, independent searches for gray whales were conducted through fix-mounted "Big Eye" binoculars during 6–25 Jan. 1995 and 7–25 Jan. 1996. The "Big Eye" study was a test of an efficient method for documenting inter-year changes in the offshore distribution of the migration. Similar to the concurrent, independent shore-based census effort, the South "Big Eye" Shed and North "Big Eye" Shed (Fig. 4) were considered separate sightings when both observers recorded the same species at about the same time and location because the efforts were completely independent. As with the shore-based sightings, location and distance offshore for each "Big Eye" sighting was calculated using NewPosLon, NewPosLat, and RetDistBE[9], respectively, and imported into ArcView.

Oceanography

Where data were available, oceanographic parameters were included with each sighting. Daily surface water temperatures were obtained from the Scripps Institution of Oceanography (SIO) Shore Station Program website[10] for waters at the Granite Canyon station. Because temperatures were available only since 1971 at Granite Canyon, we explored using other sites such as Pacific Grove (near Monterey Bay) as a proxy for the earliest census years: 1967 to 1970; however, the available data were not compatible when records were kept at both sites (t-Test, $p = 0.046$, df = 187). A monthly surface water temperature anomaly was calculated as the difference between the average monthly temperatures for a given month and the long-term mean temperature for the calendar month from 1971 to 2007 for Granite Canyon. Anomalies were then

[9]National Marine Mammal Laboratory. Software: Excel Geometry Functions. Available at: http://www.afsc.noaa.gov/nmml/software/excelgeo.php

[10]Scripps Institution of Oceanography (SIO) Shore Station Program website. Accessed 24 April 2007 [http://shorestation.ucsd.edu/data/index_data.html].

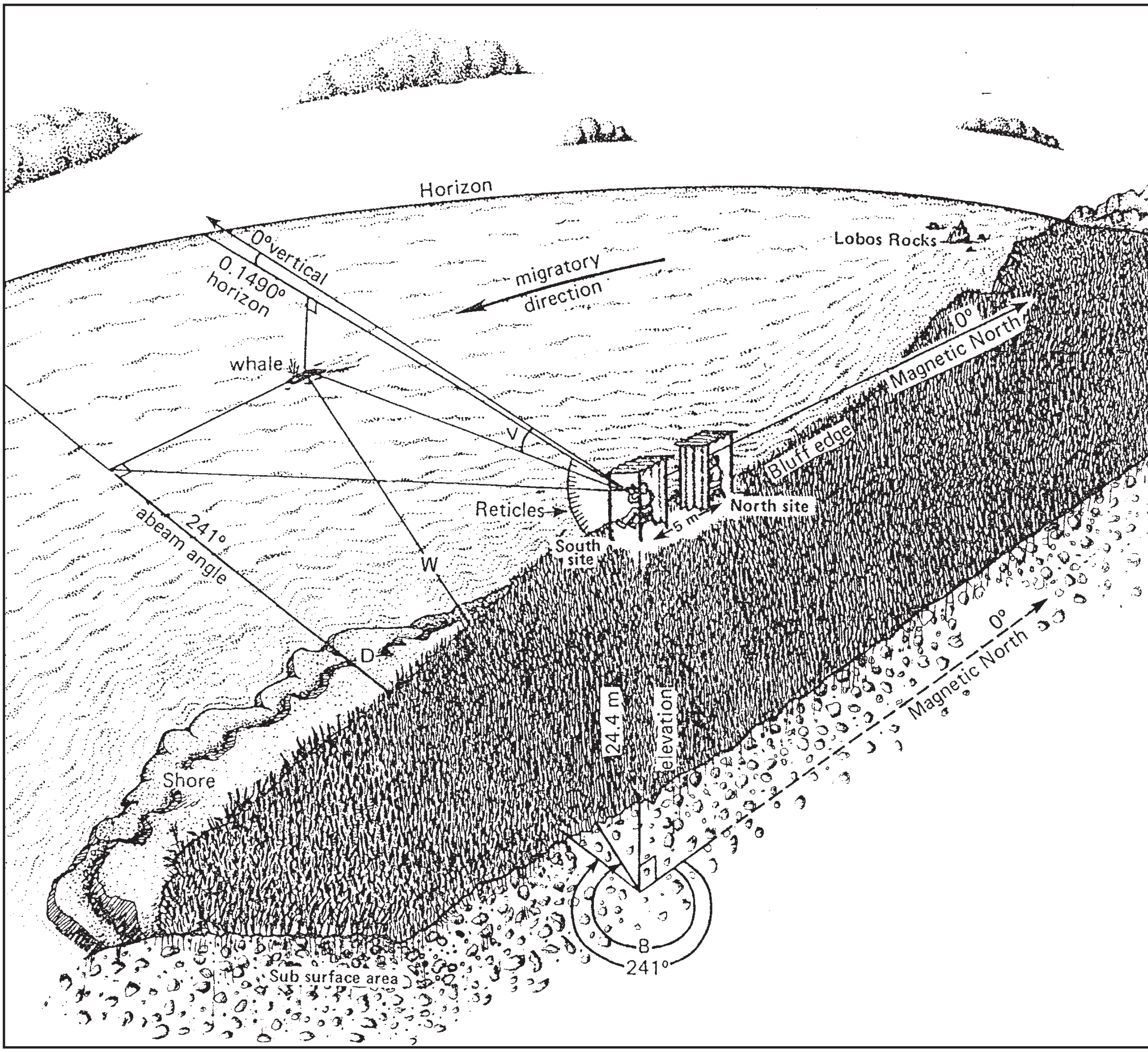


Figure 3.—Schematic of observation sheds and sighting protocol used to count gray whales during the gray whale southbound migration past Granite Canyon.

normalized by dividing by the standard deviation of the long-term mean for each month. Monthly sea surface temperature (SST) anomaly data were then linked to each sighting.

Plankton productivity is strongly tied to the upwelling of cold, nutrient-rich sub-surface waters. In particular, wind-induced coastal upwelling in which the upward movement is a consequence of wind stress (along shore) and Ekman transport (offshore) (Bakun and Nelson, 1991). Daily upwelling indices were obtained from the Pacific Fisheries Environmental Laboratory[11], NOAA. Indices were available for all census years (1967 to 2007) from a site at lat. 36° N, 122° W (33 km southwest of Point Sur and 49 km southwest of Granite Canyon). A monthly upwelling index (UI) anomaly was calculated using the technique described for the SST data.

In addition to these shorter-scale oceanic variables, comparisons were made to climate regime shifts in the North Pacific (Mantua et al., 1997; Hare and Mantua, 2000). Shifts significant enough to have potentially affected gray whale abundance estimates are purported to have occurred in 1976–77

[11]Pacific Fisheries Environmental Laboratory website. Accessed 24 April 2007 [http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/data_download.html;ftp://orpheus.pfeg.noaa.gov/outgoing/upwell/daily/p10dayac.all].

Figure 4.—Photograph of sheds used to house two 25× "Big Eye" binoculars at Granite Canyon. The paired, independent effort through these two binoculars provided a test of sighting rates.

and 1988–89 (Hare and Mantua, 2000; Benson and Trites, 2002).

Results and Discussion

Because gray whale results are reported elsewhere (e.g. Shelden and Laake, 2002; Rugh et al., 2005; Laake et al., 2009), this species is not emphasized here. In every year of the census, gray whales were seen in great numbers (from 657 to 2,853 sightings per year; mean = 1,564 sightings, SD 514). These whales were seen on almost every day of each of the 25 censuses, sometimes with >100 sightings per day. The peak of the migration occurs in mid January, and 90% of the sightings occur in January (Rugh et al., 2001).

During whale marking cruises conducted near Yankee Point in the 1960's, it was determined that few gray whales migrated beyond the visual range of observers on shore (Rice and Wolman, 1971). This was confirmed in January 1973, when five flights were conducted to test the width of the migration corridor (Sund and O'Connor, 1974). Results indicated that 96% of the whales passed within 4.8 km (2.6 n.mi.) of shore (94% within 1.6 km). This offshore distribution was also documented during aerial surveys near the Granite Canyon station, where fewer than 2% of the whales migrated beyond the sighting range of shore-based observers (Shelden and Laake, 2002). The census periods and sighting effort for the shore-based census are presented in Table 1.

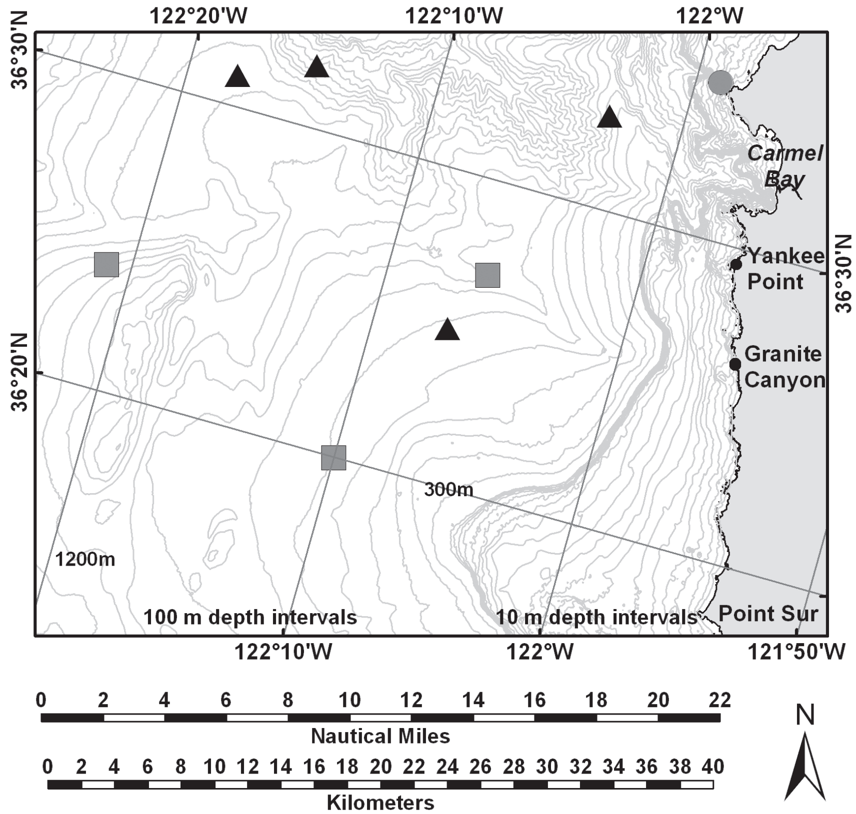
Vessel Surveys 1958–61

According to Fiscus and Niggol (1965), "about 50 percent of the large whales and 90 percent of the smaller cetaceans seen could be identified." Cetacean sightings reported in the waters between Carmel Bay and Point Sur in January and February during these vessel-based surveys included gray whales (one sighting of two whales on 28 Jan. 1959) and two odontocete species: Pacific white-sided dolphins, *Lagenorhynchus obliquidens*, and Dall's porpoise, *Phocoenoides dalli* (Fig. 5). Group sizes for Pacific white-sided dolphins ranged from 4 to over 100 while Dall's porpoise group sizes ranged from 4 to 8. All odontocete sightings occurred in February.

Shore-Based Census 1967–80

During this period from 1967 to 1980 when the gray whale census was underway, there were 22 sightings of

Figure 5.—Cetaceans observed near Granite Canyon during pelagic fur seal vessel surveys Dec.–Feb. 1959 and 1961 (Fiscus and Niggol, 1965). Symbols denote gray whales (circle), Pacific white-sided dolphins (triangle), and Dall's porpoise (square).



cetaceans other than gray whales (Table 1). Of these, on average, roughly 30% were identified to species (Table 2) which included Pacific white-sided dolphins; killer whales, *Orcinus orca*; and humpback whales, *Megaptera novaeangliae*. If an observer's comment indicated he/she was not fully confident of the species identification, the sighting was not identified to species nor used in subsequent analyses (see footnotes 1 and 2 in Table 2). All useable sightings were recorded in the month of January, with the exception of a sighting of a Pacific white-sided dolphin in February 1968. Unidentified dolphin and whale sightings were also recorded most often in January (nine sightings and two sightings, respectively). We did expect a focal species bias particularly when the bulk of the gray whale migration was passing the counting stations in January. However, there is no evidence in these data that gray whale sightings significantly eclipsed records of other cetaceans.

Aerial Surveys 1980–83

Aerial surveys of the waters between Carmel Bay and Point Sur documented six odontocete species during the winters of 1980–83 (Fig. 6). The thirteen sightings included Pacific white-sided dolphins; Dall's porpoise; killer whales; Risso's dolphins, *Grampus griseus;* northern right whale dolphins, *Lissodelphis borealis*; and harbor porpoise, *Phocoena phocoena* (Table 3). A mixed-school of Risso's dolphins and northern right whale dolphins was observed on 6 Jan. 1981 (Table 3, Fig. 6). Sightings were reported in every winter month only during 1980–81; however, we do not know if flights occurred in January 1982 or February 1983 in the study area. We suspect that most of these tracklines were well offshore (100–999 fm) given the absence of gray whale sightings.

Table 1.—Number of cetacean sightings (other than gray whales and including unidentified cetaceans) reported off central California during the winter census of gray whales by observers on shore watch. Effort days (24 h) represent when average visibility was ≤ 4 and Beaufort sea state was ≤ 4 for the period December-February. The move from the Yankee Point counting site to Granite Canyon occurred after the 1973–74 census. Gaps between census years indicate when the census was not in operation.

Census sites and dates	Effort days	Sightings	Sightings per unit effort
18 Dec 1967–4 Feb 1968	12.6	2	0.16
10 Dec 1968–7 Feb 1969	15.8	0	0
8 Dec 1969–9 Feb 1970	19.4	0	0
9 Dec 1970–13 Feb 1971	24.8	3	0.12
18 Dec 1971–8 Feb 1972	14.4	0	0
16 Dec 1972–17 Feb 1973	19.4	5	0.26
14 Dec 1973–9 Feb 1974	17.7	6	0.34
10 Dec 1974–7 Feb 1975	19.8	1	0.05
10 Dec 1975–4 Feb 1976	12.2	1	0.08
10 Dec 1976–7 Feb 1977	21.6	2	0.09
10 Dec 1977–5 Feb 1978	8.1	0	0
10 Dec 1978–9 Feb 1979	21.7	1	0.05
10 Dec 1979–7 Feb 1980	15.7	1	0.06
28 Dec 1984–7 Feb 1985	11.2	3	0.27
10 Dec 1985–7 Feb 1986	26.7	25	0.94
10 Dec 1987–7 Feb 1988	44.0	42	0.95
10 Dec 1992–7 Feb 1993	23.6	42	1.78
10 Dec 1993–17 Feb 1994	30.0	56	1.87
6–26 Jan 1995	3.4	4	1.18
10 Dec 1995–23 Feb 1996	19.9	28	1.40
9–23 Jan 1997	6.9	9	1.30
13 Dec 1997–24 Feb 1998	22.3	31	1.39
13 Dec 2000–5 Mar 2001	31.2	68	2.18
12 Dec 2001–5 Mar 2002	25.0	34	1.36
12 Dec 2006-22 Feb 2007	23.1	43	1.87
Total	490.6	407	

Shore-Based Census 1984–2007

Non gray whale cetacean sighting rates increased significantly after 1984 (Table 1). Although there were some minor methodological changes made during the 1985–86 census, they do not account for such a dramatic change in sighting rates. The data forms and instructions used in 1985–86 were first used during the 1979–80 census. The only changes to survey methods were including paired, independent effort during January, reducing the length of watch periods, and providing vertical and horizontal data on each sighting. These changes are not thought to have raised or lowered the probability of recording sightings.

After comparing observers and sighting records from the earliest years of the census, we determined that observers were recording any cetacean they saw. It was just that cetaceans other than gray whales "were few and far between" in those early years of the census (Rice[12]). Comparisons among the primary sighting efforts show a significant difference in sightings rates from 1967–84 ($n = 14$, mean = 0.11, SD = 0.11) to 1985–2007 ($n = 11$, mean = 1.48, SD = 0.47; t-Test: $p < 0.001$, df = 23). Within-season comparisons showed good agreement, in that sighting rates between the paired sheds (Table 4) were not significantly different (t-Test: $p = 0.58$, df = 18).

Eleven species were identified during the latter half of the census years, since 1985 (Table 5), including seven species reported during the earlier studies: Pacific white-sided dolphins, Dall's porpoise, killer whales, Risso's dolphins, northern right whale dolphins, harbor porpoise, and humpback whales. A little over half (on average 57%) of all odontocete sightings reported by shore-based observers were identified to species compared to 71% of mysticete sightings (Table 5). Dall's porpoise, harbor porpoise, and northern right whale dolphins were rarely observed from shore (Table 5). These species are found year-round off the central California coast (Leatherwood et al., 1982; Forney, 1997; Chivers et al., 2002). Dall's porpoise can be very visible when "rooster tailing," but group sizes were small. Small group sizes and low surfacing profile also made detection of northern right whale dolphins and harbor porpoise difficult, and northern right whale dolphins were only observed in mixed-species groups.

Three species (Risso's dolphins; common dolphins, *Delphinus* spp.; and bottlenose dolphins, *Tursiops truncatus*) were first recorded by the census teams during the 1980's. Two separate species of common dolphins occur off central California (Heyning and Perrin, 1994; Benson et al., 2002): long-beaked, *Delphinus capensis,* and short-beaked, *D. delphis*. However, observers did not report common dolphins to the species level. Bottlenose dolphins were also seen north and south of the gray whale census study site in December 1984, January 1985, and December 1986, during periods when the census was not in operation (Wells et al., 1990). Our first sighting of bottlenose dolphins (a group of 15 seen on 28 December 1987) occurred only one day before the sightings reported by Alan Baldridge (Wells et al., 1990). The coastal population of bottlenose dolphins is usually found within 1 km (0.5 n.mi.) of shore (Hansen, 1990; Hanson and Defran, 1993) with a preference for depths of 20 m or less (Leatherwood and Reeves, 1982) (Fig. 7, Box A). All three of these species have been observed during almost every census since the 1982–83 El Niño (Table 5). These species are often observed in large surface-active schools, increasing their likelihood of detection.

[12] Rice, Dale, Gray Whale Census Project Leader 1967–1980. National Marine Mammal Laboratory, NOAA, NMFS, Seattle, Wash. Personal commun. 23 April 2007.

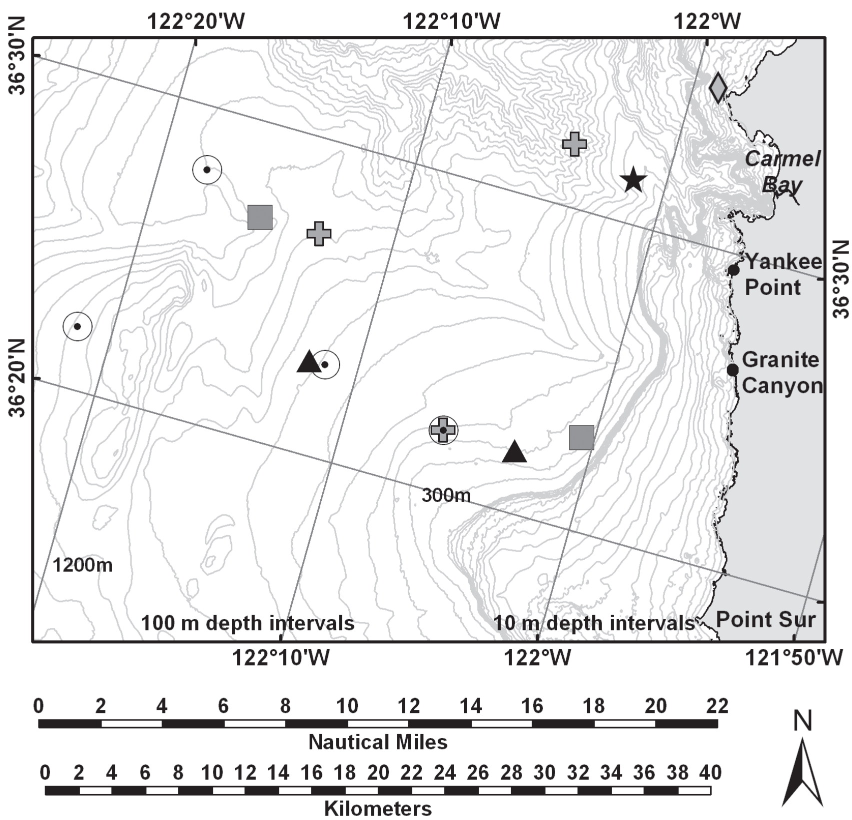


Figure 6.—Cetaceans in the Granite Canyon study area observed during aerial surveys Dec.–Feb. 1980–83 (Dohl et al.[1,2]). Symbols denote Pacific white-sided dolphins (triangle), Dall's porpoise (square), northern right whale dolphins (circle), killer whales (star), Risso's dolphins (cross), and harbor porpoise (diamond).

Two whale sightings were tentatively identified as minke whales, *Balaenoptera acutorostrata*, during the 1972–73 census (Table 2: footnote 2); however, it was not until the 1985–86 season that 12 confirmed sightings were reported (Table 5).

Blue whales, *Balaenoptera musculus*, were seen only during the 1992–93 census (Table 5). The sighting of two whales traveling south occurred in December. Blue whales as well as humpback whales migrate to waters south of California in the winter and do not return until spring (Calambokidis and Barlow, 2004; Croll et al., 2005; Keiper et al., 2005; Dohl et al.[1,2]).

Overall, shore-based observers were limited by their ability to detect and identify species at great distances. Shelden and Laake (2002) noted that shore-based observers were able to see some gray whales as far away as the horizon (16 km, as calculated with reticles in 7×50 binoculars) under ideal conditions, but most searching is conducted without the aid of binoculars, so generally whale surfacings occurring at distances of 9 km or greater may go undetected. For other cetaceans observed during the census, all sightings identified to species were within 7.4 km (4 n.mi.) of shore (Fig. 7).

Table 2.—Cetaceans reported during the southbound gray whale census, 1967–80 (for the period December–February). For identified species, number of sightings is followed by group size in parenthesis. The move from the Yankee Point counting site to Granite Canyon is shown by the gap dividing the two time periods.

Census	Pacific white-sided dolphins	Killer whales	Humpback whales	Unidentified dolphins	Unidentified whales
1967–68	1 (3-4)			1	
1968–69					
1969–70					
1970–71		1 (4-5)		2	
1971–72					
1972–73				3[1]	2[2]
1973–74				5	1
1974–75	1 (4-5)				
1975–76				1	
1976–77		1 (2)		1	
1977–78					
1978–79			1 (2)		
1979–80				1	
Total sightings	2	2	1	14	3

[1] Observer comment on one sighting stated "noticed successive pods of porpoises coming toward site, they were probably Pacific striped" (i.e. *Lagenorhynchus obliquidens*).

[2] Observer comment on one sighting stated "following shoreline, small whale with low shapeless blow visible only in south quadrant with sun shining through it, small slightly hooked dorsal fin, looked more like a minke whale than any beaked whale shown in the "Guide…"

Table 3.—Cetaceans reported during winter aerial surveys, 1980–83 (Dohl et al.[1,2]). Number of sightings is followed by parenthesis containing group size(s). Number of surveys where cetaceans were observed is shown in parenthesis for each winter (total effort is not known).

Years	Pacific white-sided dolphins	Killer whales	Risso's dolphins	Northern right whale dolphins	Dall's porpoise	Harbor porpoise
1980–81 (5 surveys)	1 (10)	1 (4)	2 (12, 150[1])	4 (6, 18, 400, 2000)	1 (1)	
1981–82 (2 surveys)					1 (8)	1 (1)
1982–83 (2 surveys)	1 (10)		1 (21)			
Total sightings	2	1	3	4	2	1

[1] This group of Risso's dolphins (about 150 animals) was in a mixed-school with about 400 northern right whale dolphins (noted as a separate sighting in this table, see also Fig. 6).

Table 4—Number of cetacean sightings (other than gray whales and including unidentified cetaceans) reported off central California during the winter census of gray whales by observers on shore watch in years when a secondary effort occurred. Effort days (24 h) represent when average visibility was ≤ 4 and Beaufort sea state was ≤ 4 for the time period mid-December to mid-February.

	Primary watch			Secondary watch		
Census	Effort days	Sightings	Sightings per unit effort	Effort days	Sightings	Sightings per unit effort
1985–86	22.2	21	0.95	4.6	4	0.87
1987–88	22.2	18	0.81	21.8	24	1.10
1992–93	18.4	33	1.79	5.2	9	1.72
1993–94	22.9	42	1.84	7.1	14	1.96
1995–96	17.6	20	1.14	2.3	8	3.46
Jan. 1997	3.5	6	1.71	3.4	3	0.88
1997–98	16.7	22	1.32	5.6	9	1.61
2000–01	21.6	52	2.41	9.6	16	1.66
2001–02	19.7	28	1.42	5.3	6	1.13
2006–07	19.4	34	1.76	3.7	9	2.43
Total	184.1	276	Mean = 1.51 SD = 0.48	68.8	102	Mean = 1.68 SD = 0.80

Aerial Surveys 1988–96

In the 4 years aerial surveys were conducted concurrent with shore-based census operations, 7 of the 11 species were reported (Table 6). On average, 75% of odontocete sightings and 100% of baleen whales were identified to species. Most sightings occurred beyond the continental shelf (Fig. 8). Risso's dolphins comprised over half of the total sightings. Risso's and common dolphins were the only species reported during all aerial survey years (Table 6). Detections were likely biased toward larger schools of surface-active species given the survey altitude of 305 m (1,000 ft) and the intense focus on documenting all gray whales within the study area.

"Big Eye" Watches 1992–2007

The "Big Eye" study provided yet another perspective to documenting cetaceans during the eight years this project occurred concurrent with the census. All species with the exception of blue and humpback whales recorded by census observers were also recorded by "Big Eye" observers (Table 7). Similar to aerial survey results, Risso's and common dolphins were the only species reported during all survey years (Table 7). The fixed aspect of the binoculars and narrow field of view limited sightings to a band along the 241° magnetic bearing (Fig. 9), with the exception of a

Table 5.—Cetaceans reported during the southbound gray whale census, 1984–2007 (for the time period mid-December to mid-February). Number of sightings is followed by parenthesis containing the number of sightings for which an offshore position (latitude, longitude) could be calculated from the reticle and bearing provided in the comment string. Group sizes (where recorded) for each sighting are reported in Appendix 1 (available from authors).

Species	1984–85	1985–86	1987–88	1992–93	1993–94	Jan. 1995	1995–96	Jan. 1997	1997–98	2000–01	2001–02	2006–07	Total
Minke whale		12	4 (3)	1 (1)	1 (1)		2 (2)						20 (7)
Blue whale				1 (1)									1 (1)
Common dolphin	1		6 (5)	16 (13)	10 (10)	1 (1)	2 (1)	2 (2)	7 (7)	9 (9)	1 (1)	3 (3)	58 (52)
Risso's dolphin		5		12 (11)	9 (7)			3 (3)		10 (10)	3 (3)	14 (13)	56 (47)
Northern right whale dolphin				1 (1)									1 (1)
Pacific white-sided dolphin				1 (1)	2 (2)			1 (1)		1 (1)		1 (1)	6 (6)
Humpback whale				1 (1)	1 (1)		2 (1)			3 (3)		2 (2)	9 (8)
Killer whale		4			2 (2)	1 (1)	2 (2)	1 (1)	5 (5)	3 (2)			18 (13)
Dall's porpoise						1 (1)				1 (1)			2 (2)
Harbor porpoise				1 (1)						1 (1)			2 (2)
Bottlenose dolphin			2 (2)		2 (2)		3 (3)	1 (1)	3 (3)		11 (11)	8 (8)	30 (30)
Unidentified dolphins	2	4	28 (18)	5 (5)	28 (23)	1	17 (16)	1 (1)	16 (13)	38 (32)	13 (13)	15 (12)	168 (133)
Unidentified whales			2 (1)	3 (3)	1 (1)					2 (2)	6 (6)		14 (13)
Total	3	25	42 (29)	42 (38)	56 (49)	4 (3)	28 (25)	9 (9)	31 (28)	68 (61)	34 (34)	43 (39)	385 (315)

few sightings made in December 1992 when binoculars were not yet locked in place horizontally (Fig. 9, main map and box A inset). Although cetaceans were identified to species as far as the horizon (about 17 km (9 n.mi.)), most identifications occurred within 5.5 km of shore (Fig. 9, boxes B and C; Table 8). Sighting effort beyond 6.3 km was 36% to 53% lower than in sighting bins closer to shore due to visibility (Table 8). The field of view in these binoculars also excluded any sightings that may have occurred within 0.6 km of shore.

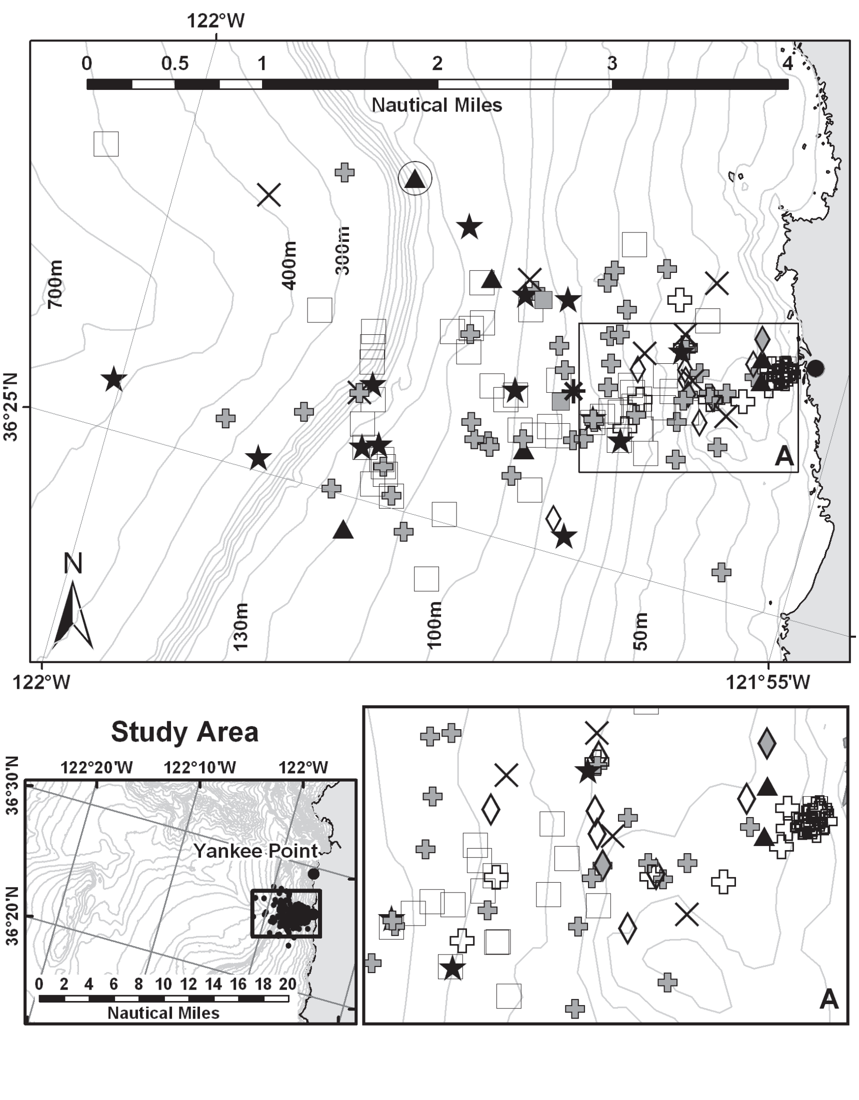


Figure 7.—Cetaceans seen within about 7 km (4 n.mi.) of the Granite Canyon research station during the southbound migration of gray whales mid-December to mid-February 1987–2007. The overview map shows the 7 km sighting range from Granite Canyon. Symbols denote Pacific white-sided dolphins (black triangle), Dall's porpoise (gray square), northern right whale dolphins (open circle), killer whales (black star), Risso's dolphins (gray cross), harbor porpoise (gray diamond), minke whale (open diamond), blue whale (black asterisk), humpback whale (× symbol), common dolphins (open square), and bottlenose dolphins (open cross). Box A zooms in on the cluster of sightings closest to the survey station (the tight cluster nearest shore includes 4 sightings of common dolphins and 21 sightings of bottlenose dolphins).

Survey Platform Comparison

During periods when all three survey platforms were operating concurrently (January 1993, 1994, 1996), we compiled sightings into distance bins and included only those species reported by at least two of the survey platforms (Fig. 10). The three plots show some of the limitations of each dataset given the diversity of species present in the study area and factors that influence observer detection rates such as habitat and behaviors. Five species were observed from all platforms: minke whales, common dolphins, Risso's dolphins, Pacific white-sided dolphins, and killer whales.

All sightings of minke whales were of lone animals, with the shore-based platform detections occurring closest to shore (Fig. 10a, b) and the aerial observation occurring at the offshore end of a trackline (Fig. 10c). Minke whales have been observed in the study area year-round and seem to have established home ranges (Dorsey et al., 1990), but they tend to be very cryptic, travel alone, and rarely display active surfacing behaviors (Leatherwood et al., 1982; Stern, 1992). In contrast, the odontocetes reported by all three platforms were rarely alone.

The number and distribution of common dolphin sightings were similar among the survey platforms (Fig. 10), with the exception of two aerial sightings that occurred beyond 18 km offshore (Fig. 10c).

Aerial sightings of Risso's dolphins were distributed across the range of distance bins with the majority of sightings occurring beyond the visual range of census observers (Fig. 10c), which may be indicative of a pelagic distribution (Leatherwood et al., 1980). This preference for deep water could explain why Risso's dolphins were not reported by census observers in 1988 (Table 5), although aerial surveys documented 24 sightings in the study area (Table 6). When aerial surveys extended north to Monterey Bay (1988 and 1993), Risso's dolphins were also observed primarily over submarine canyons.

Pacific white-sided dolphins were reported in most of the distance bins, but sightings appeared to peak around 5–7 km from shore (Fig. 10b, c), once again near the outer limits for census observers to successfully identify this species. In 1996, the largest number of sightings occurred during aerial (Table 6) and "Big Eye" (Table 7) studies, yet Pacific white-sided dolphins were not reported by census observers that winter (Table 5).

For killer whales, group sizes (when noted) ranged from one to five animals and often included at least one adult male. All sightings (aerial and Big Eye) were within the visual range of the census observers (Fig. 10). Killer whales are also observed year-round in central California waters (Black et al., 1997; Dohl et al.[1,2]). There are three ecotypes, each of which has been observed in the Monterey area during winter (Black et al., 1997; Black[13]). "Resident" killer whales feed exclusively on fish and seem to be rare visitors to California. Photographs of killer whales seen in Monterey Bay on 29 Jan. 2000 and 13 Mar. 2003 were matched to whales usually seen in Washington State waters (Black[13]). "Offshore" killer whales occur in groups of 40 to 100 and are

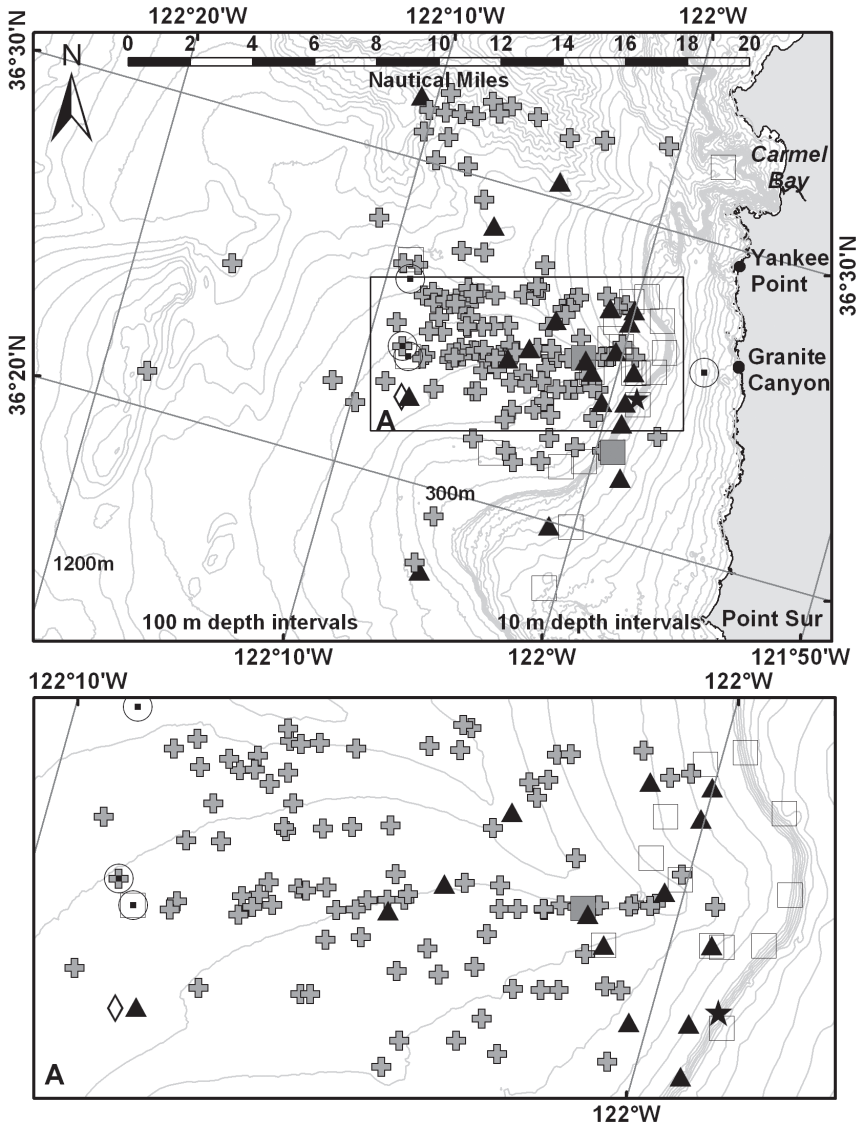


Figure 8.—Cetaceans in the study area observed during aerial surveys of the southbound migration of gray whales, Jan. 1988–96. Symbols denote Pacific white-sided dolphins (black triangle), Dall's porpoise (gray square), northern right whale dolphins (open circle), killer whales (black star), Risso's dolphins (gray cross), minke whale (open diamond), and common dolphins (open square). Box A zooms in on the cluster of sightings near the Granite Canyon survey station.

[13]Black, N. A. 2000. Killer whales from Puget Sound observed in Monterey Bay. Monterey Bay Whale Watch website. Accessed 15 Aug. 2006. http://www.montereybaywhalewatch.com/Features/feat0002.htm

occasionally seen in the Monterey area in winter. "Transient" killer whales are the most frequently observed ecotype in the Monterey area (Black et al., 1997; Black[13]). This ecotype travels in small groups and preys on other marine mammals. Killer whale presence during census years was correlated to the seasonal presence of gray whale calves (Shelden et al., 1995), implying that the killer whales observed in this study might be transient-type animals. This assumption is also supported by the small group sizes observed.

Table 6.—Cetacean sightings reported during aerial surveys of the southbound gray whale migration, January 1988–96. Effort hours in conditions where visibility was fair or better include tracklines (10–20 n.mi.: Shelden and Laake, 2002), pod size estimation experiments, and photogrammetric surveys. Group sizes (where recorded) for each sighting are reported in Appendix 2 (available from authors).

Species	1988 (25.5 h)	1993 (16.1 h)	1994 (31.0 h)	1996 (15.2 h)	Total
Minke whale				1	1
Blue whale					0
Common dolphin	8[1]	1	5	9	23
Risso's dolphin	24[1]	16	83	12	135
Northern right whale dolphin			2	2	4
Pacific white-sided dolphin	6			14	20
Humpback whale					0
Killer whale				1	1
Dall's porpoise	1		2		3
Harbor porpoise					0
Bottlenose dolphin					0
Unidentified dolphins	20[1]	8	17	9	54
Unidentified whales					0
Total	59	25	109	48	241
Sightings per unit effort	2.31	1.55	3.52	3.16	

[1] Total includes sightings made during photographic surveys where latitude and longitude data were not collected: three sightings of common dolphins, two sightings of Risso's dolphins, and two sightings of unidentified dolphins.

Table 7.—Cetaceans reported during 25× "Big Eye" binocular watches of the southbound gray whale migration, 1992–2007. Group sizes (where recorded) for each sighting are reported in Appendix 3 (available from authors). Effort hours include visibility 4 (fair) or better for all reticle fields.

Species	1993 1/3–31 (23.0 h)	1994 1/10–31 (39.8 h)	1995 1/7–25 (146.6 h[1])	1996 1/7–25 (252.6 h[1])	1998 1/7–26 (107.6 h[1])	2000–01 12/29–1/23 (54.6 h[1])	2002 1/3–2/4 (53.1 h[1])	2007 1/8–31 (19.6 h[1])	Total
Minke whale			2	2	1		1		6
Blue whale									0
Common dolphin	8	1	19	15	2	7	2	1	55
Risso's dolphin	7	2	4	7	3	14	3	2	42
Northern right whale dolphin				5					5
Pacific white-sided dolphin				13	3	1			17
Humpback whale									0
Killer whale		1	4		10	2	1		18
Dall's porpoise			4			1			5
Harbor porpoise			3	3	2	1			9
Bottlenose dolphin		1					3		4
Unidentified dolphins	4	3	21[2]	55[2]	17[2]	13	4	3[2]	120
Unidentified whales			2			1			3
Total	19	8	59	100	38	40	14	6	284

[1] From 1995 onward, visibility codes were applied to reticle bins for the horizon (0.0) to 1.0 reticles (R), 1.1–2.0 R, 2.1–3.0 R, 3.1–4.0 R, and 4.1–20.0+ R. The greatest amount of effort occurred in the 4.1–20.0+ R bin (shown here). Effort per reticle bin is further defined in Table 8.

[2] Total includes one sighting where reticle was not provided.

Table 8.—Effort hours where visibility was 4 (fair) or better for all reticle fields, and number of cetacean sightings identified to species (with unidentified sightings in parenthesis) during 25x "Big Eye" binocular watches of the southbound gray whale migration. Paired, independent searches occurred in January 1995 and 1996 (shown as South and North shed). Note: 0.0 = horizon (at 9.1 n.mi. (16.8 km) offshore); 0.35 n.mi. (0.65 km) is the closest to shore a sighting could be detected in the field of view of the binoculars (about 24 reticles).

	1995		1996					
Reticle bins	South	North	South	North	1998	2000–01	2002	2007
0.0–1.0	30.9, 0(2)	29.2, 0(3)	48.7, 5(14)	46.2, 7(8)	60.9, 4(6)	22.5, 0(6)	24.6, 1(2)	14.2, 0(0)
1.1–2.0	47.4, 9(4)	47.1, 7(1)	83.9, 12(15)	89.2, 6(8)	78.7, 7(7)	43.5, 4(3)	40.3, 2(0)	17.0, 2(0)
2.1–3.0	65.2, 3(1)	65.2, 3(2)	112.0, 3(3)	114.6, 5(2)	98.9, 1(2)	52.4, 4(2)	51.2, 1(2)	18.7, 1(0)
3.1–4.0	71.9, 4(2)	71.3, 3(0)	119.8, 2(0)	125.1, 0(0)	105.5, 2(0)	53.8, 9(2)	52.8, 3(0)	18.9, 0(0)
4.1–20.0+	73.6, 1(2)	73.0, 6(5)	124.0, 2(3)	128.6, 3(1)	107.6, 7(1)	54.6, 9(1)	53.1, 3(0)	19.6, 0(2)

Northern right whale dolphins were recorded by "Big Eye" and aerial observers but very rarely by census observers (the lone sighting reported by census observers occurred in December 1992: see Table 5). As mentioned earlier, all sightings of this species occurred in close proximity to or within mixed-species schools of dolphins which, along with their low surfacing profile and lack of dorsal fin, increases the likelihood of under-reporting this species.

Harbor porpoise and bottlenose dolphins were never reported by aerial observers. Most bottlenose dolphin sightings made by census observers occurred in the surf zone (Fig. 10a), an area where whitecaps would make aerial detections difficult and, in most cases, too close to shore to be seen in the "Big Eye" binoculars. Harbor porpoise were in the study area year-round and seem to have established home ranges (Chivers et al., 2002), but they also present a low profile when surfacing and usually travel alone (Leatherwood et al., 1982), leading to under-reporting. Aerial surveys conducted by the Southwest Fisheries Science Center have been used to estimate abundance of these species along the central California coast since the mid-1980's (Forney et al., 1991; Forney et al., 1995; Forney, 1997, 1999; Carretta et al., 2009). However, these surveys were flown at about 213 m (650 to 700 ft; much lower than the gray whale aerial surveys at 305 m (1,000 ft)) "because of the small body size of harbor porpoise"[14] and in the earlier years only found the offshore, not coastal, population of bottlenose dolphins (Forney et al., 1995; Forney, 1997). Forney et al. (1995:25) concluded that "[p]recise estimates of abundance for harbor porpoise and inshore bottlenose dolphins will require

[14] Southwest Fisheries Science Center (SWFSC). Harbor Porpoise Aerial Survey website. Accessed 17 Sept. 2010. http://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=148

dedicated aerial surveys designed for those species."

Overall, shore-based observers were limited by their ability to identify species at great distances, and "Big Eye" observers were unable to survey within 0.6 km of shore. Aerial surveys were conducted at 305 m (1,000 ft) altitude, ideal for viewing large whales and large schools of dolphins but not for smaller cetaceans that tend to travel alone or in small groups.

Oceanography

The increased diversity of cetacean species observed after 1980 off central California (Dohl et al.[1,2]; our study) may, in part, be because of oceanographic warming observed from the 1980's through the 1990's (Lluch-Belda et al., 2001, 2003, 2005). This was evident in the number of warm months that occurred during gray whale census operations after 1989 (Table 9). A similar increase in diversity of odontocete species in Monterey Bay was observed following the onset of the 1997–98 El Niño (Benson et al., 2002).

Northward dispersal of fauna during warm periods has been described for a number of southern California species (Lluch-Belda et al., 2003, 2005). These faunal assemblages include prey important to cetaceans such as sardines, *Sardinops sagax*; anchovy, *Engraulis mordax*; squid, and zooplankton. Genetic analysis of population structure of the market squid, *Loligo opalescens*, a common prey species of many of the odontocetes described here, suggests a north and south migration within shelf waters (Reichow and Smith, 2001) as well as inshore and offshore movements during the spawning season (Spratt, 1979). Warm waters play a key role in the spawning cycles and locations used by many of these prey species (Hernandez-Vazquez, 1994; Lluch-Belda et al., 2001), and the range of some of these species has extended north to Alaska during strong El Niño years (Wing and Mercer, 1990; Wing et al., 2000).

The 1977 and 1989 Pacific regime shifts also affected abundance, recruitment, and biomass of a number of cetacean prey species. Small pelagic fishes appeared to benefit from warmer temperatures while declines were noted in a number of larger pelagic fishes (e.g. Pacific salmonids) and groundfish (see review in Benson and Trites, 2002). In particular, after the 1989 regime shift, production improved off California for Pacific hake, *Merluccius productus*; herring, *Clupea pallasi;* and sardines (Benson and Trites, 2002). The distribution of hake and sardines northward was also observed after 1989 (Benson and Trites, 2002). It is possible that sighting rates of common, Risso's, Pacific white-sided, and bottlenose dolphins were also driven by these shifts in prey availability (e.g. Keiper et al., 2005).

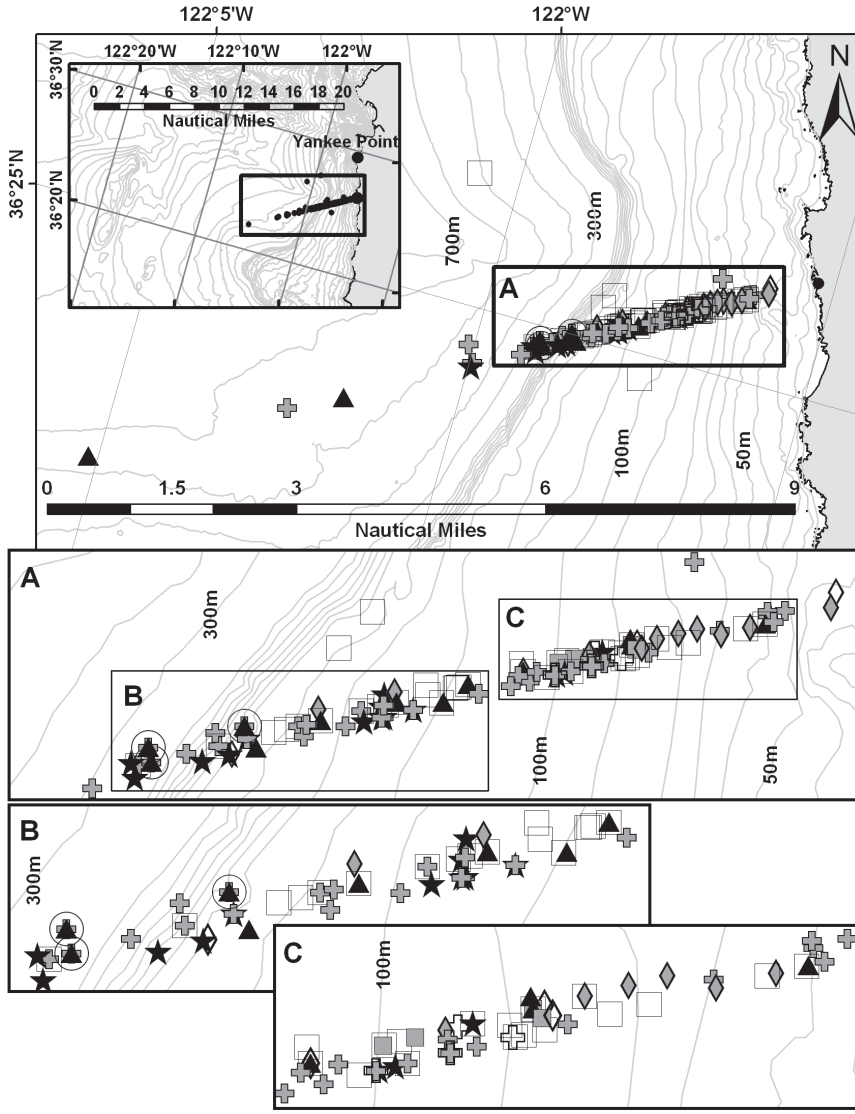
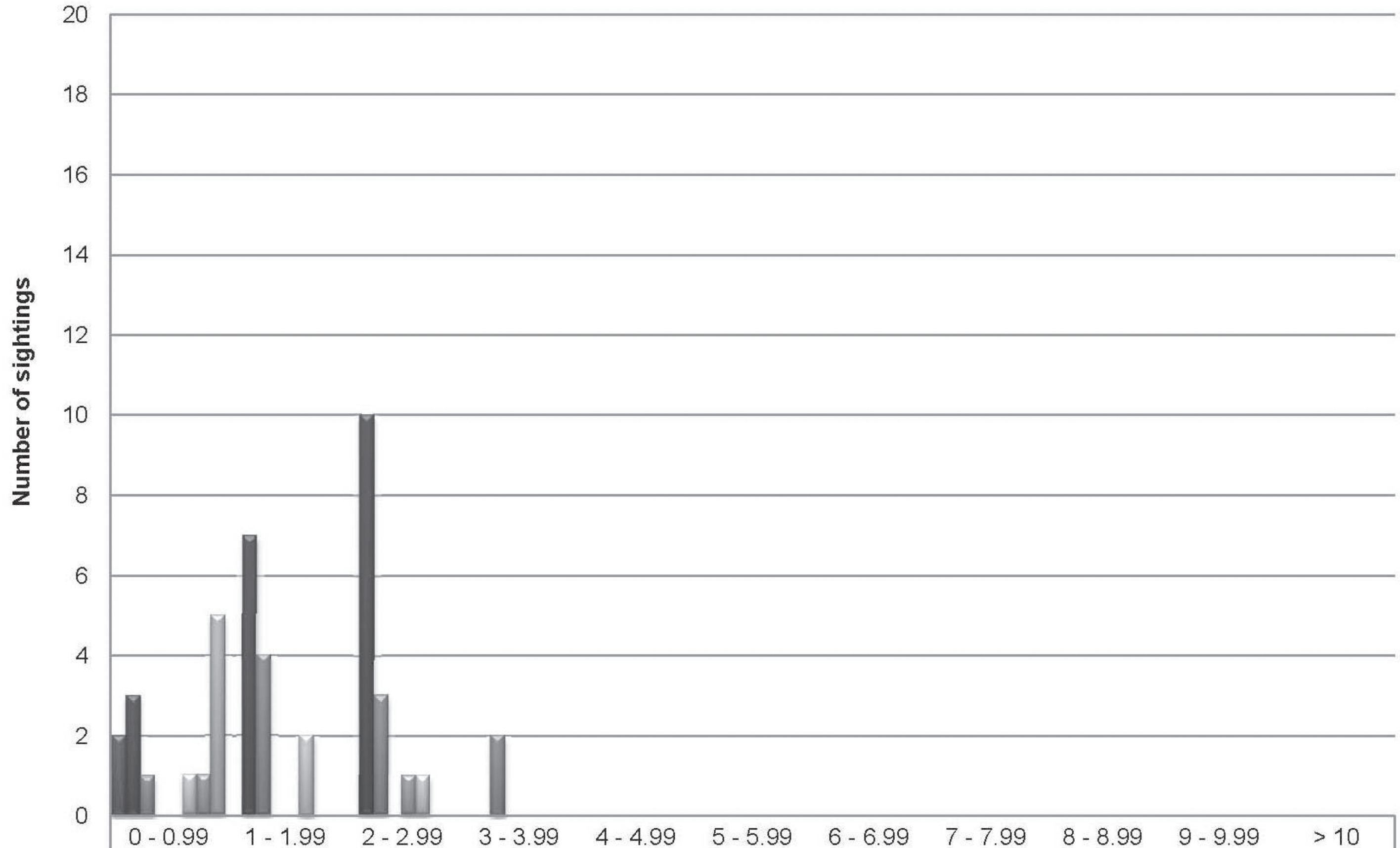


Figure 9.—Cetaceans in the Granite Canyon study area observed through "Big Eye" (25×) binoculars (see also Fig. 4) during systematic watches of the southbound migration of gray whales, 1992–2007. Symbols denote Pacific white-sided dolphins (black triangle), Dall's porpoise (gray square), northern right whale dolphins (open circle), killer whales (black star), Risso's dolphins (gray cross), harbor porpoise (gray diamond), minke whale (open diamond), common dolphins (open square), and bottlenose dolphins (open cross). Boxes A, B, and C zoom in on the cluster of sightings closer to shore.

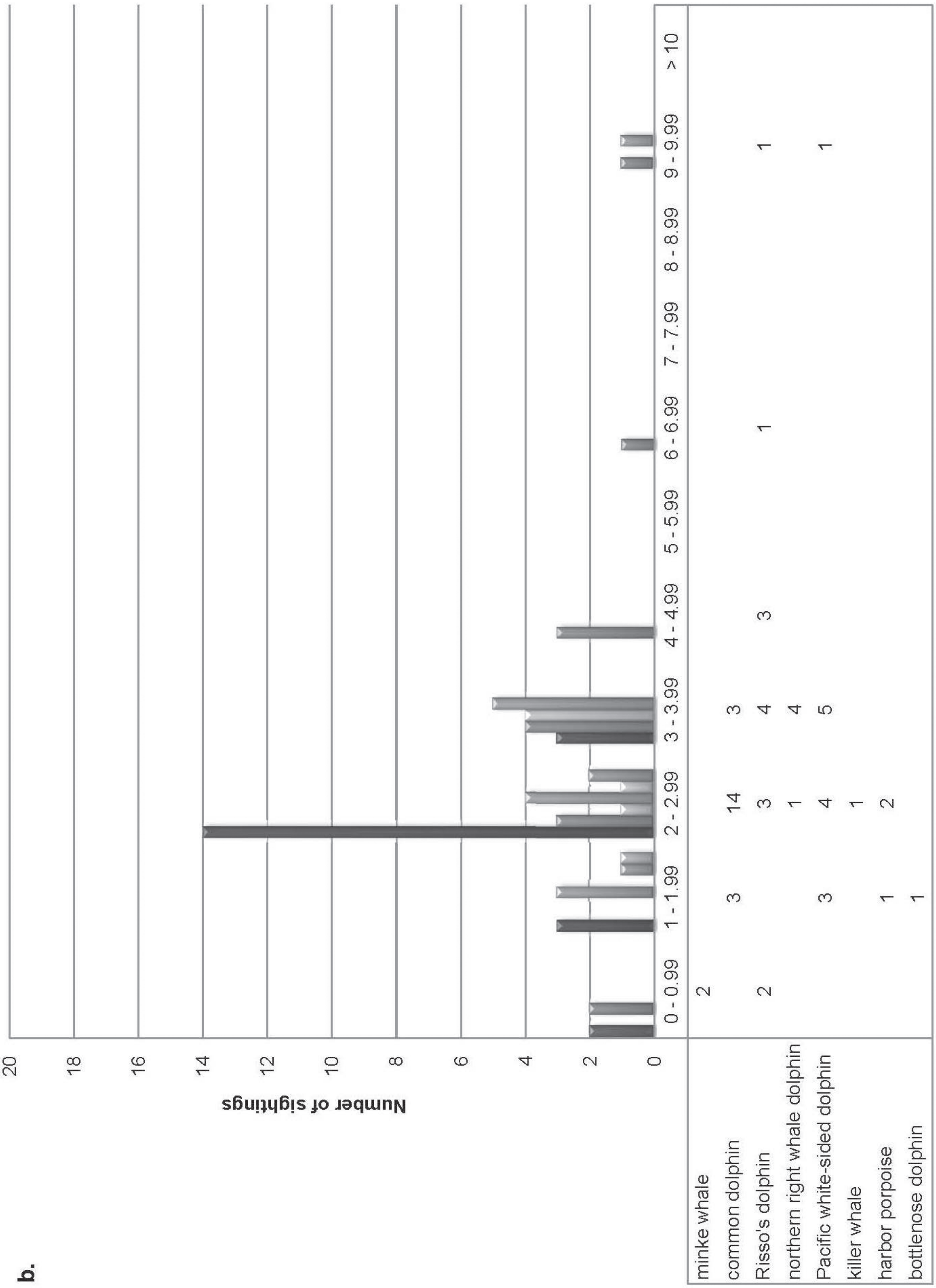
a.



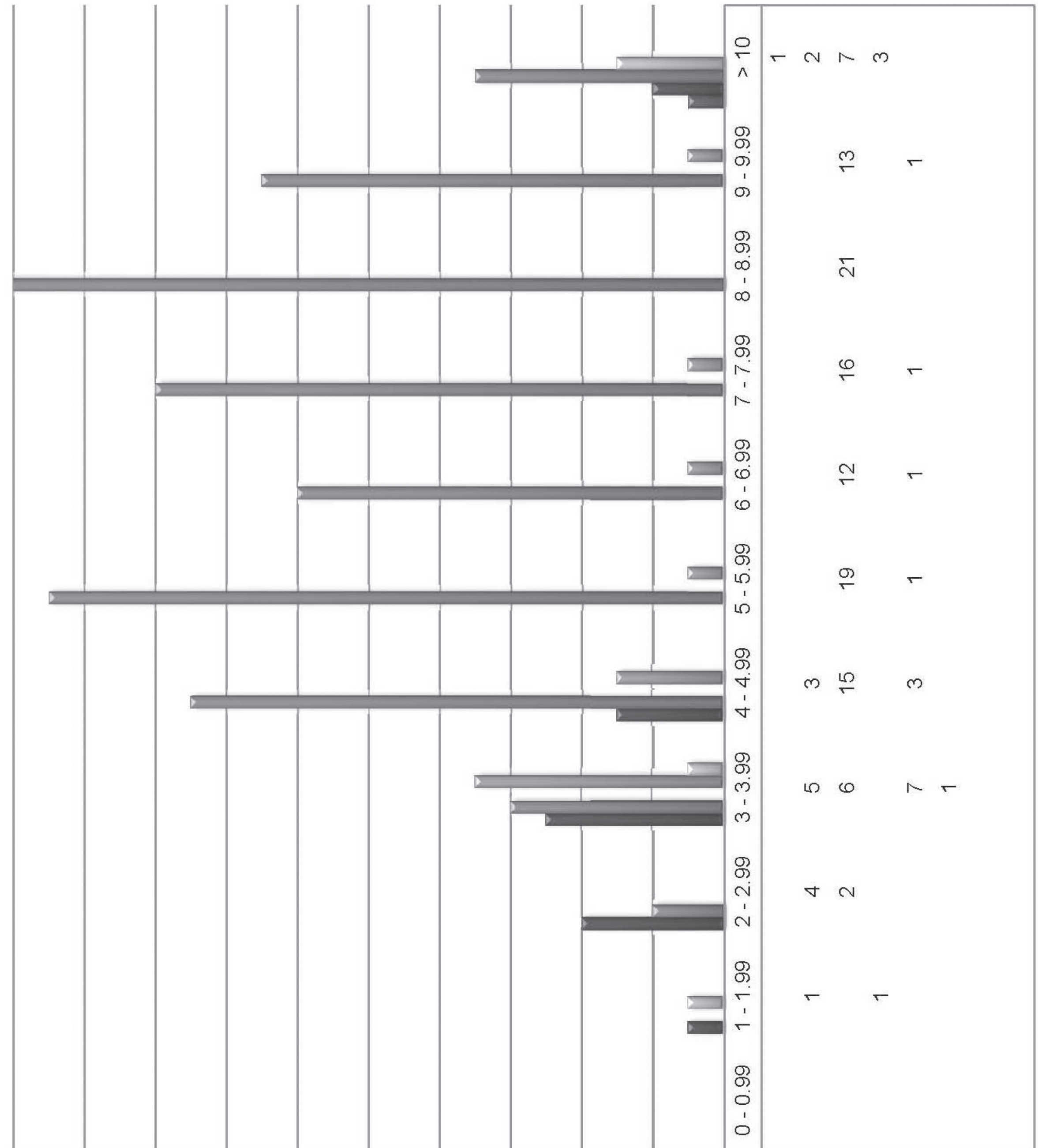
	0 - 0.99	1 - 1.99	2 - 2.99	3 - 3.99	4 - 4.99	5 - 5.99	6 - 6.99	7 - 7.99	8 - 8.99	9 - 9.99	> 10
minke whale	2										
common dolphin	3	7	10								
Risso's dolphin	1	4	3	2							
northern right whale dolphin											
Pacific white-sided dolphin			1								
killer whale	1	2	1								
harbor porpoise	1										
bottlenose dolphin	5										

Figure 10.—Cetacean sightings from three research platforms at Granite Canyon: a) observation sheds; b) “Big Eye” binocular watches; and c) aerial surveys operating concurrently in January 1993, 1994, and 1996. Distance bins are in nautical miles (1 n.mi. = 1.85 km).

b.


Number of sightings
0
2
4
6
8
10
12
14
16
18
20
0 - 0.99
1 - 1.99
2 - 2.99
3 - 3.99
4 - 4.99
5 - 5.99
6 - 6.99
7 - 7.99
8 - 8.99
9 - 9.99
> 10
minke whale 2
common dolphin 3 14 3
Risso's dolphin 2 3 4 3 1 1
northern right whale dolphin 1 4
Pacific white-sided dolphin 3 4 5 1
killer whale 1
harbor porpoise 1 2
bottlenose dolphin 1

c.



	0 - 0.99	1 - 1.99	2 - 2.99	3 - 3.99	4 - 4.99	5 - 5.99	6 - 6.99	7 - 7.99	8 - 8.99	9 - 9.99	> 10
minke whale											1
common dolphin		1	4	5	3						2
Risso's dolphin			2	6	15	19	12	16	21	13	7
northern right whale dolphin		1									3
Pacific white-sided dolphin				7	3	1	1	1		1	
killer whale				1							
harbor porpoise											
bottlenose dolphin											

Forays into waters north of Point Sur during the winter months by common dolphins (Fiscus and Niggol, 1965) and bottlenose dolphins (Wells et al., 1990; Feinholtz, 1996) appeared to be uncommon before the 1982–83 El Niño. The studies by Fiscus and Niggol (1965) and Dohl et al.[1,2] happened to coincide with strong El Niño events followed by protracted warm periods that lasted well after the tropical signal had disappeared (McGowen et al., 1998; Lluch-Belda et al., 2005). These events may explain why a large group of common dolphins was observed well north of our study area, near San Francisco Bay in February 1959 (Fiscus and Niggol, 1965). Common dolphins are considered intermittent visitors to this region and are strongly associated with warmer waters (Benson et al., 2002). Bottlenose dolphins along the California coast have also been described as warm water species (Wells et al., 1990).

In the mid to late 1800's, a prolonged warm water period occurred with a number of moderate to strong El Niño events (Quinn, 1993; Engstrom, 1994). Warmer water fishes moved northward and persisted in the waters near Monterey (Hubbs, 1948). A few specimens (jawbones and skulls) of bottlenose dolphins from this time period were collected near Monterey and San Francisco Bay (Andrews, 1911; Kenyon, 1952; Orr, 1963). Banks and Brownell (1969:269) noted these possible links between warm water events and shifts northward in the range of bottlenose dolphin as they followed their preferred prey.

Risso's dolphins were found year-round in offshore waters of central California but movements inshore seemed to occur during warm periods, particularly where the continental shelf narrows in the Monterey area (Leatherwood et al., 1980; Dohl et al.[1,2]). Dohl et al.[1,2] found that in winter Risso's dolphins were in greatest abundance and closer to shore (approaching the 183 m isobath) than during any other season (see also Fig. 6). Pacific white-sided dolphins are also found year-round in the study area (Black, 1994). Black (1994) noted when sea surface temperature anomalies were high, Pacific white-sided dolphins were more abundant and closer to the shelf edge. Foraging Pacific white-sided dolphins were also found closer to the shelf edge and in shallower water than during any other activity (Black, 1994:39).

Table 9.—Monthly oceanographic anomalies observed during the census of southbound migrating gray whales (1967–2007). The number of warm and cold sea surface temperature (SST) months and negative and positive upwelling indices (UI) months are shown for periods before and after Pacific regime shifts (Mantua et al., 1997; Hare and Mantua, 2000; Benson and Trites, 2002).

	Number of census months				
Monthly anomaly	Before 1977	1977–1989	After 1989	Total	*p*-value
Warm SST	7	11	17	35	0.003[1]
Cold SST	20	10	6	36	
Negative UI	20	19	17	56	0.11
Positive UI	7	1	7	15	

[1] = total anomaly months were significantly different among regime periods.

Overview and Conclusions

Shore-based sites south of Carmel were selected for counting gray whales during their southbound migration because these whales pass close to the shore in this area, apparently an effect of having just crossed some deep maritime canyons to the north. Results from these gray whale counts have been published in numerous journals (see Literature Cited section), but a valuable part of the dataset that was ignored in these publications was the record of other cetaceans also seen from these research sites. Although there were unknown numbers of animals missed by shore-based observers, the consistent search effort from early December to mid February with one person searching at a time provides a documentation of sighting rates that can be compared across the 40-year history of this project. Some aspects of the research protocol have changed, especially in the late 1980's with increased emphasis on detailed records of sighting time and location (Laake et al., 2009), but the methodological changes have not significantly altered the search effort.

A consistency in effort has been important to the goals of the gray whale census because accurate estimates of whale abundance and trends require consistent, predictable effort. By following a strict, systematic research protocol, the search effort lends itself to tests of the system, allowing for correction factors that can improve the accuracy of abundance estimates, which is vital for species management. This uniformity in effort has provided an excellent platform for the current study, documenting cetaceans seen during the gray whale census.

Despite difficulties in detecting and identifying the variety of cetaceans in coastal waters of central California, there seemed to be an increase in the diversity of species and sighting rates through the study period, 1967–2007. Warm periods and El Niño events likely played a role (e.g. Benson et al., 2002; Dohl et al.[1,2]). The warm period observed during the 1990's (Table 9) may partially explain the increase in sighting rates and diversity observed at the census site compared to the much cooler temperatures of the 1970's. This suggests a response to regime change (e.g. Fiedler, 2002; Chavez et al., 2003) rather than shorter scale variability such as a warm or cool year. Unfortunately, gaps in the census dataset exist during particularly strong El Niño and La Niña events in the 1980's and 1990's. Overall, this time-series is unique in that it spans four decades and provides some insights into cetacean habitat use in central California during winter months.

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